

對流尺度系集預報系統（CEPS） 2026年作業更新與效能評估

蘇奕叡、李志昕

科技發展組

中央氣象署

對流尺度系集預報系統—模式設定

(Convective-scale Ensemble Prediction System, CEPS)

Taiwan domain for 12 hours forecast
Hourly update

Deterministic
forecast

RWRF
2 KM

Provide
perturbations for
hybrid DA

Ensemble DA

LETKF
2 KM

Provide initial
perturbations

Ensemble
Forecast

CEPS
2 KM

3 hourly update
18 hours forecast

Member

16 members

Forecast time

18 hours

Grid spacing

2 km

Grid points

450 × 450 grid points

Vertical levels

52 eta levels

IC

使用LETKF 之16個成員分析場

BC

RWRF側邊界+WEPS擾動

RUC

LETKF逐時更新，同化雷達+地面觀測資料

Physics Suite (operational deterministic WRF)

Microphysics

TCWA1

SW/LW radiation

RRTMG
scheme

Planetary Boundary
Layer

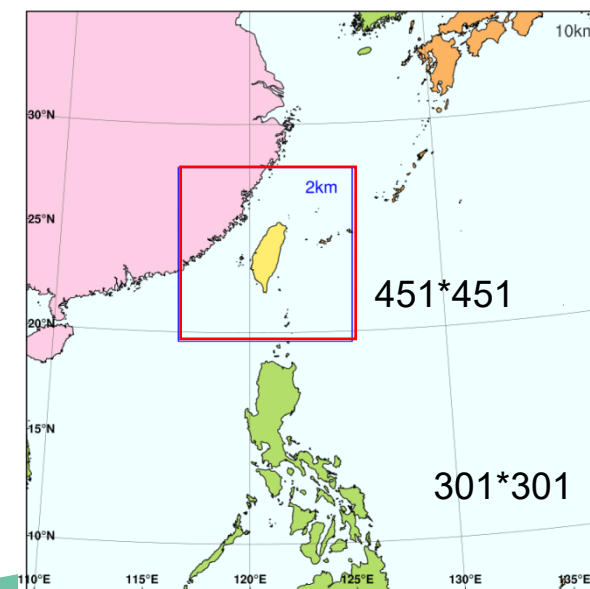
YSU

Land Surface Layer

MM5
similarity(91)

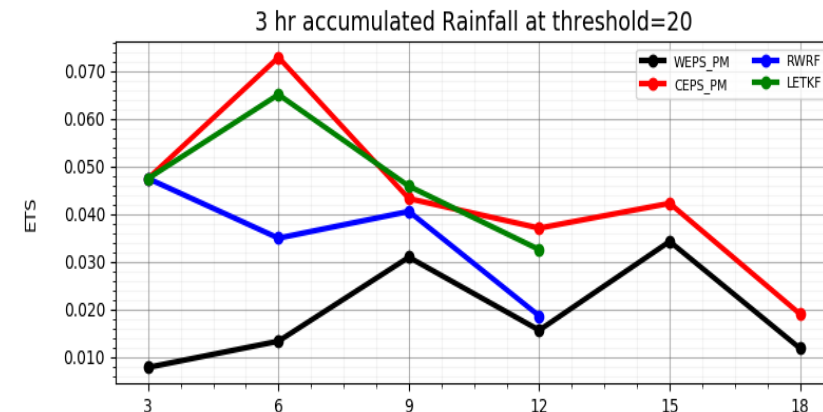
Land Surface Model

Noah Land
Surface Model

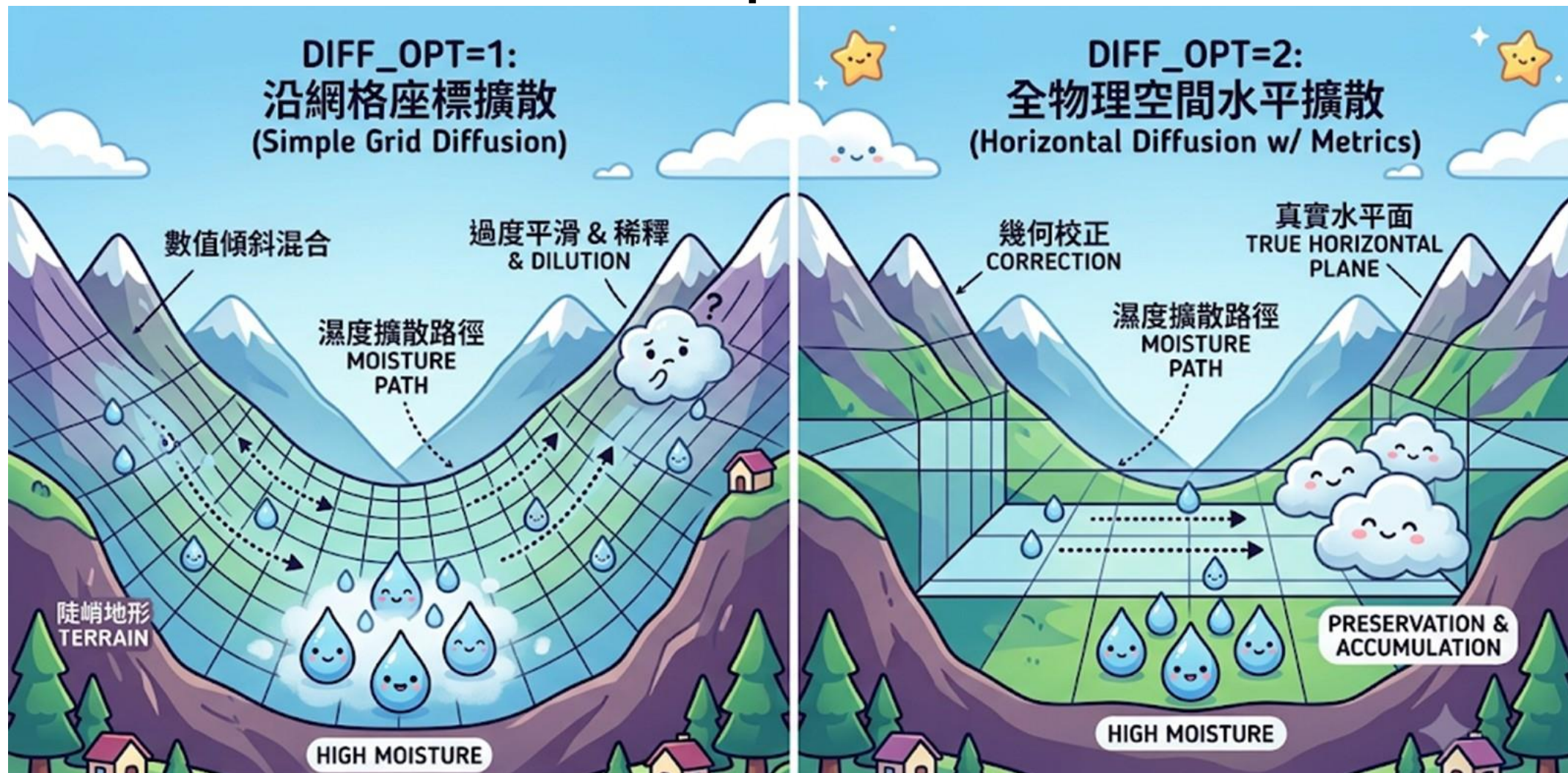


過去研究

- 關於CEPS 1.0 (謝等人，2024):
 - 測試CEPS於局部對流等個案表現良好。
 - 地面預報與降水預報均優於決定性(RWRF, LETKF-mean)等預報表現，提供不同的降水情境
 - 面對極端降水情形會有離散度不足的情形。
- 關於WRF
 1. 針對地面設定加入diffopt=2 (改善Q2預報表現)
 2. NOAH土壤參數法調整 (改善urban之T2預報表現)
 3. 測試YSU跟RRTMG之SPP增加系集離散度
 4. 模式擾動平行化加速方案
- 關於後處理產品
 - 氣象署統一為GRIB2格式，減少存儲資源需求

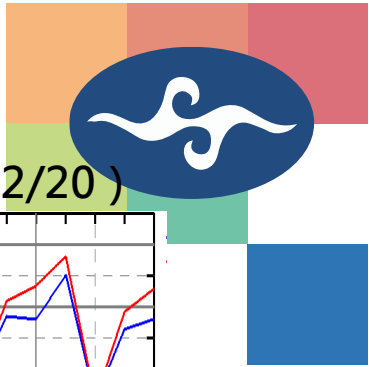


過去研究- 1. Diff_opt調整



➤ Diffusion實驗(II)

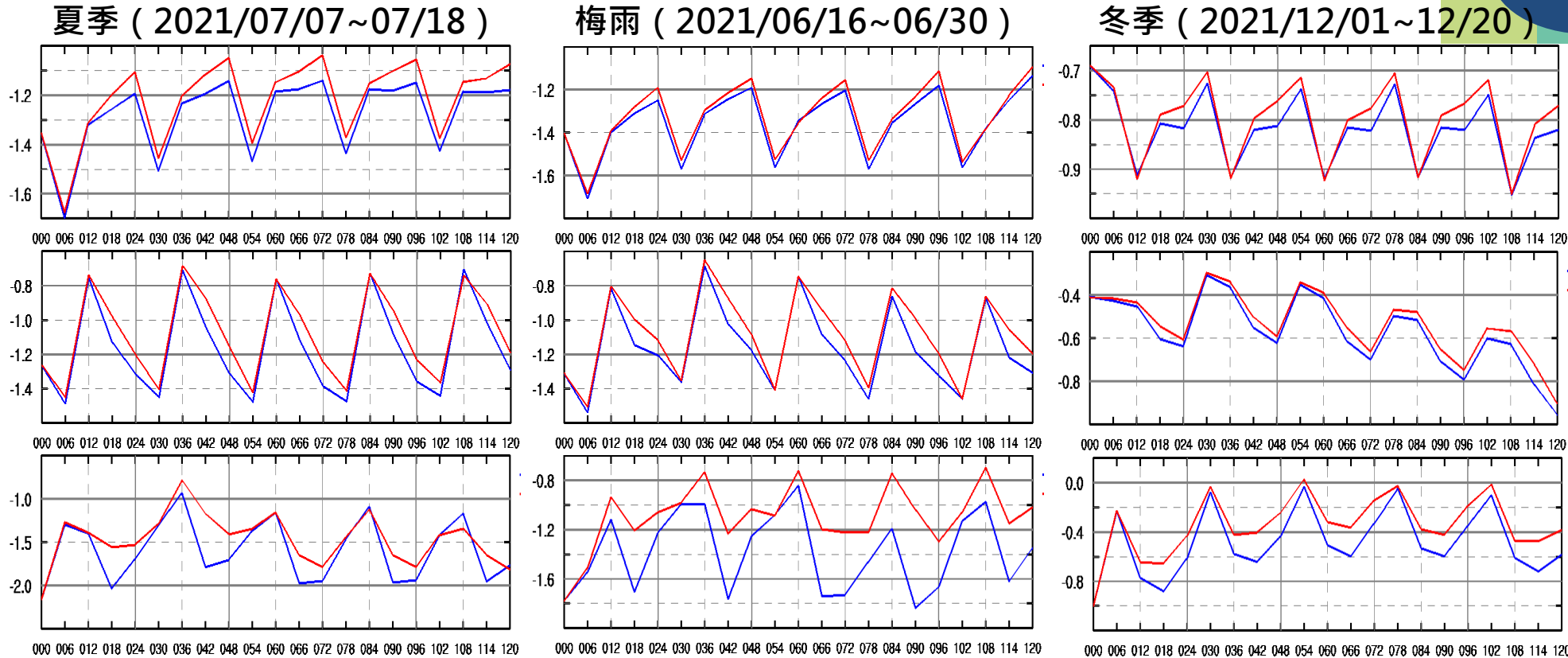
Q2_ME



@15-km
—OP50
—diffop2

@3-km

@Taiwan

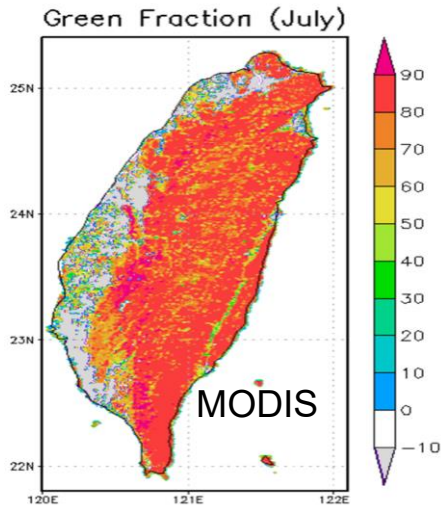


Q2 ME	夏季		梅雨		冬季	
@15-km	-1.28	-1.22	-1.35	-1.33	-0.82	-0.80
@3-km	-1.16	-1.08	-1.16	-1.09	-0.57	-0.53
@Taiwan	-1.59	-1.46	-1.38	-1.09	-0.49	-0.34

diff <= 0.01 中性
diff > 0.01 較差
diff > 0.01 較佳

✓ diffopt2實驗：水氣乾偏差皆有改善，尤其是夜間及臺灣區域改善最為顯著

過去研究- 2. NOAH土壤參數法調整



Original NOAH LSM

SHDFAC = 0.05
RSMIN = 400.0
SMCMAX = 0.45
SMCREF = 0.42
SMCWLT = 0.40
SMCDRY = 0.40

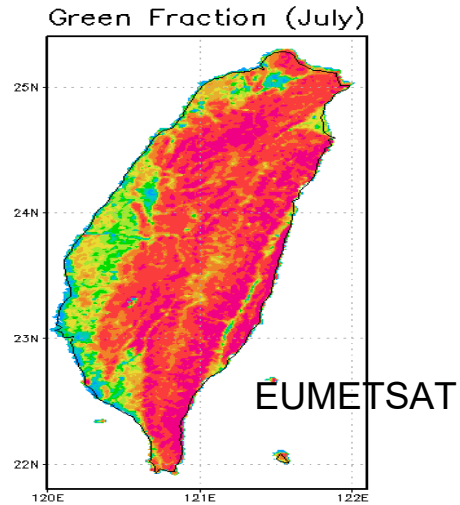


OP51 version

SHDFAC = from static data
 $RSMIN = 400.0 * (1 - SHDFAC) + 40.0 * SHDFAC$
 $SMCMAX = 0.45 * (1 - SHDFAC) + SMCMAX * SHDFAC$
 $SMCREF = 0.42 * (1 - SHDFAC) + SMCREF * SHDFAC$
 $SMCWLT = 0.40 * (1 - SHDFAC) + SMCWLT * SHDFAC$
 $SMCDRY = 0.40 * (1 - SHDFAC) + SMCDRY * SHDFAC$

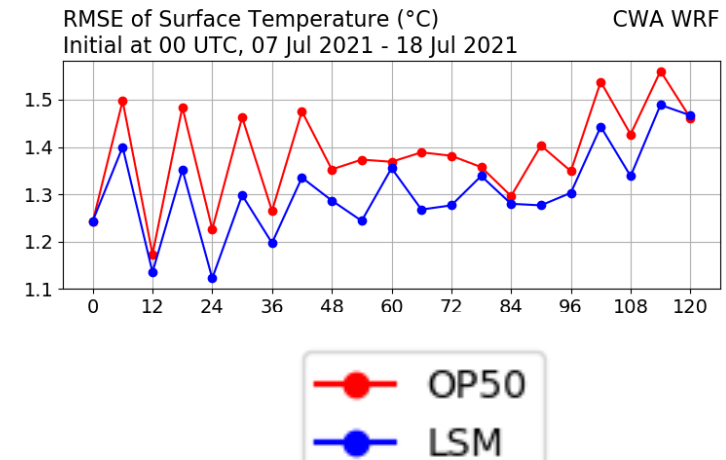
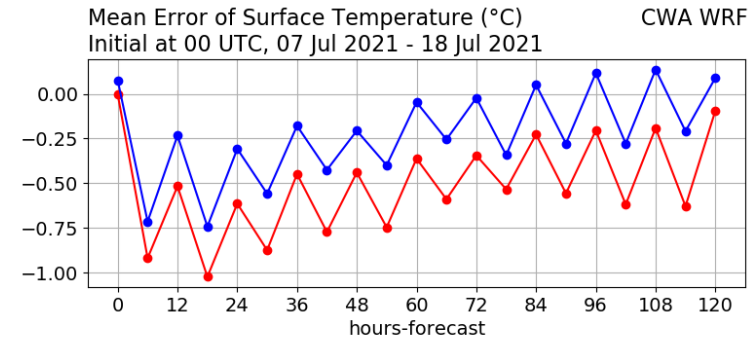
- 參數皆設為定值
→ 幾乎為無植被的過強都市效應
- 有顯著暖偏差及乾偏差

- 參數設定使用static data做權重
- 改善OP50冷偏差現象，但乾偏差較顯著。



僅校驗urban

夏季：(2021/07/07~07/18)

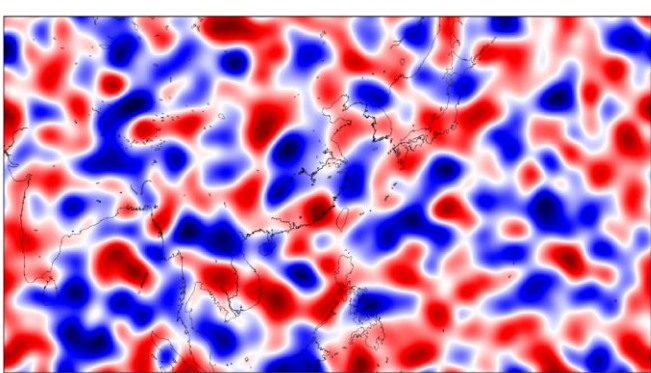


過去研究- 3. SPP參數法

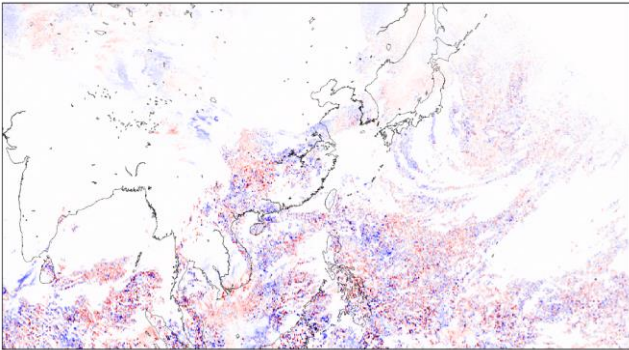
$$X^* = [1 \pm r(x,y,t)] X$$

(Palmer et al. 2009)

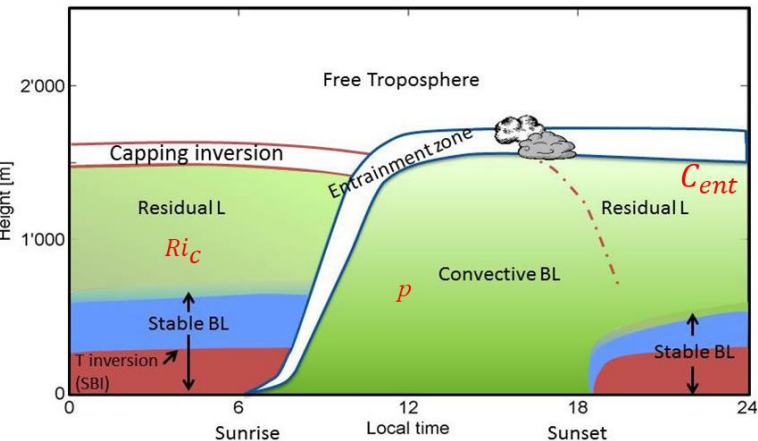
X can be a variable or parameter, and r is a 2D perturbation field



lengthscale_spp= 150,000 m

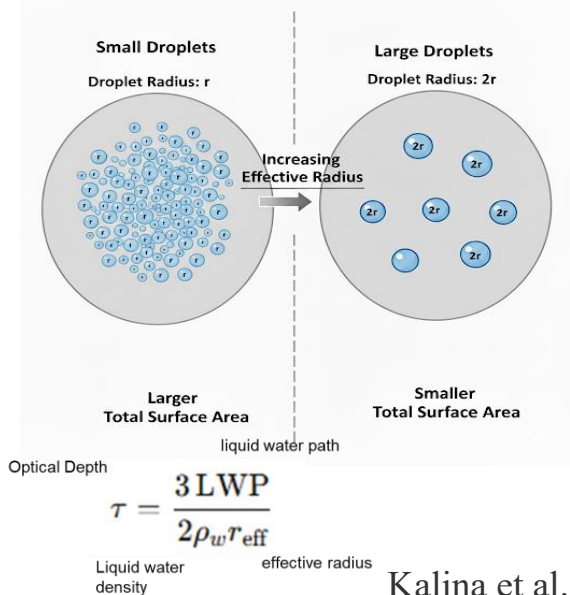


▲ RRTMG-SPP affects shortwave downward radiation.



$$K_m = \kappa w_s z \left(1 - \frac{z}{h}\right)^p$$

Su et al. 2025



$$\tau = \frac{3LWP}{2\rho_w r_{eff}}$$

Liquid water density effective radius

Kalina et al. 2021

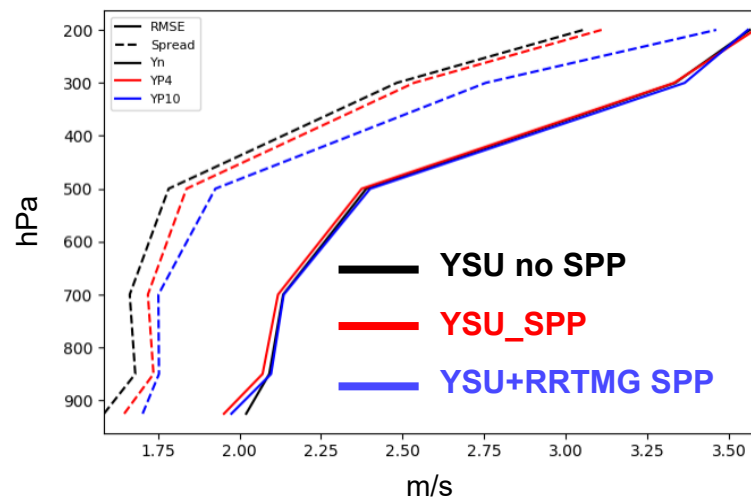
Field	physical meaning	Host Parameterizati on Scheme	Percent magnitude perturbation (for one std dev)
K_M	momentum diffusion coefficient	YSU-PBL	$\pm 30\%$
γ_c	counter-gradient correction	YSU-PBL	$\pm 30\%$
z_{facent}	height-dependent factor	YSU-PBL	$\pm 30\%$
Z_0	roughness length	MM5 similarity-sfclay	$\pm 50\%$
U^*	friction velocity	MM5 similarity-sfclay	$\pm 10\%$
p	Profile shape exponent	YSU-PBL	$\pm 30\%$ (from 2 between 1 and 3)
Ri_c	Critical bulk Richardson number	YSU-PBL	$\pm 30\%$ (from 0.25 between 0.1 and 0.5)
C_{ent}	Entrainment coefficient	YSU-PBL	$\pm 30\%$ (from 0.15 between 0.075 and 0.3)
Re_l	liquid water effective radius	RRTMG-ration	$\pm 10\%$
Re_i	ice particle effective radius	RRTMG-ration	$\pm 10\%$

WEPS加入YSU-SPP 跟 RRTMG-SPP之表現

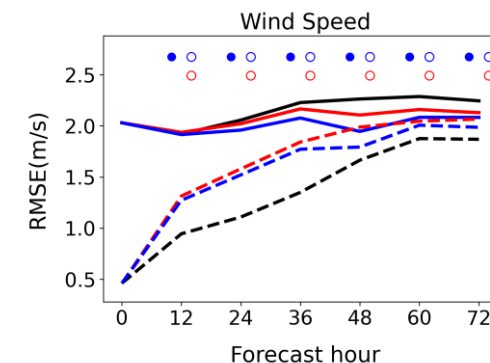
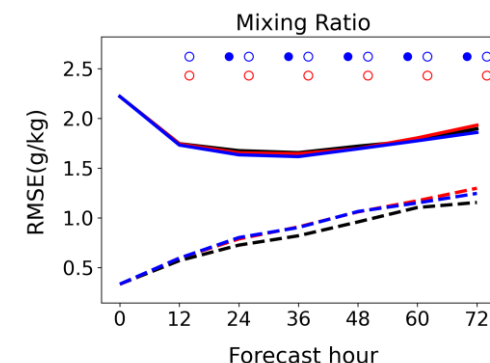
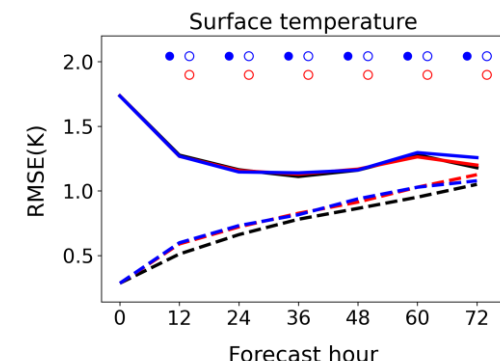
- 綜觀上看到加入輻射參數法能有效增加離散度
- 地面校驗顯示離散度有顯著提升。
- 個案中將水FSS有明顯提升。
- 加入平行化設定，計算時間有明顯加速。

Summer
(240930-1005)

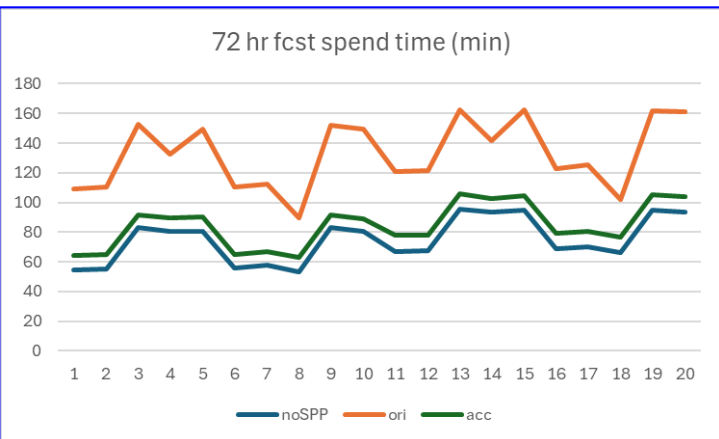
48-h forecast of wind speed @ 15km



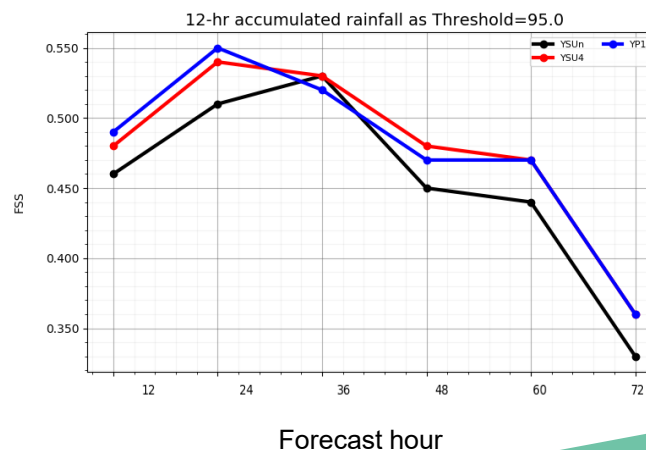
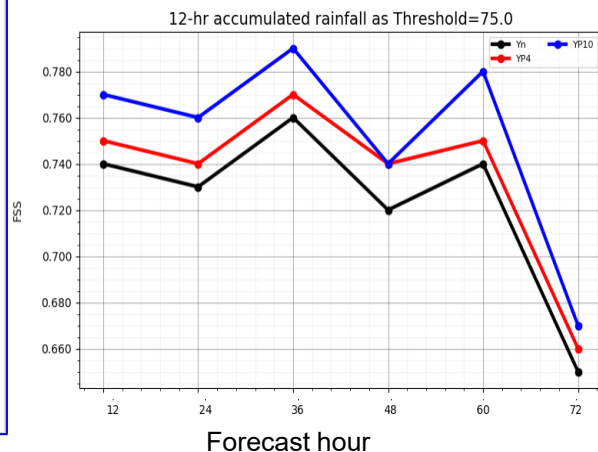
Surface verification @ 3km



CPU time



Rainfall verification @ 3km
75%



CEPS 1.0 與 CEPS 1.2 版本更新對比

設定項目	CEPS 1.0 (舊作業版)	CEPS 1.2 (2026 最新上線版)	更新效益與目的
WRF 核心版本	OP50	OP51-spp	強化降水與地面的預報能力
擴散選項 (Diff_opt)	Diff_opt = 1	Diff_opt = 2	改善近地面 2m 混合比 (Q2) 預報
雷達反射率處理	do_radar_ref = 0	do_radar_ref = 1	開啟雷達反射率診斷計算
陸面模式 (LSM)	標準 Noah LSM	Noah LSM 城市參數修正	降低城市區域近地面 2m 溫度 (T2) 偏差
隨機參數化 (SPP)	未開啟	YSU-SPP + RRTMG-SPP (開啟)	大幅提升風速與溫濕度之系集離散度
後處理產品格式	DMS key (binary)	Grib2	節省硬碟空間，統一格式

整合測試

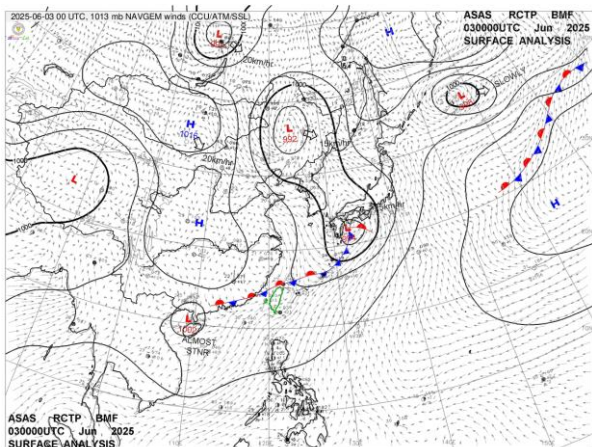
- 地面校驗: 6/2~6/14
- 降水個案比較 :6/2~6/5 鋒面降水較明顯; 6/6~6/11午後對流明顯;
6/12~6/13 受熱帶氣旋影響

鋒面個案

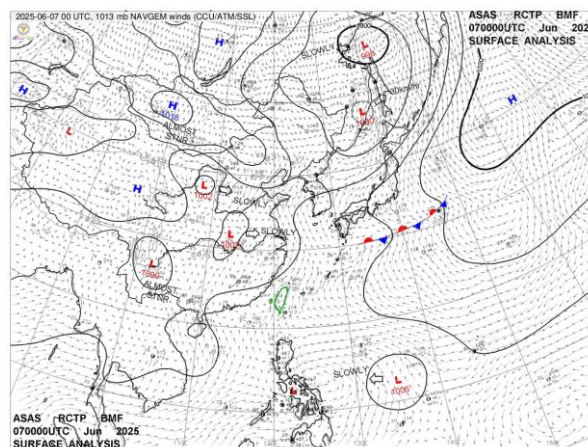
午後個案

熱帶氣旋個案

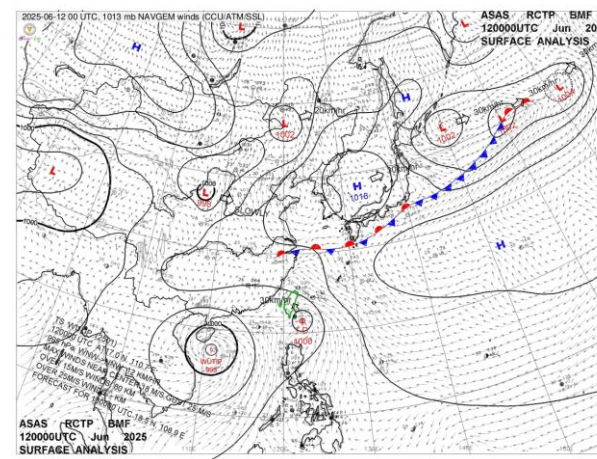
6/2



6/6



6/12

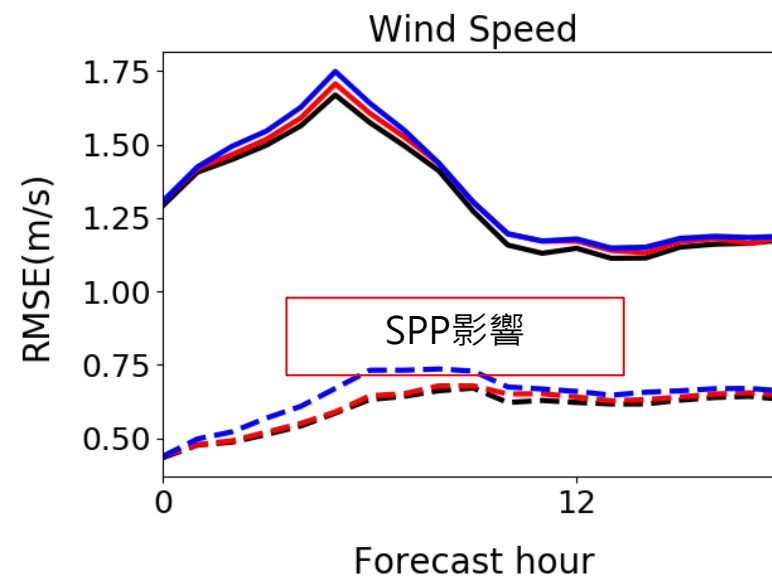
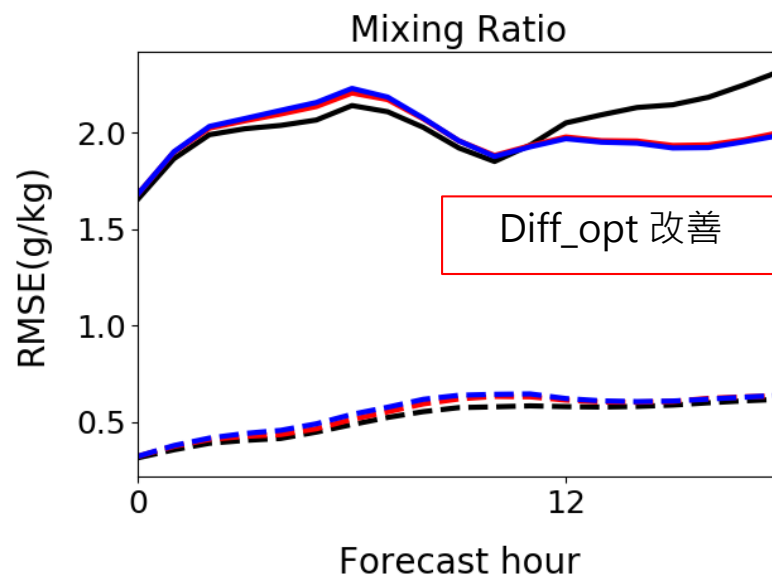
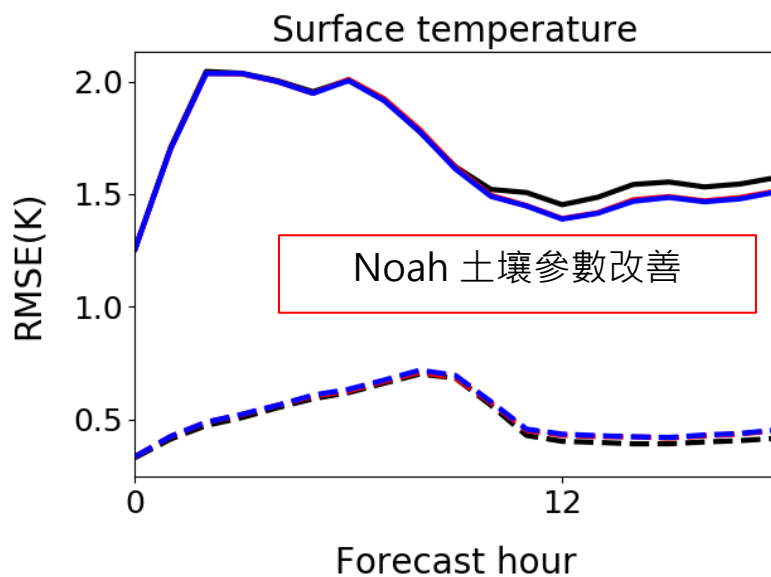
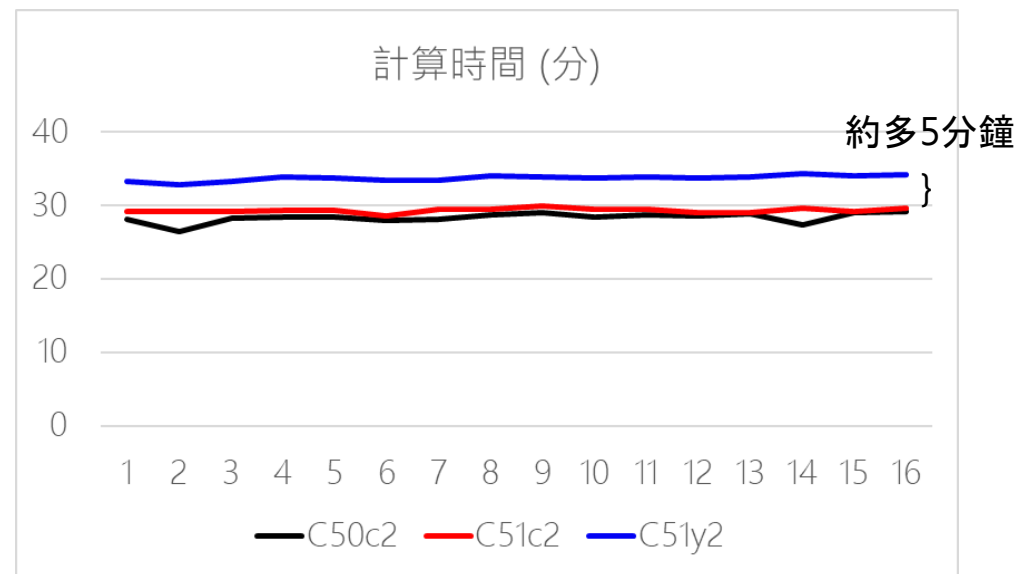


6/14

整合測試

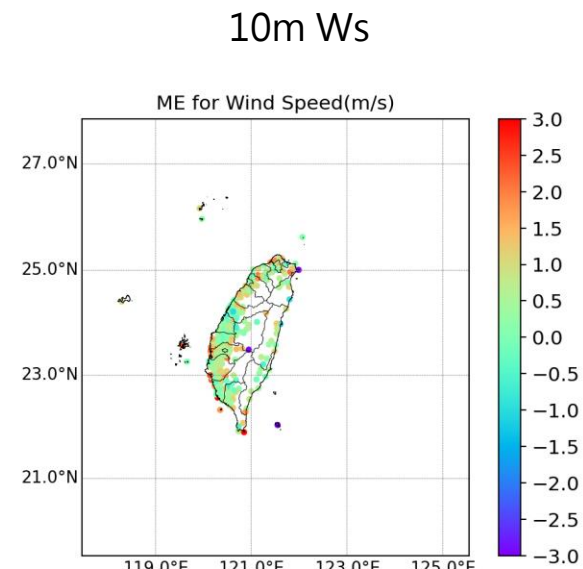
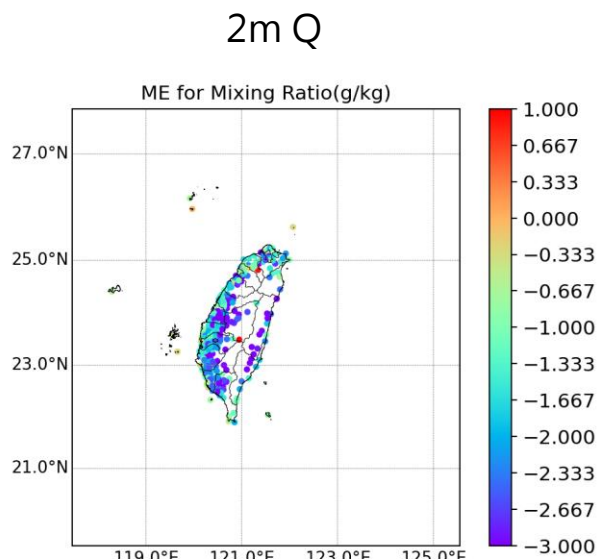
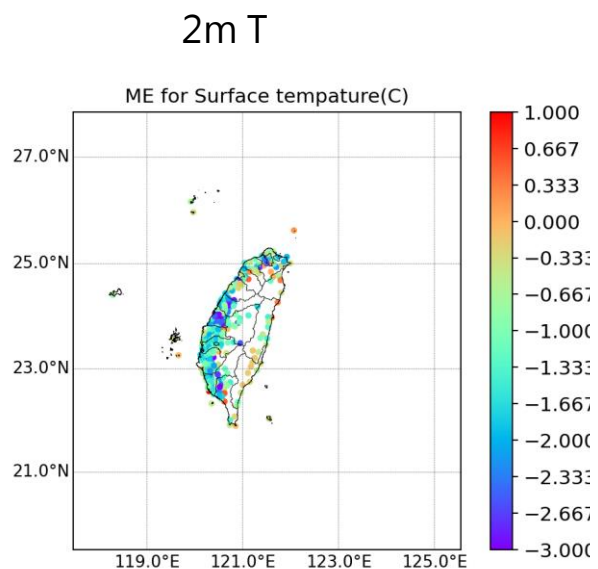
實驗時間: 25060200-25061400 只執行00 run

實驗名稱	Wrf.exe	BC (WEPS)	YSU SPP +RRTMG SPP
C50c2	OP50	V	
C51c2	OP51-spp	V	
C51y2	OP51-spp	V	V

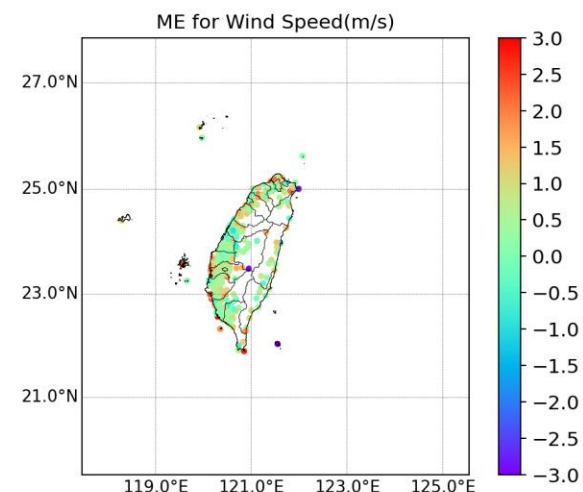
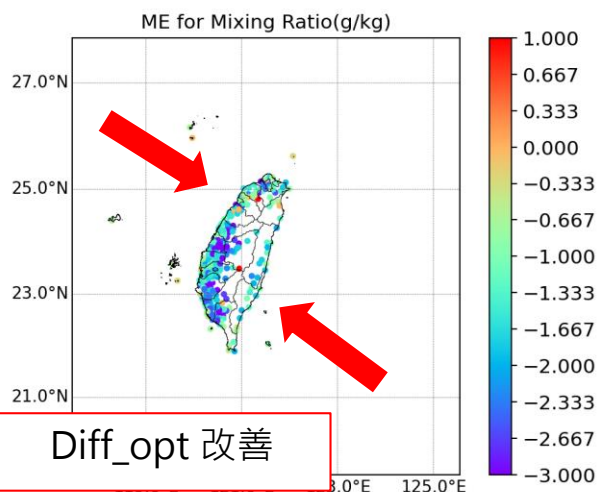
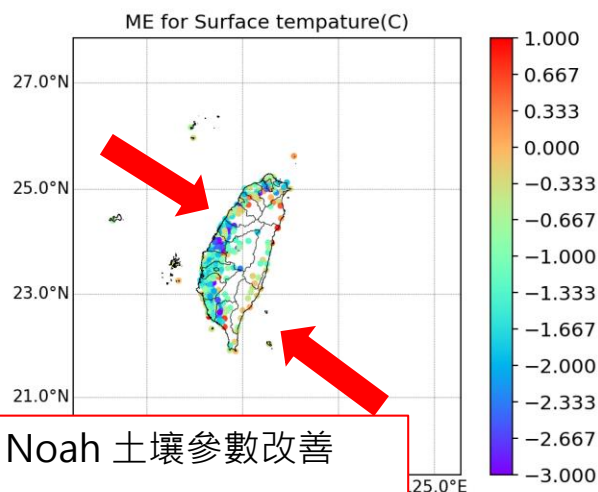


2D Mean error @ 18h

C50c2

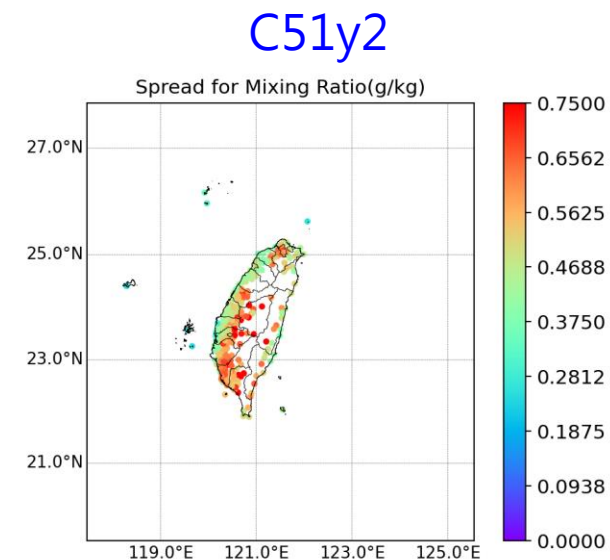
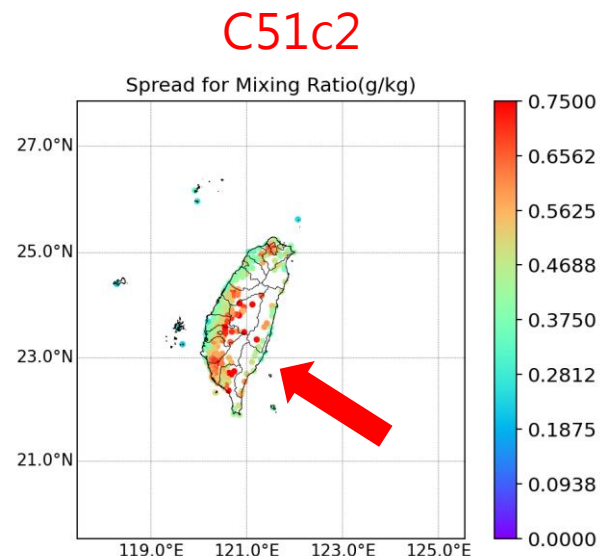
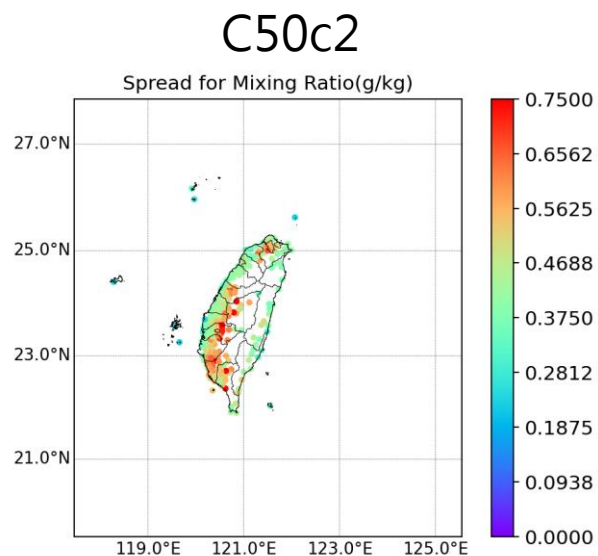


C51c2

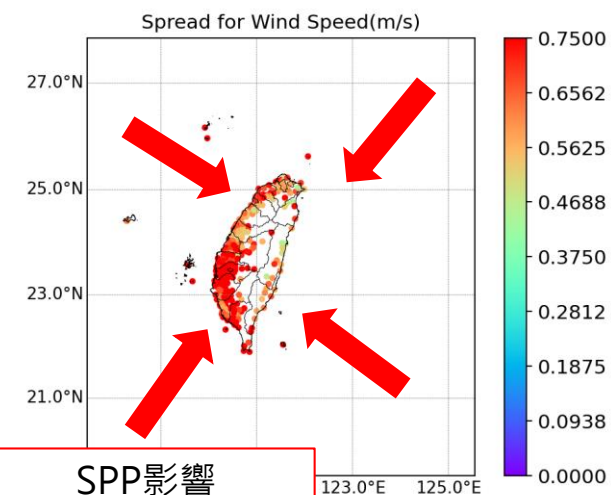
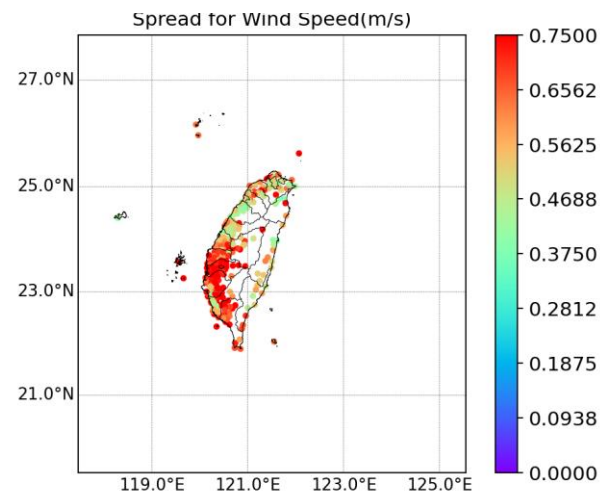
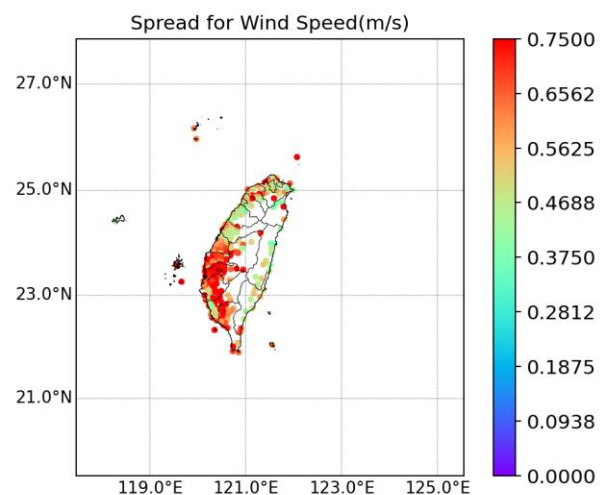


2D spread @ 6h

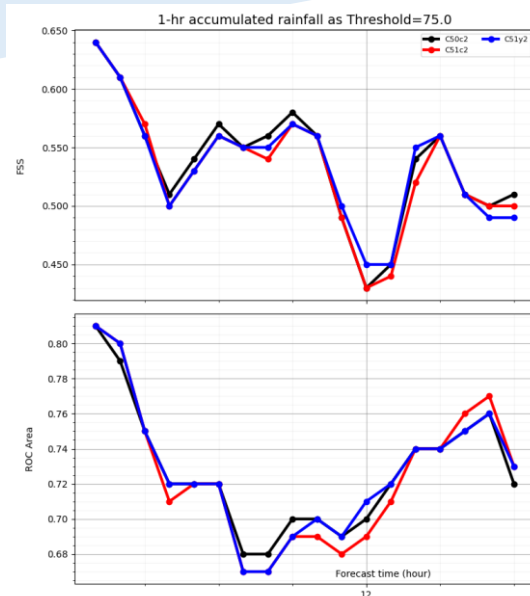
2m Q



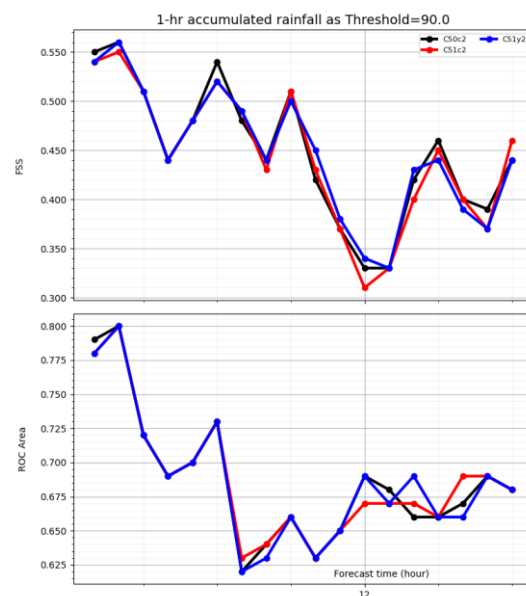
10m Ws



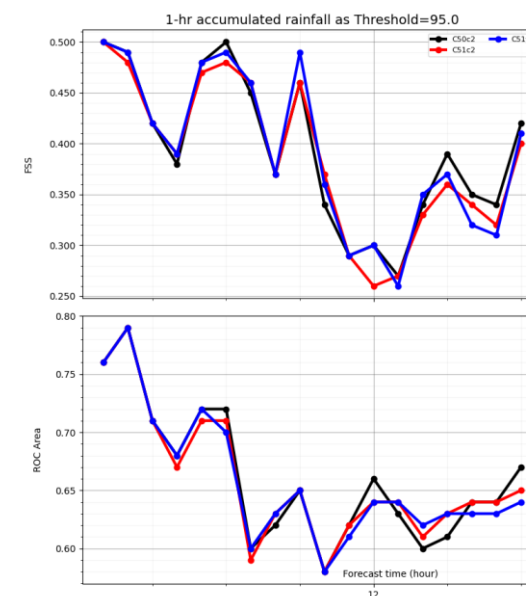
75%



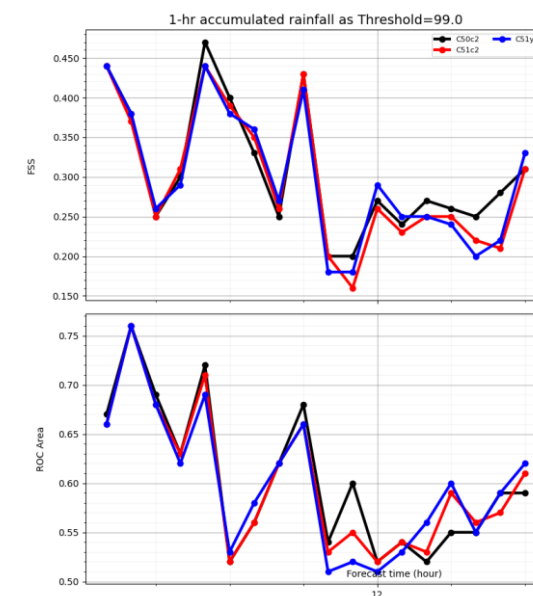
90%



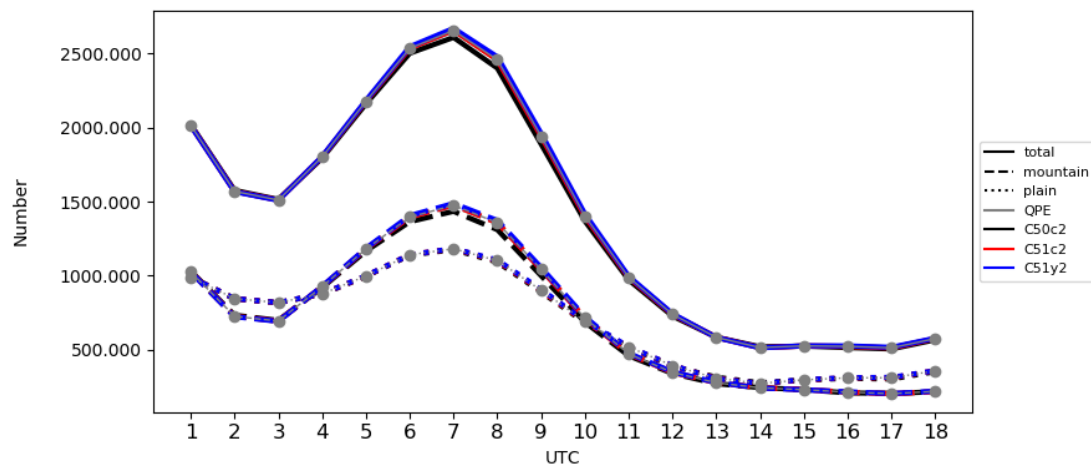
95%



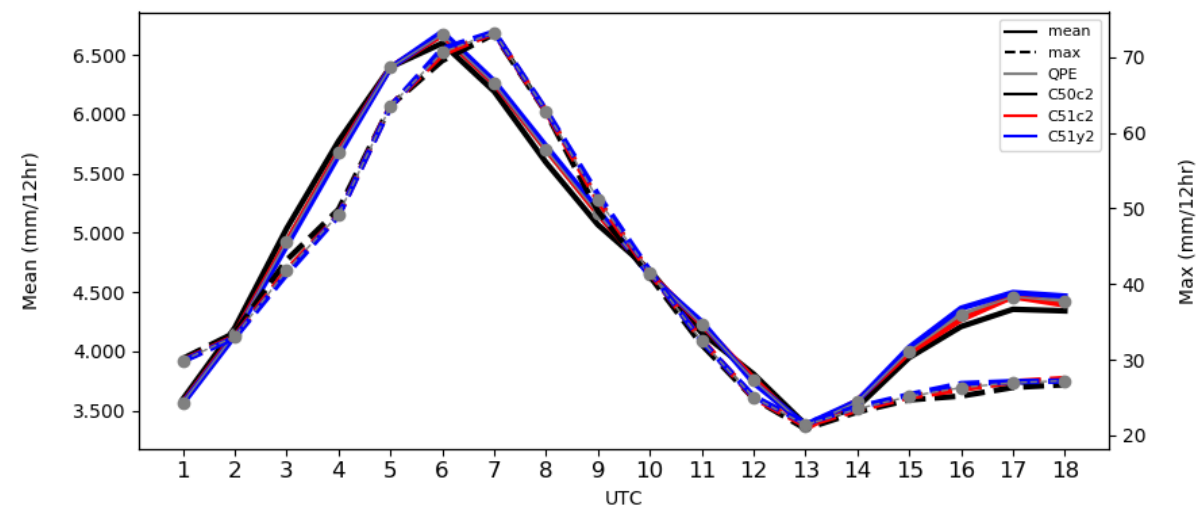
99%



Rainfall grid number



Mean/Max rainfall



整體降水來看時序差異小，且預報時序都正確，故針對個案來分析

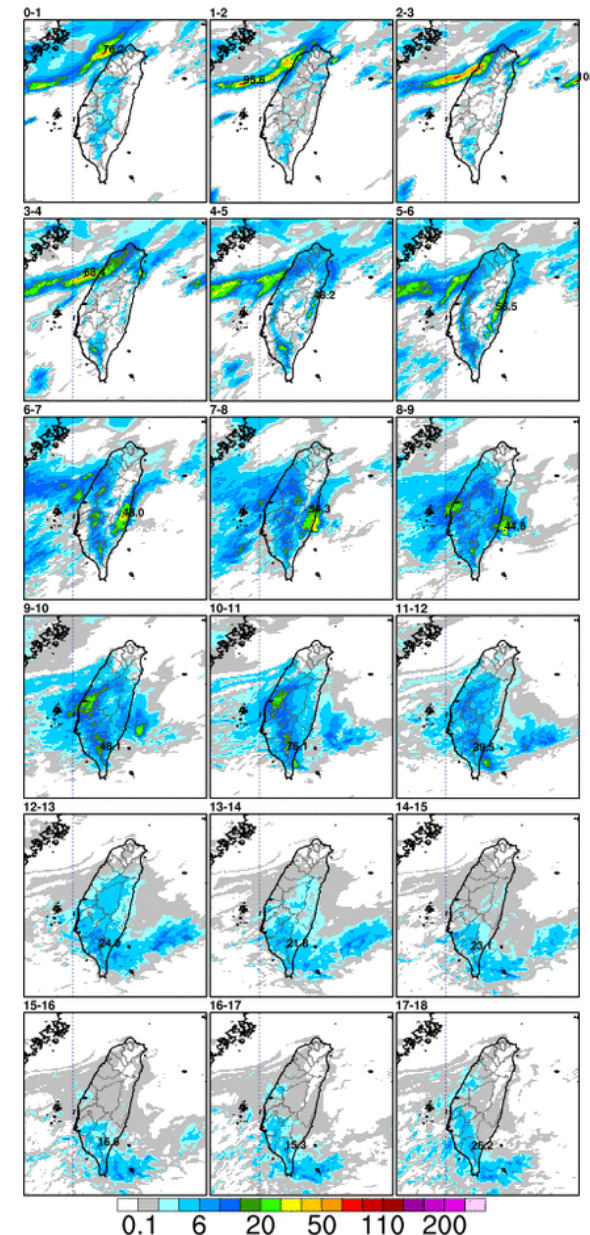
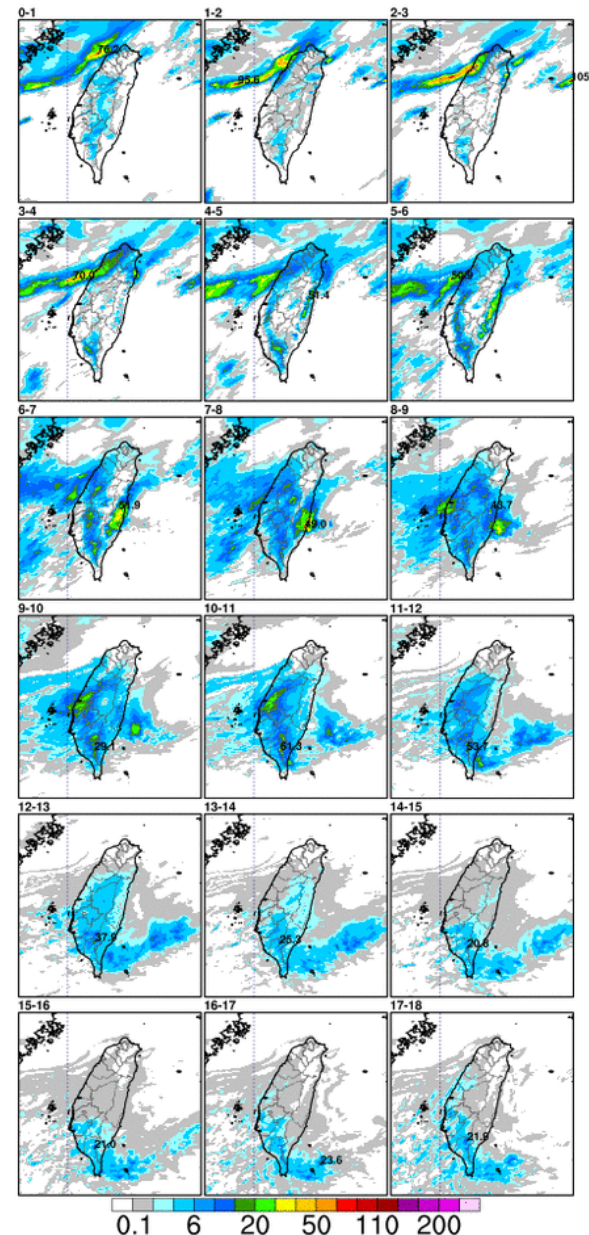
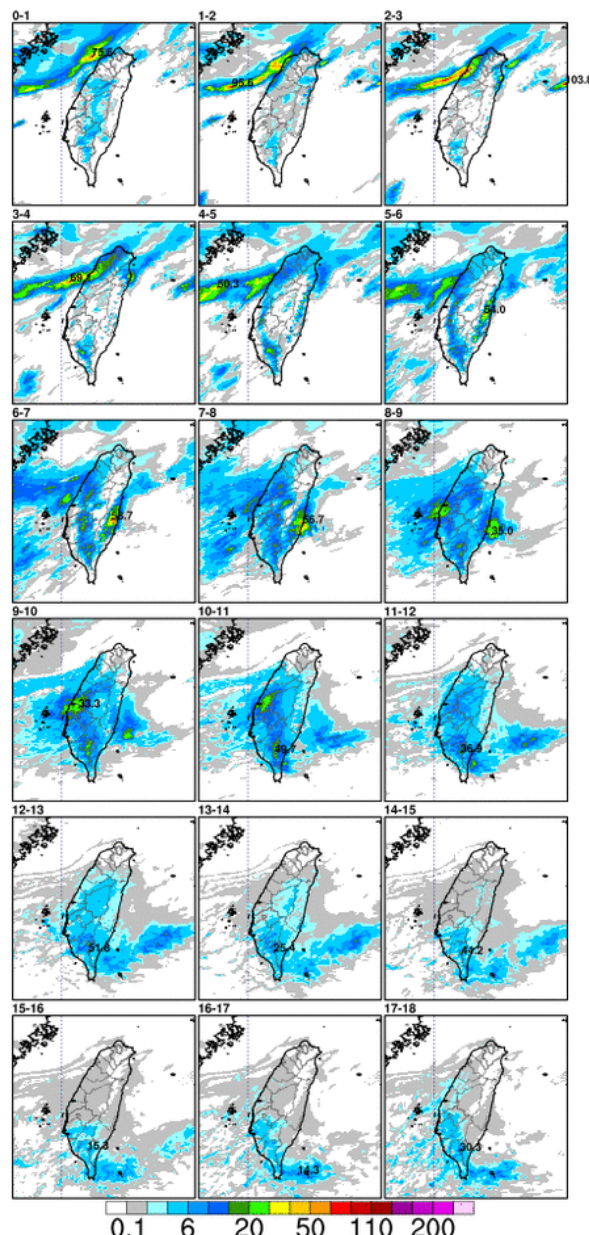
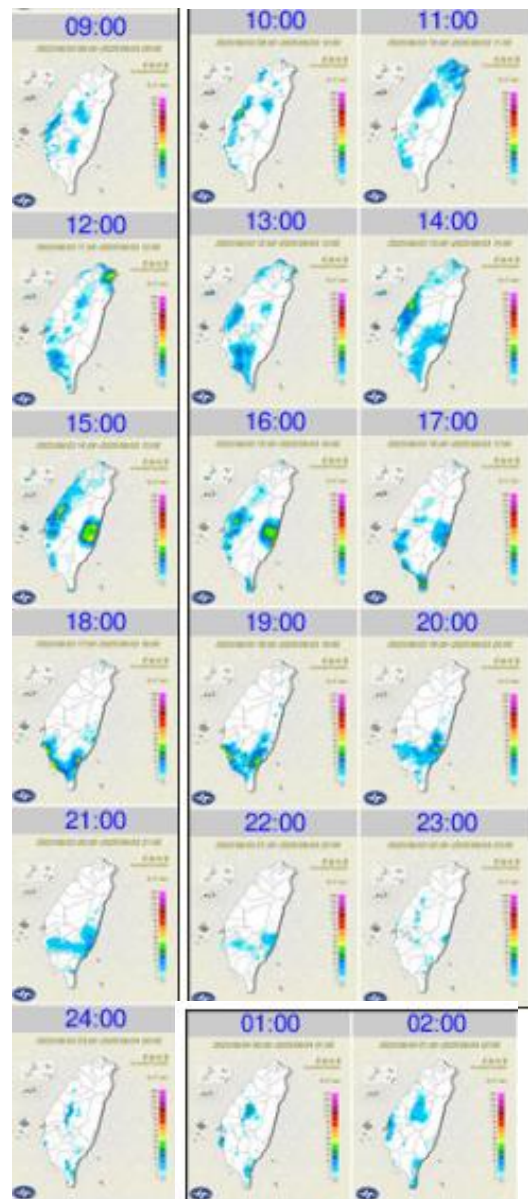
鋒面個案 (6/3)

C50c2 PM

C51c2 PM

C51y2 PM

6/3



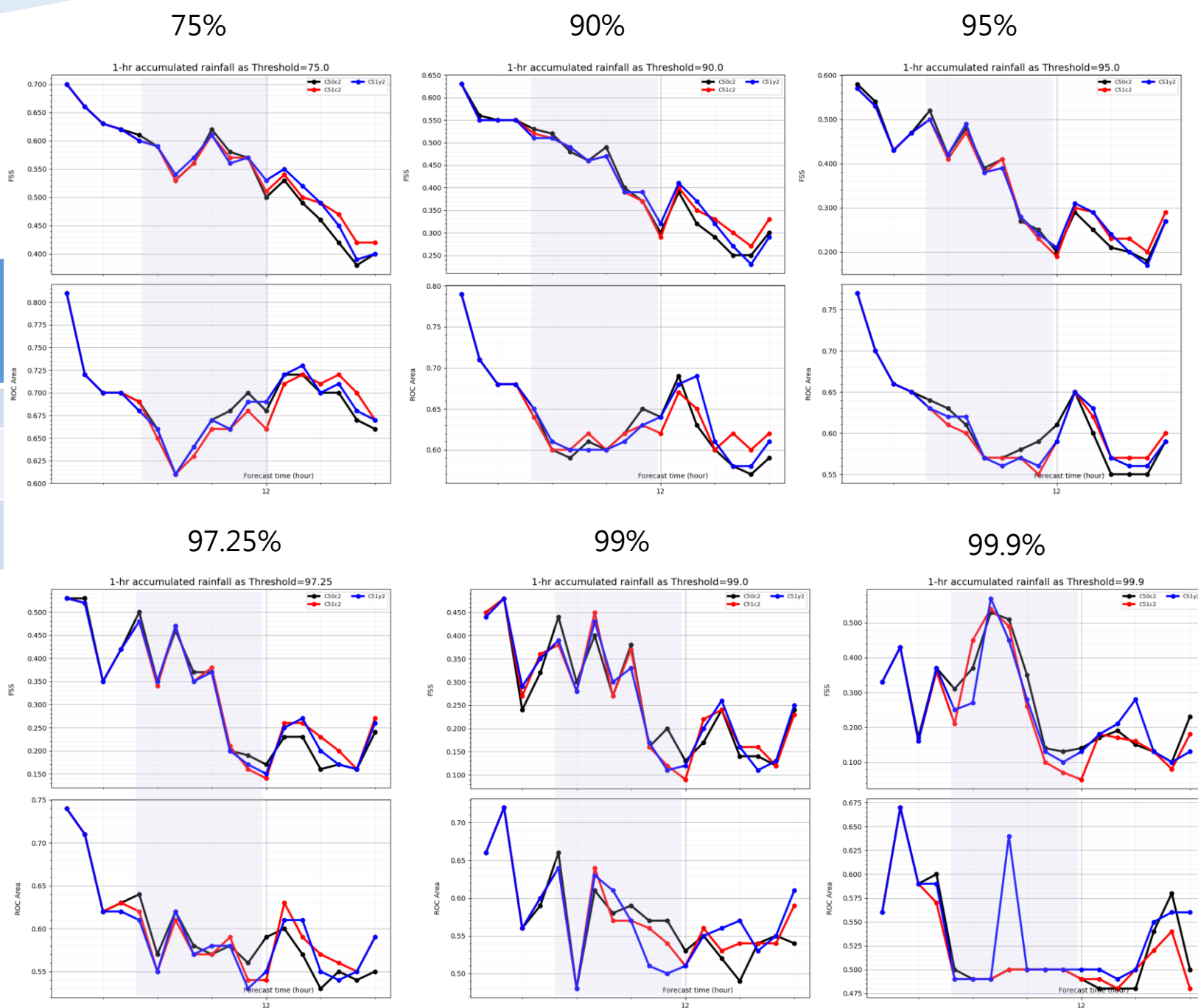
鋒面個案

25060200-25060500

實驗名稱	Wrf.exe	BC (WEPS)	YSU SPP +RRTMG SPP
C50c2	OP50	V	
C51c2	OP51-spp	V	
C51y2	OP51-spp	V	V

鋒面個案在初始預報良好，但是後來分數下降，主要是對於鋒面位置的掌握不佳。

而在入夜後有較低的預報分數。更新WRF版本在此時有較好的表現。

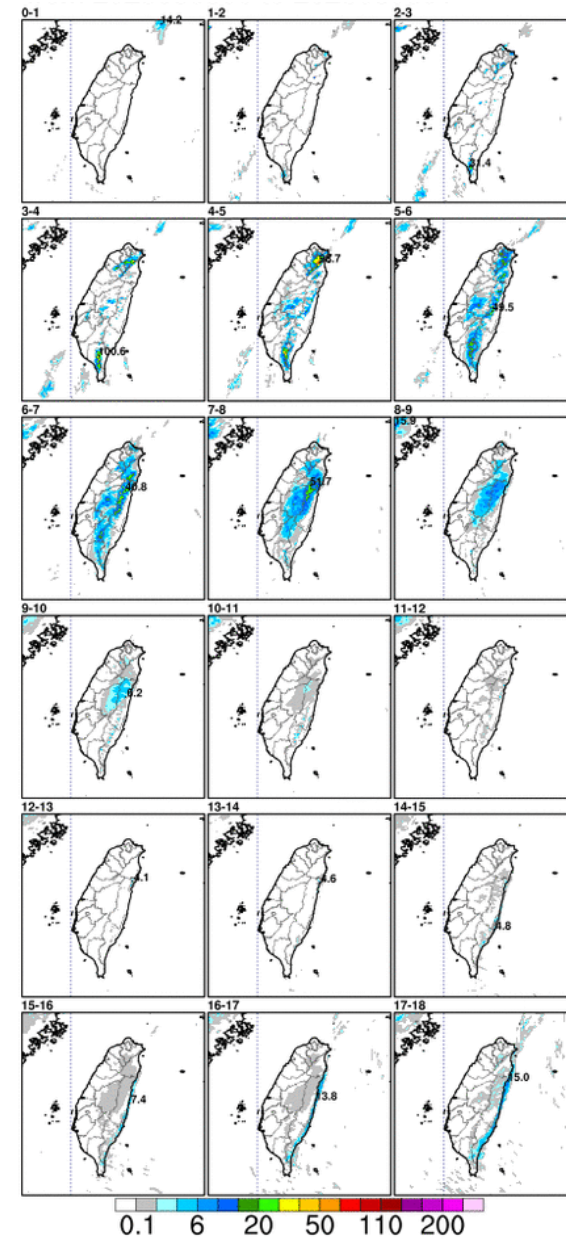
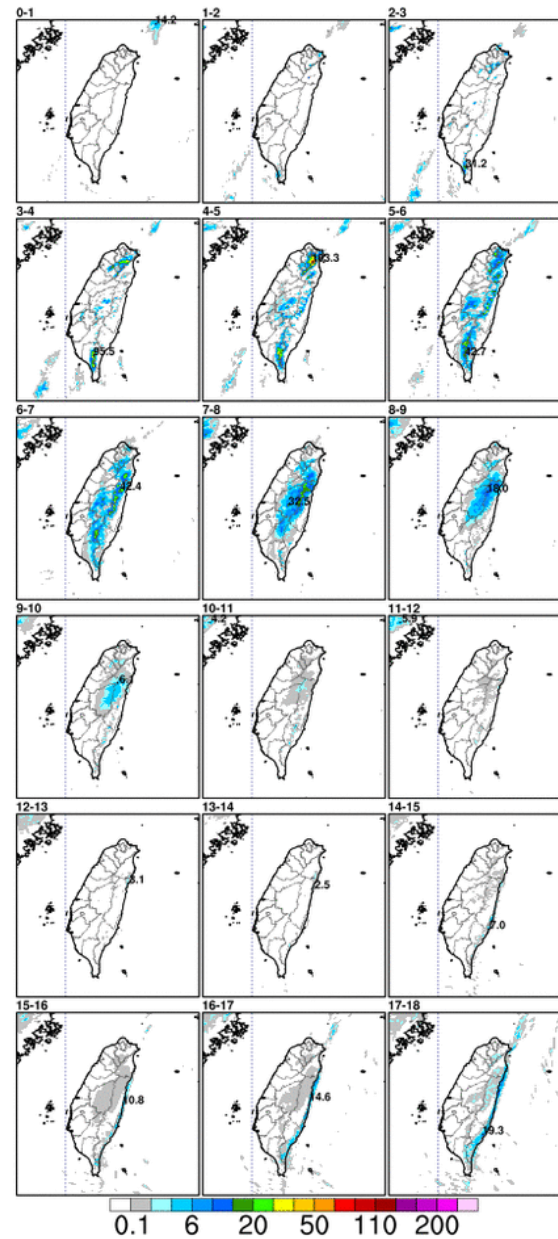
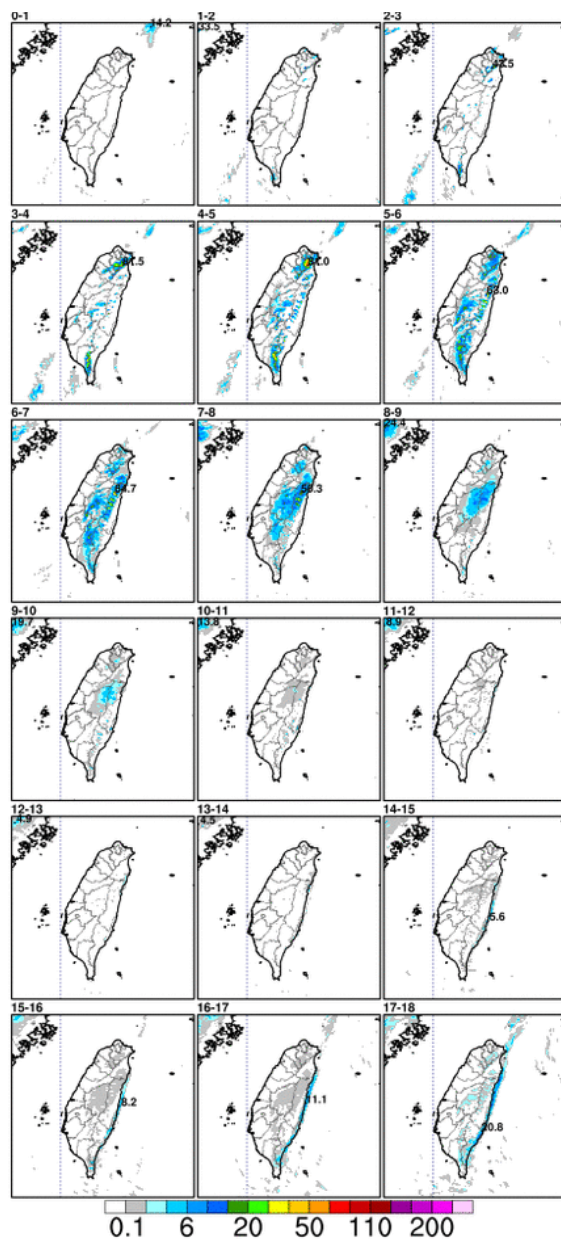
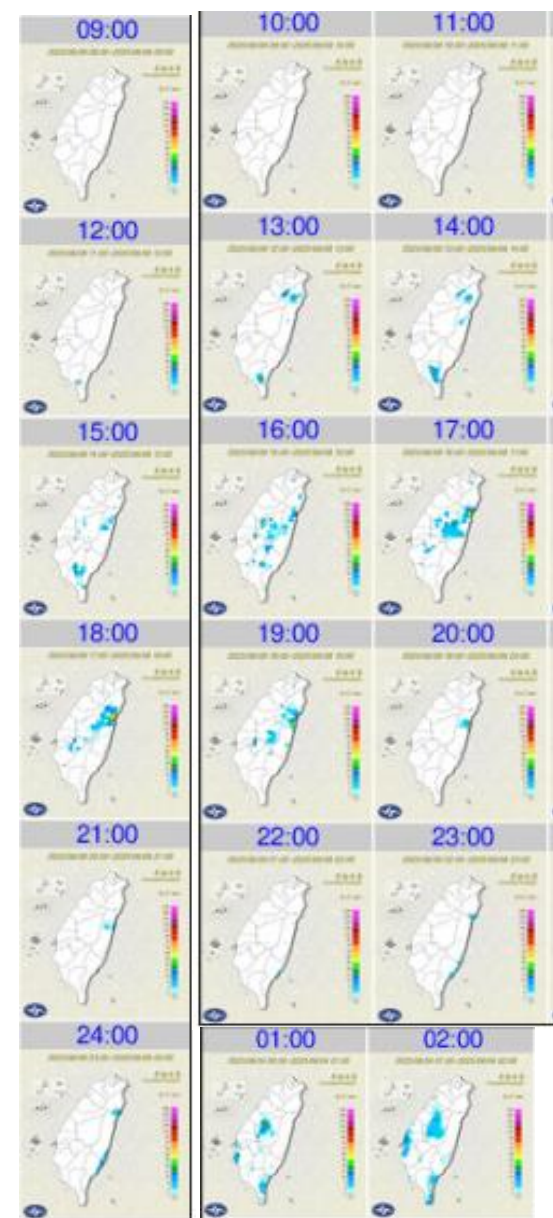


午後對流個案 (6/8)

C50c2 PM

C51c2 PM

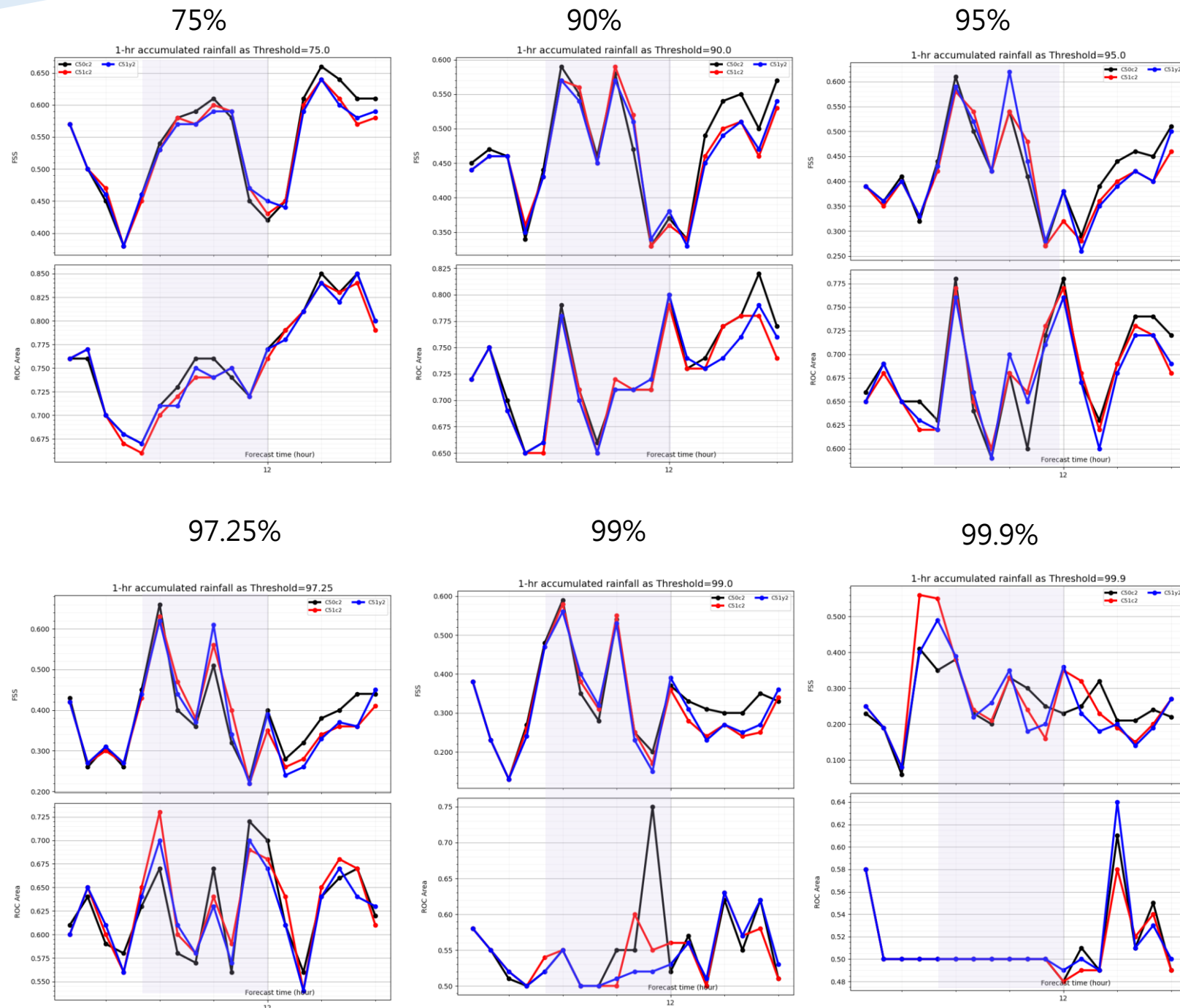
C51y2 PM



午後對流個案 25060600-25061100

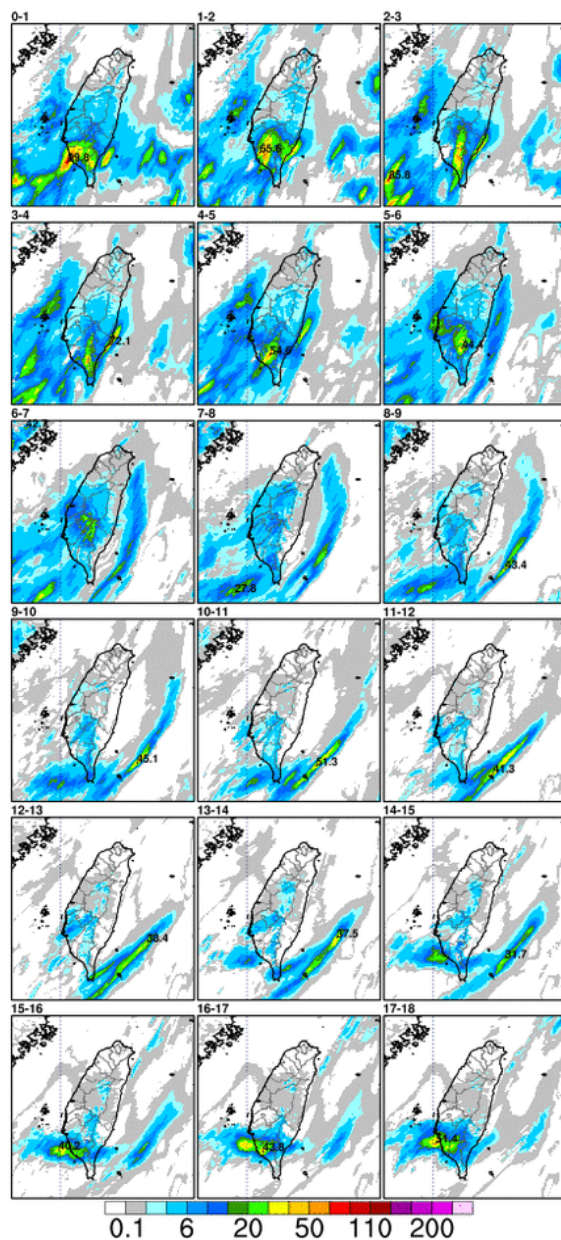
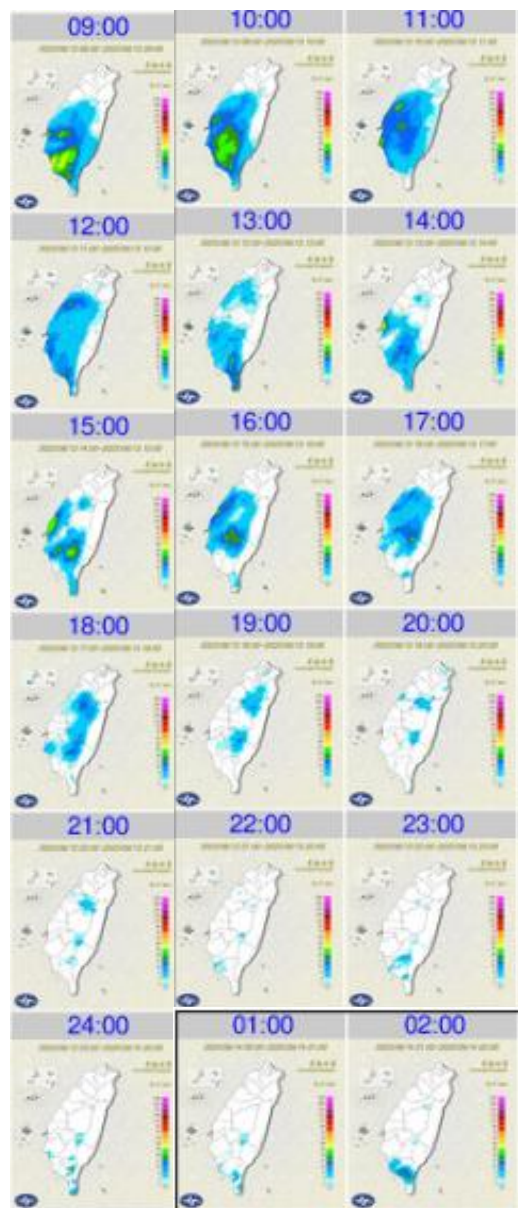
實驗名稱	Wrf.exe	BC (WEPS)	YSU SPP +RRTMG SPP
C50c2	OP50	V	
C51c2	OP51-spp	V	
C51y2	OP51-spp	V	V

對於午後對流的個案，CEPS的整體表現是良好的，尤其是在紫色區域午後對流發生的時機。
對於入夜後的降雨有良好的掌握，使得在入夜後有明顯的分數提升。但更新WRF版本在晚上的預報分數稍低。

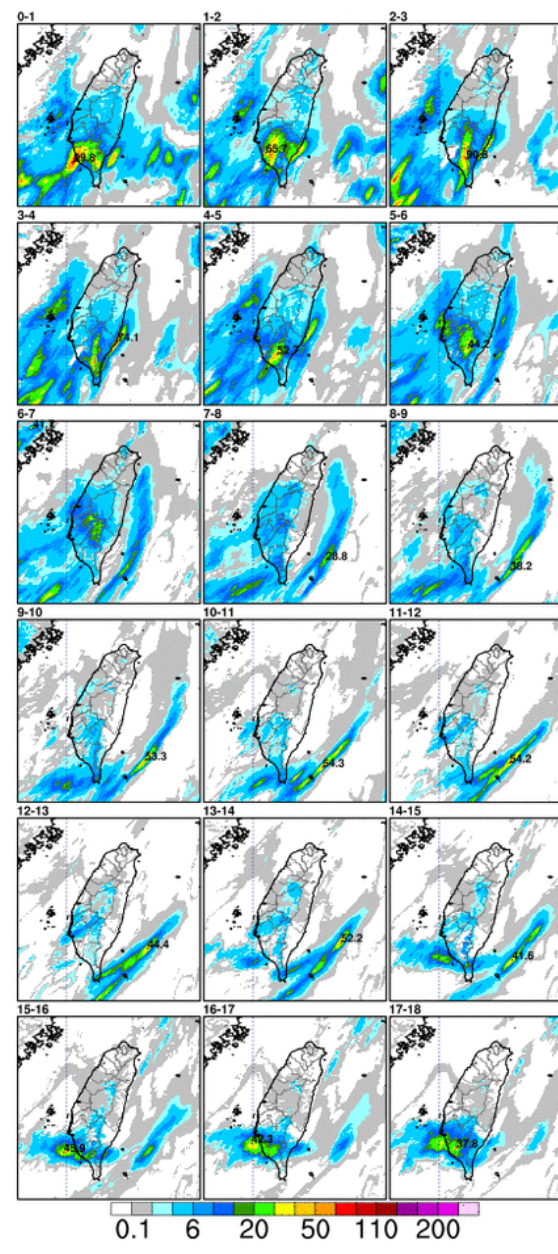


熱帶氣旋個案 (6/13)

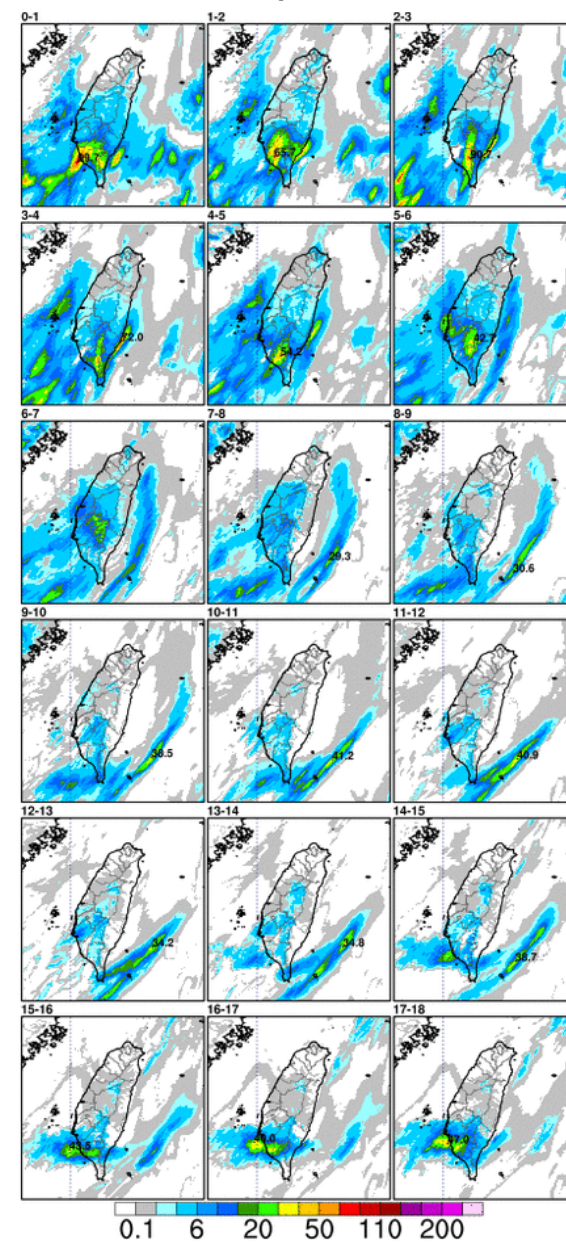
C50c2 PM



C51c2 PM



C51y2 PM



熱帶氣旋個案

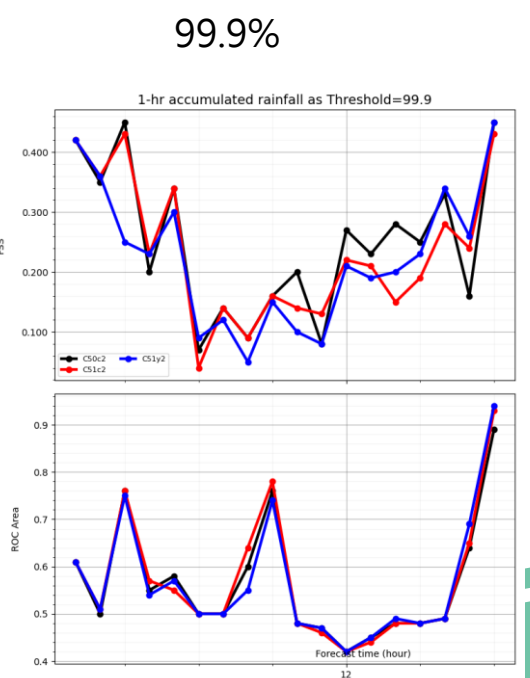
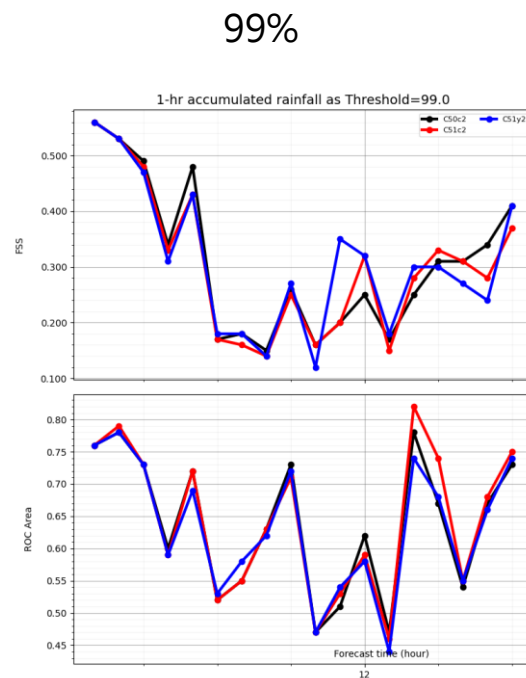
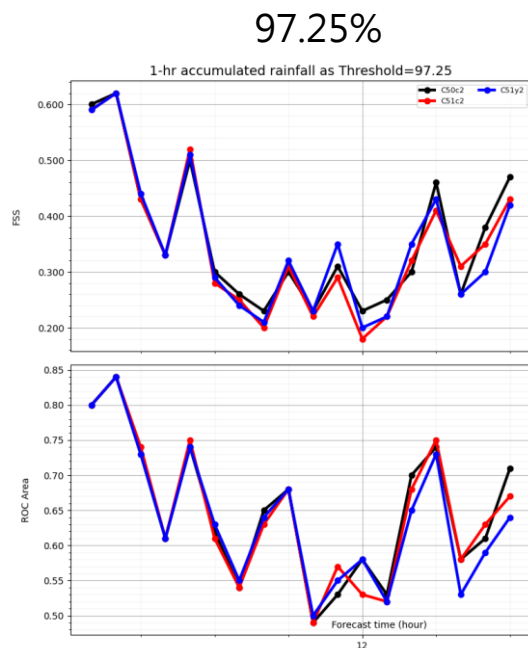
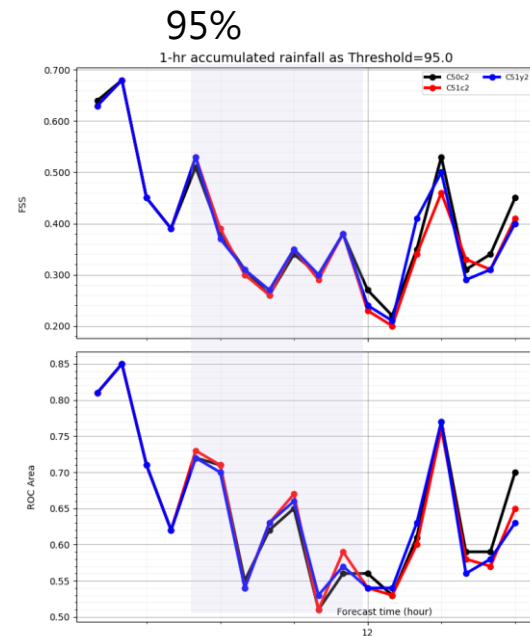
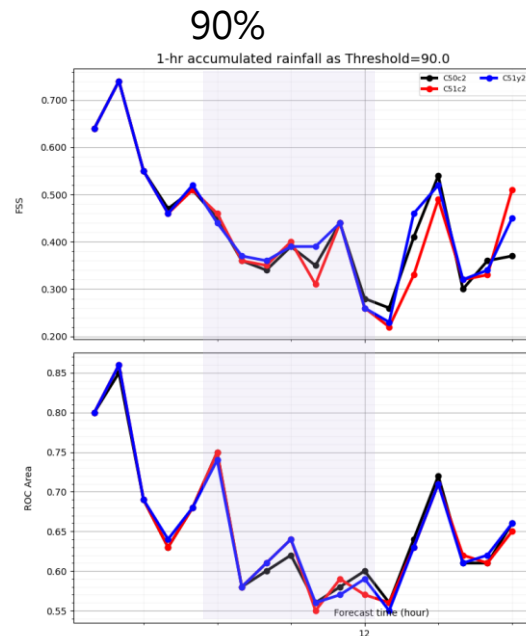
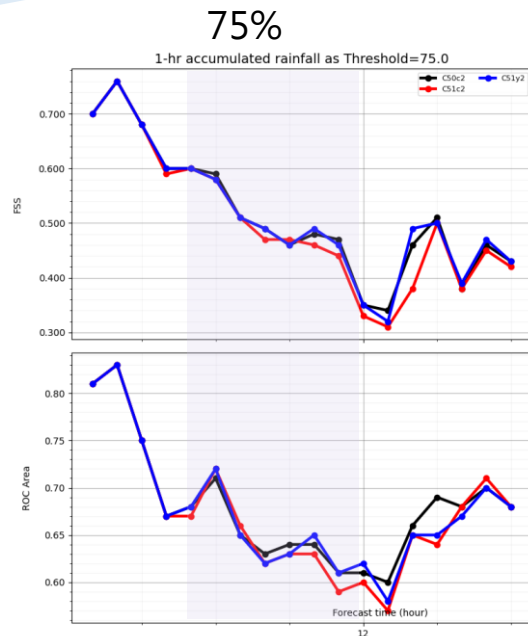
25061200-25061400

實驗名稱	Wrf.exe	BC (WEPS)	YSU SPP +RRTMG SPP
C50c2	OP50	V	
C51c2	OP51-spp	V	
C51y2	OP51-spp	V	V

CEPS在前6小時都有很高的分數，從PM郵票圖可以看到掌握良好，這是由於初始場來自LETKF的優勢。

但由於模式範圍較小，沒辦法完整模擬出颱風的結構，在後期的降水分數會明顯下降。

三個實驗差異不大。



總結

- SPP平行化加速方案顯示加入SPP只會增加**5分鐘**預報時間，對於CEPS預報影響不大。
- C51y2為本次更新之最新版本，**在地面校驗顯示能改善地面溫濕度的誤差，且對風速的離散度增加顯著**。
- 降水校驗來看變化不大，CEPS的整體雨量格點數預報良好。
- 針對三個個案分析CEPS的降水表現，顯示CEPS對於午後對流表現最佳，而鋒面跟颱風個案則受大尺度影響預報能力較差。
- 模式版本更新對於入夜後的降水表現有較大的差異，但從雨圖來看三個實驗的**降水預報差異並不顯著**
- 本次上線預計以C51y2實驗 (即CEPS1.2版本)進行上線

未來工作

- 針對**CEPS**的初始場離散度不足問題進行調整
 - **LETKF**引入**SPP**方法
 - 加入初始場擾動
- 配合**AI**發展**CEPS**降水與陣風預報產品。