

# 評估新版TCWA1(Taiwan Central Weather Administration 1-moment) 雲微物理方案於中央氣象署區域模式之 預報表現

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地點：R311

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# 大綱

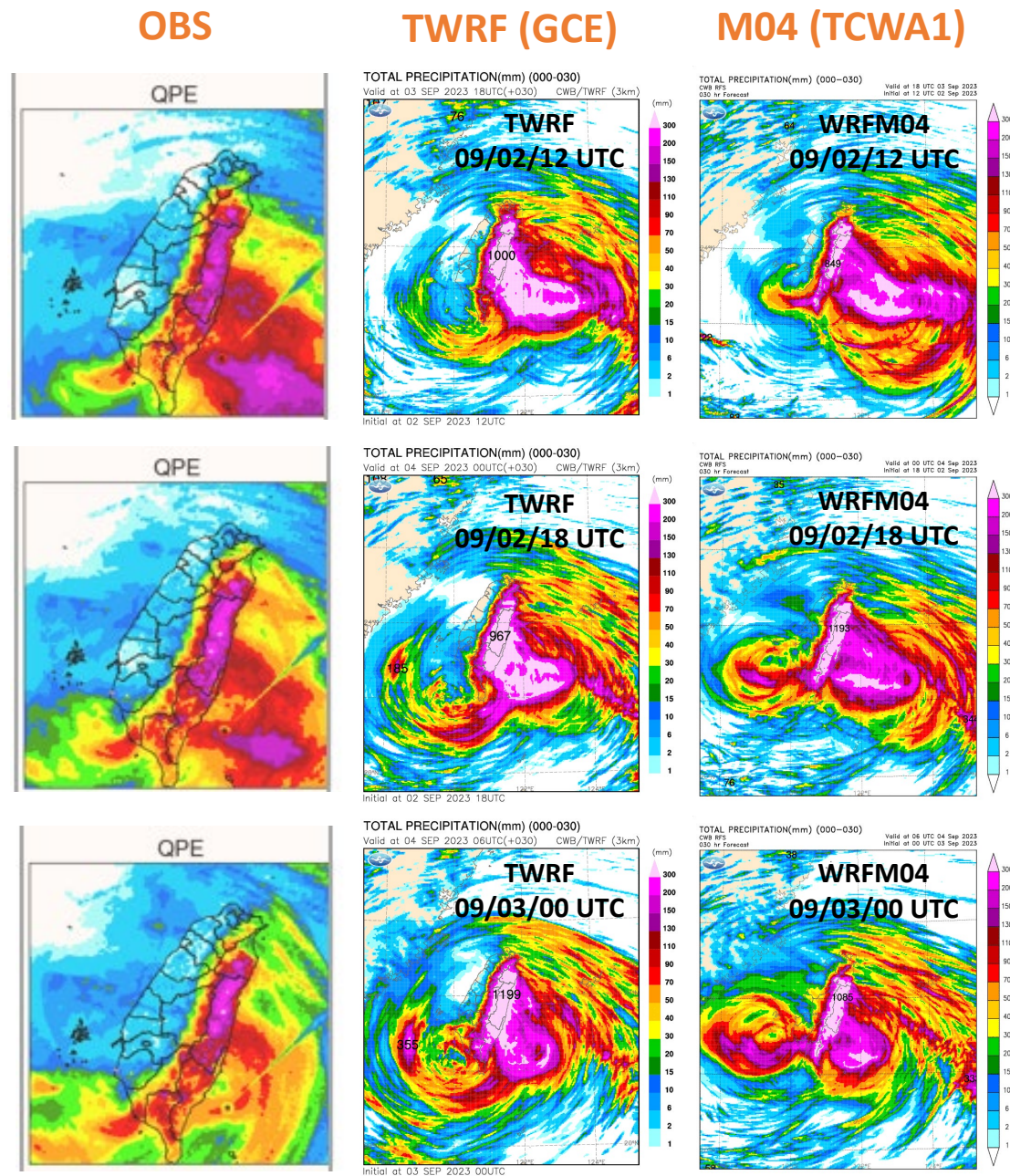
1. TCWA1優化動機、內容修改
2. 個案測試
  - (1) 單一個案 - a. 2021年梅雨豪大雨個案 (DTG:21061900)  
b. 2023年海葵颱風個案 (DTG:23090300)
  - (2) 多個案實驗
    - a. 2023年小犬颱風23100300-23100500 (9 case, 6hr)
    - b. 2021年梅雨個案21061912-21062212 (7 case, 12hr)
    - c. 2021年夏季/熱對流個案21071100-21071700 (7 case, 24hr)
    - d. 2021年冬季個案21120500-21121300 (9 case, 24hr)
3. 結論與未來工作

# 動機

1. 2023年海葵颱風個案，使用原版GCE與TCWA1所模擬之雨量皆有過報的誤差。

-> 期望藉由優化雲微物理參數法改善定量降水預報

2. 另TCWA1移植至本署TGFS全球模式，高層大氣緯向均溫出現冷偏差亦需改善

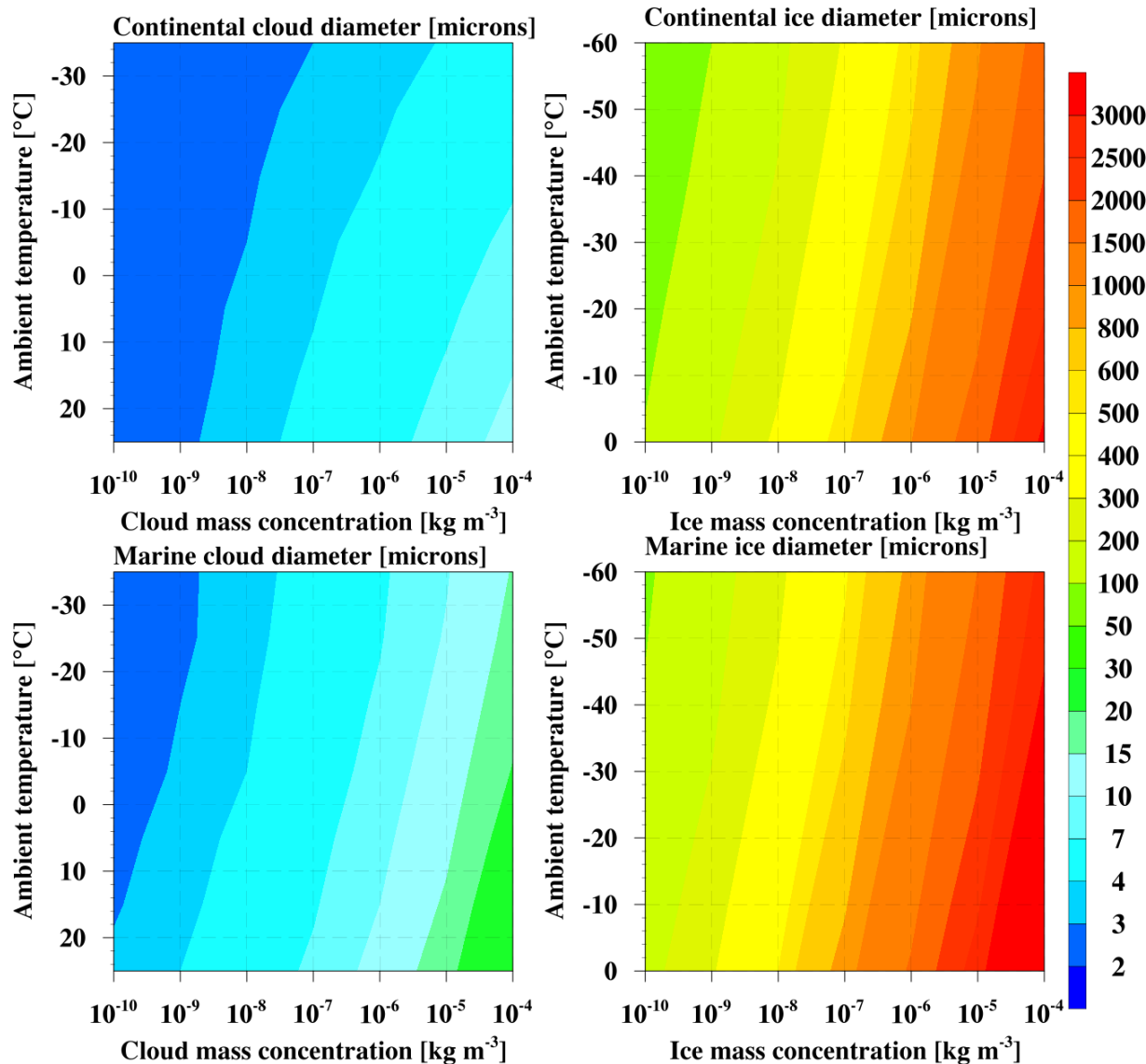


# TCWA1 更新內容

	GCE	TCWA1
微物理過程調整	採原有設定 飽和度調整法(不允許過飽和)	1. 雲水自動轉換為雨水的參數式 2. 雲冰核化、凍結與二次生成之參數式  ✓ 飽和度預報法，參考P3 scheme (Morrison and Milbrandt 2015) 之方法並結合粒徑譜假設計算水氣擴散過程，除可允許過飽合條件外，亦可考慮冰水共存時之白吉龍過程
水物特性假設	雪(snow)、軟雹(graupel)密度為定值，分為 $100kg/m^3$ 與 $400kg/m^3$	1. snow密度為質量及溫度的函數 graupel密度為質量和融化比例的函數 2. graupel及hail可共存 ( Ziegler 1985)  ✓ 雲水、雲冰會依照陸地或海洋下墊面，具有不同特性之有效(effective)粒徑
水物落速參數	固定參數	1. 雨滴落速引進Khvorostyanov and Curry, 2002 理論方法 2. snow落速經驗式之係數修正  ✓ 引用NTU半理論之雲冰落速參數法，並結合雲冰粒徑譜，符合冰晶主要及次要成長習性區間
水物粒徑譜假設	Marshall-Palmer 分佈	Rain, Snow, Graupel/Hail 改為伽碼(Gamma)分佈  ✓ 雲水、雲冰更改為Gamma粒徑分布.

紅色字體為本研究新增修改內容

# Gamma-type spectrum in TCWA1



➡ 依據陸地或海洋特性，雲冰、雲水有效(effective)粒徑略不同

$$N(D) = N_0 D^\alpha \exp(-\lambda D)$$

$$D_m = f(Q, TK) \quad D_e = f(\rho_x, D_m)$$

$D_e$  : effective diameter

$D_m$  : mean-volume diameter

$$q \equiv \frac{M_0 M_3^2}{M_2^3} = \frac{M_0 M_3^3}{M_2^3 M_3} =$$

$$\left(\frac{M_3}{M_2}\right)^3 \left(\frac{M_0}{M_3}\right) = \left(\frac{D_e}{D_m}\right)^3$$

$$\alpha = \frac{6 - 3q + \sqrt{q(q + 8)}}{2(q - 1)}$$

$$\lambda = \frac{(\alpha + 3)M_2}{M_3} = \frac{(\alpha + 3)}{D_e}$$

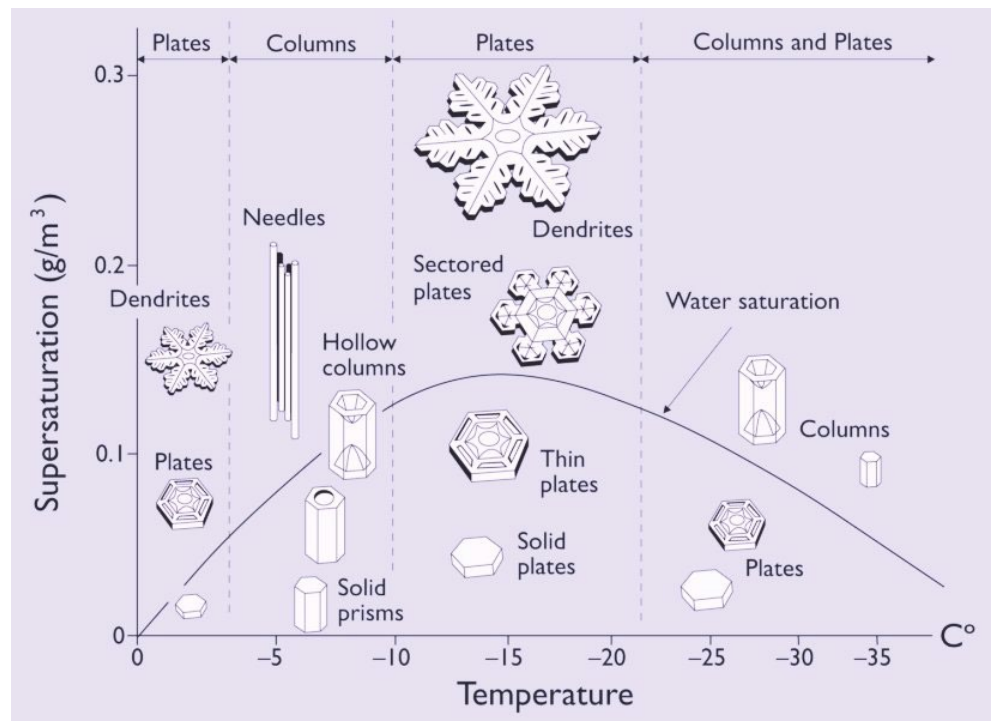
$$N_0 = \frac{M_3 \lambda^{\alpha + 4}}{\Gamma(\alpha + 4)}$$

mapping spectrum with  
3 variable parameters

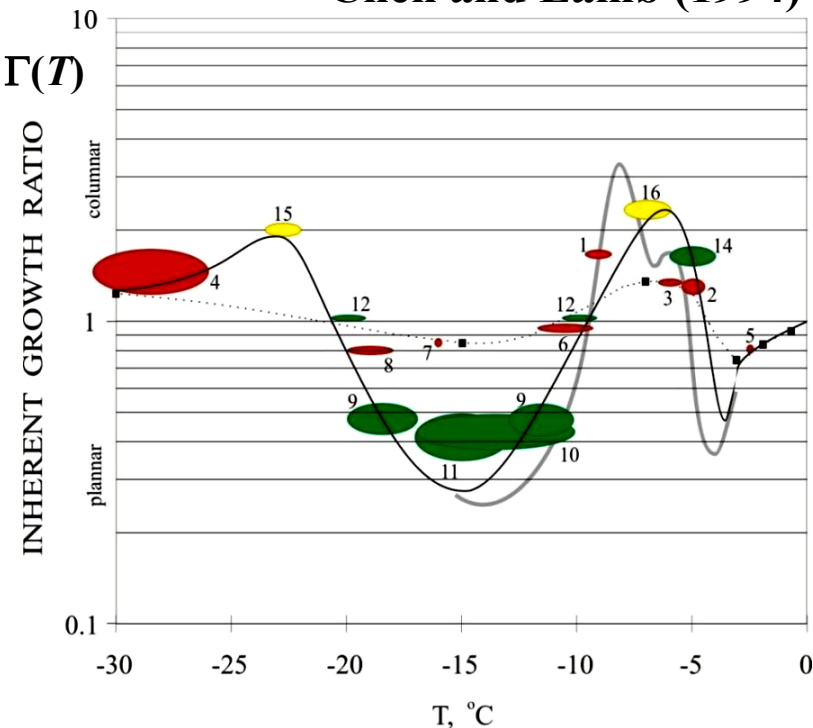
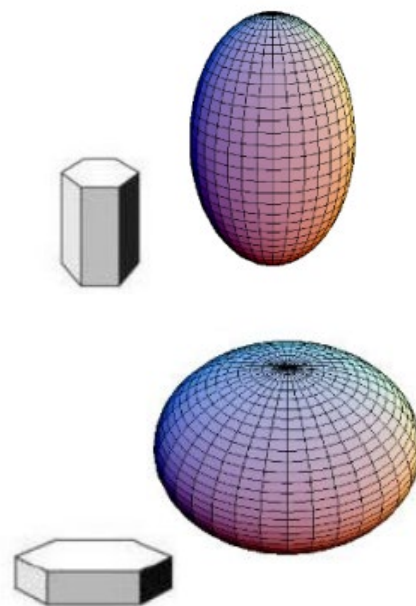
# 冰晶主要 (溫度) 及次要 (過飽和度) 之成長習性

Chen and Lamb (1994)

0 °C ~ -40 °C  $\Gamma(T)$



## Spheroidal parameterization



$$\Gamma(T) \equiv \frac{\alpha_c}{\alpha_a}, \text{ inherent growth ratio}$$

$\alpha$  is accommodation coefficient

$$\rho_{i,dep} = 910 \exp \left[ \frac{-3 \times (\Delta\rho_v - 5 \times 10^{-5})}{\Gamma(T)} \right]$$

(Chen and Lamb, 1994a; Chen and Tsai 2016)

<http://www.cas.manchester.ac.uk/resactivities/cloudphysics/topics/lightscattering/fig2/>

Approximation in TCWA  $\beta \sim \Gamma(T)^{1/3}$

$$\phi_i = \left( \frac{D_i}{D_0} \right)^{\frac{\beta-1}{\beta+2}} \text{ for ice aspect ratio (shape)}$$

# Cloud ice fall speed

WRF idealized 2D simulations

GCE adopted

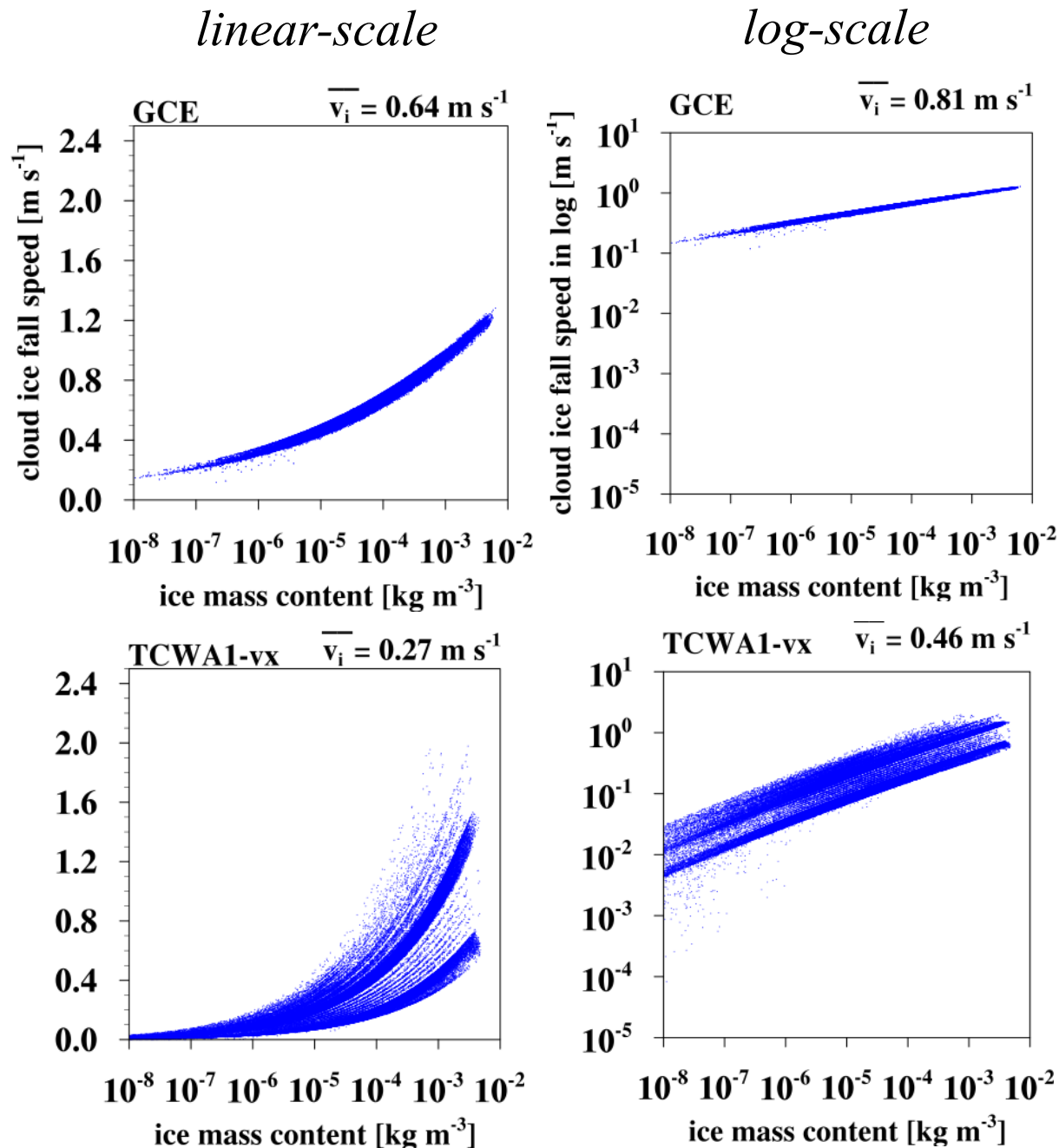
Heymsfield and Donner (1990)

$$v_i = f(Q_i, \rho_a)$$

TCWA1 adopted semi-theoretical approach with prescribed ice properties (shape and density)

$$v_i = f(\phi_i) f(\rho_i) f(D_i) f(\rho_a) \\ \rightarrow f(Q_i, TK, \rho_v, \rho_a)$$

雲冰落速為質量混合比、溫度、過飽和度及大氣密度的函數



# 現行作業版本TCWA1\_OP50與本研究 優化之TCWA1\_OPT進行比較

## 測試個案

單一個案 (1) 2021061900 梅雨個案 (2) 2023090300 海葵颱風

## 多個案

- |                  |                                  |
|------------------|----------------------------------|
| 1. 2023年小犬颱風     | 23100300-23100500 (9 case, 6hr)  |
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| 3. 2021年夏季/熱對流個案 | 21071100-21071700 (7 case, 24hr) |
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# Haikui Typhoon

**GCE**

*1923 mm*

**TCWA1\_OP50**

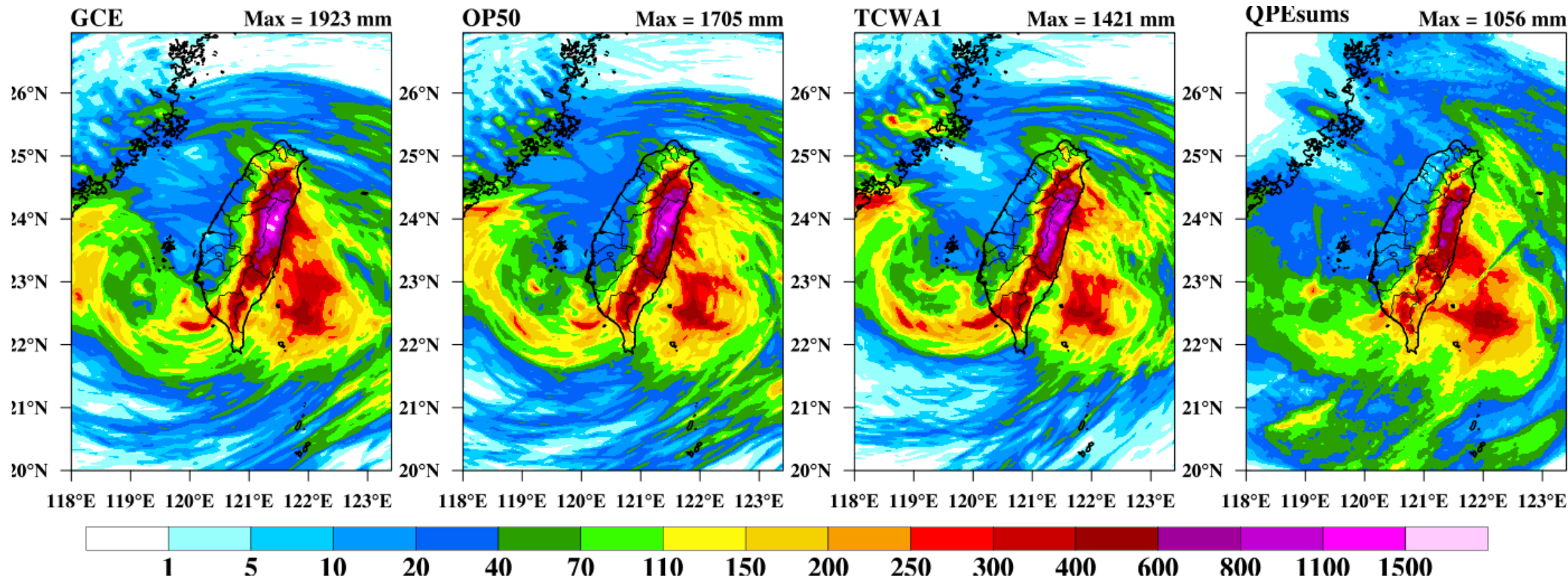
*1705 mm*

**TCWA1\_OPT**

*1421 mm*

**OBS**

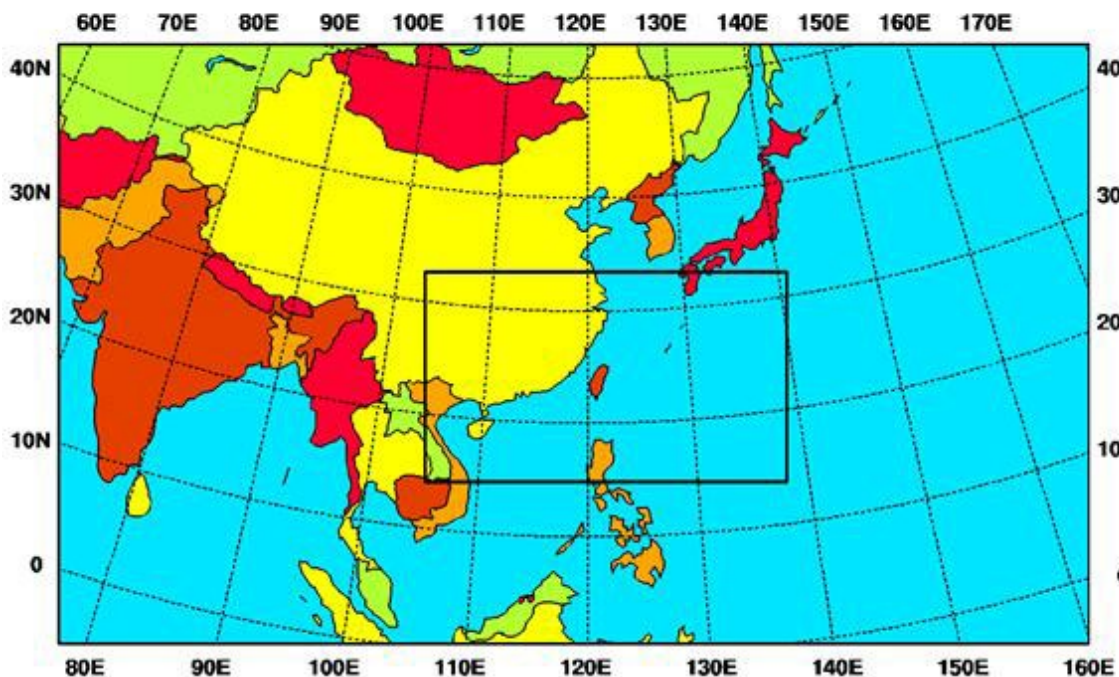
*1056 mm*



The 72-hour accumulated precipitation along the east side of the Central Mountain Range is overpredicted, with a peak at 1923 mm in the GCE and also 1705 mm in the OP50 run, compared to the observed maximum of 1056 mm. Yet, it indicated that the total rainfall over the eastern part of Taiwan has been reduced with a peak of 1421 mm using the TCWA1 scheme.

# Domain 範圍與參數化方法

Domains of CWBWRP OP50



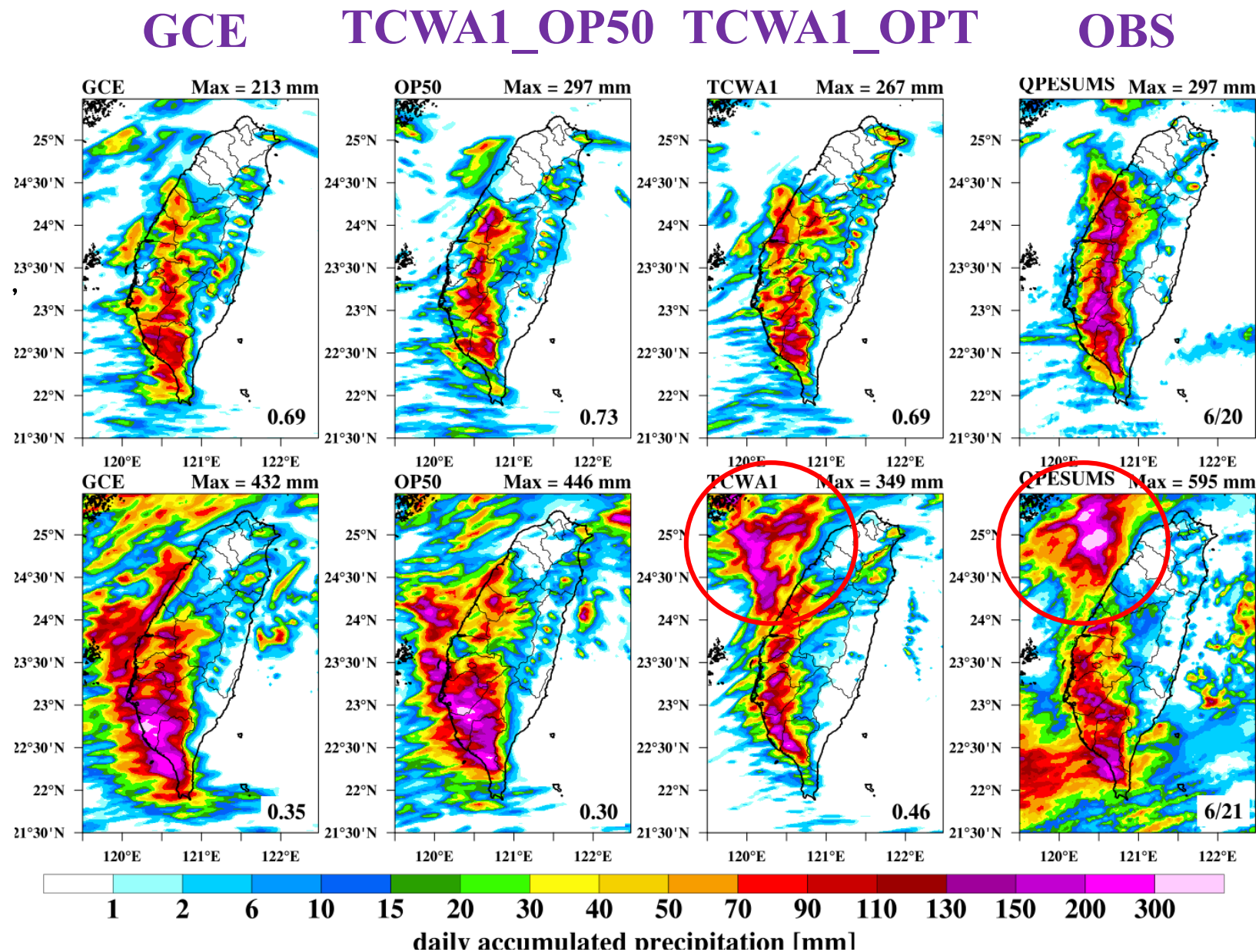
	Domain 1	Domain 2
網格解析度(km)	15 km	3 km
X方向格點數	662	1161
Y方向格點數	386	676
垂直層數	52層	

	Domain 1	Domain 2
物理參數化設定		
積雲參數化法 (mp_CuP)	Kain-Fritch with new trigger function	None
微物理參數化法 (mp_physics)	TCWA1_OP50 / TCWA1_OPT	TCWA1_OP50 / TCWA1_OPT
邊界層參數化法 (bl_pbl_physics)	Yonsei University scheme	Yonsei University scheme
長波輻射參數化法 (ra_lw_physics)	RRTMG scheme	RRTMG scheme
短波輻射參數化法 (ra_sw_physics)	RRTMG scheme	RRTMG scheme
地表參數化法 (sf_sfclay_physics)	Monin-Obukhov scheme	Monin-Obukhov scheme
土壤模式 (sf_surface_physics)	NOAH	NOAH
土壤層數	4層	

# Mei-yu front

為確認優化後之TCWA1\_OPT亦能掌握梅雨鋒面之豪大雨故選取2021年降水最顯著之個案進行模擬比較

Even the TCWA1 run produced less surface precipitation (349 mm) against the GCE (432 mm) and OP50 (446 mm) runs, its rainfall distribution improved significantly with the pattern correlation increasing from 0.30 to 0.46 on 6/21.



# 雨量校驗 - 2023年小犬颱風 - 12hr累積

# 23100300-23100500 (5 case, 12hr)

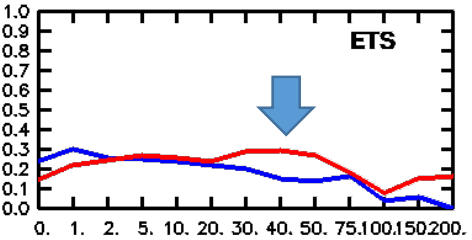
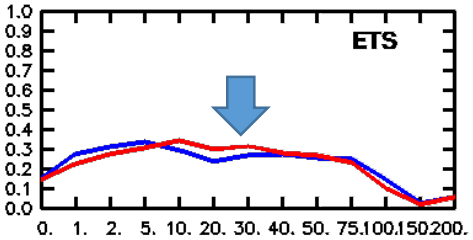
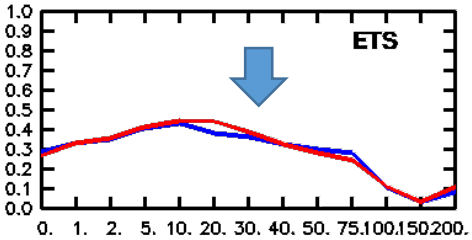
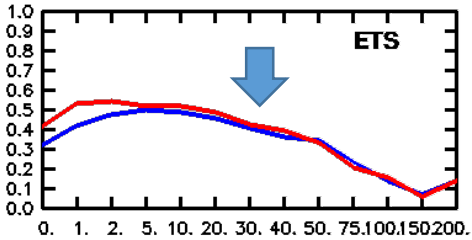
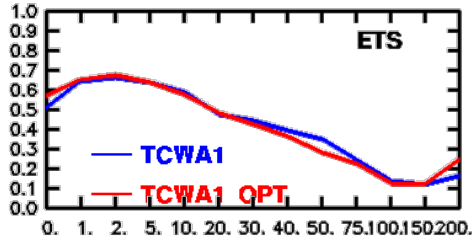
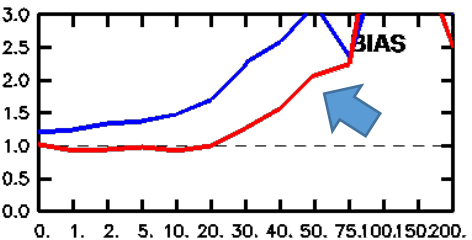
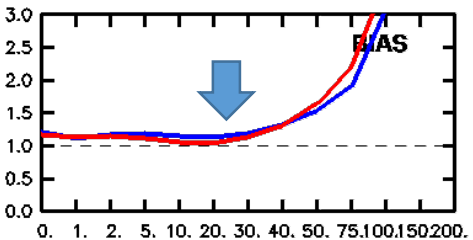
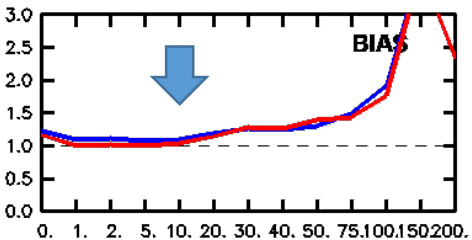
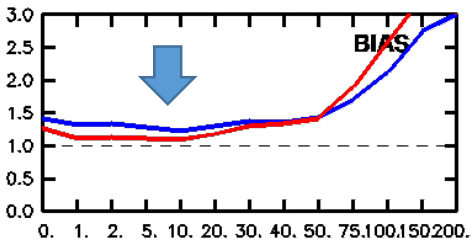
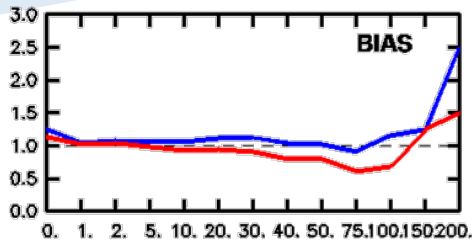
RAINSORE 3km 00-12 hr  
23100300-23100500 UTC Initial

RAINSORE 3km 12-24 hr  
23100300-23100500 UTC Initial

RAINSORE 3km 24-36 hr  
23100300-23100500 UTC Initial

RAINSORE 3km 36-48 hr  
23100300-23100500 UTC Initial

RAINSORE 3km 48-60 hr  
23100300-23100500 UTC Initial



# 雨量校驗 - 2021年夏季 - 24hr累積

# 21071100-21071700 (7 case, 24hr)

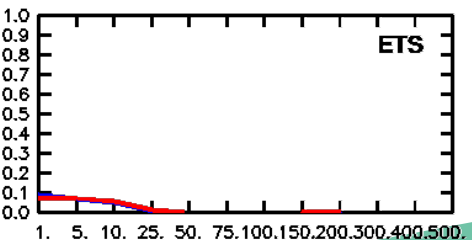
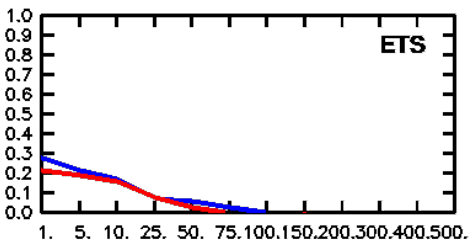
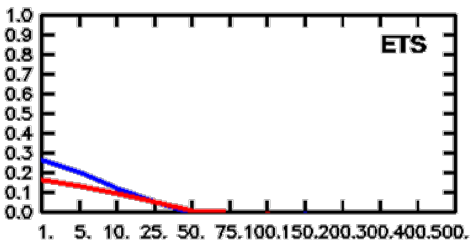
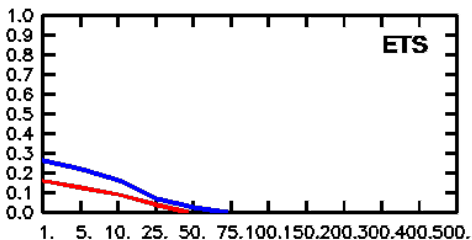
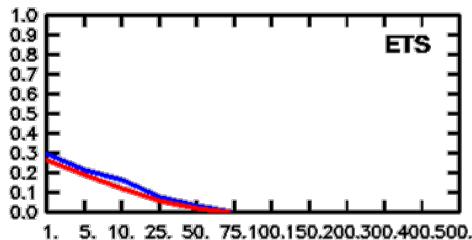
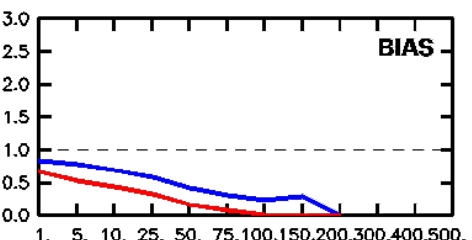
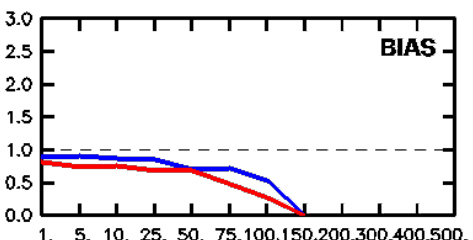
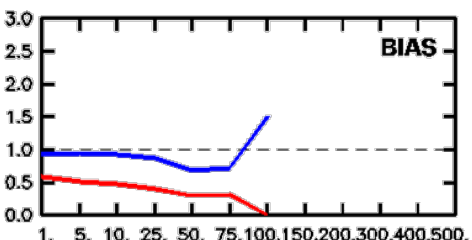
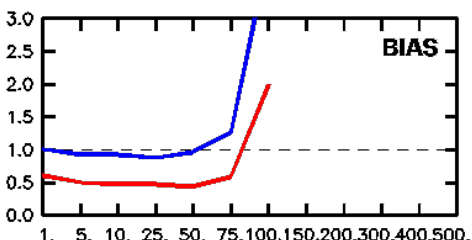
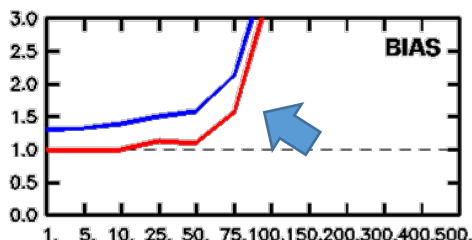
RAINSORE 3km 00-24 hr  
21071100-21071700 UTC Initial

RAINSORE 3km 24-48 hr  
21071100-21071700 UTC Initial

RAINSORE 3km 48-72 hr  
21071100-21071700 UTC Initial

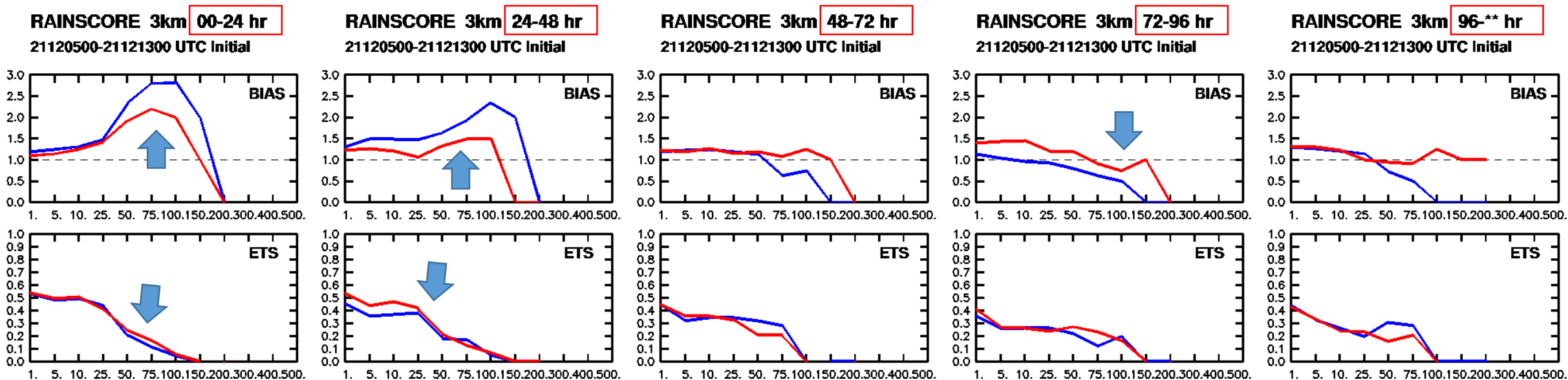
RAINSORE 3km 72-96 hr  
21071100-21071700 UTC Initial

RAINSORE 3km 96-\*\* hr  
21071100-21071700 UTC Initial



箭頭處表示TCWA1\_OPT較優，夏季個案表現較差

—— TCWA1\_OP50      —— TCWA1\_OPT



00-24 24-48小時校驗結果 TCWA1\_OPT表現佳

—— TCWA1\_OP50 —— TCWA1\_OPT

72-96在75mm門檻值 亦可改善低報之雨量

# 總結

1. 雨量校驗：降雨校驗分數TCWA1\_OPT與TCWA1\_OP50相當，然而BIAS分數過報問題有明顯改善
2. 夏季與冬季系統皆有改善效果，但午後對流個案預報後期掌握程度變差

## 未來工作

綜觀校驗顯示TCWA1\_OPT之模擬結果，其RMSE值都較目前TCWA1\_OP50差，需進一步瞭解原因並改善此問題，並期望於明年度之決定性預報模式更新上線。

