

Analysis of MPD Lidar Data from Northern Taiwan and the Effects of Humidity and Radar Data Assimilation

鍾高陞 王采琳

中央大學 大氣科學系

第四十屆天氣分析與預報研討會

2026/Sep/03



Introduction

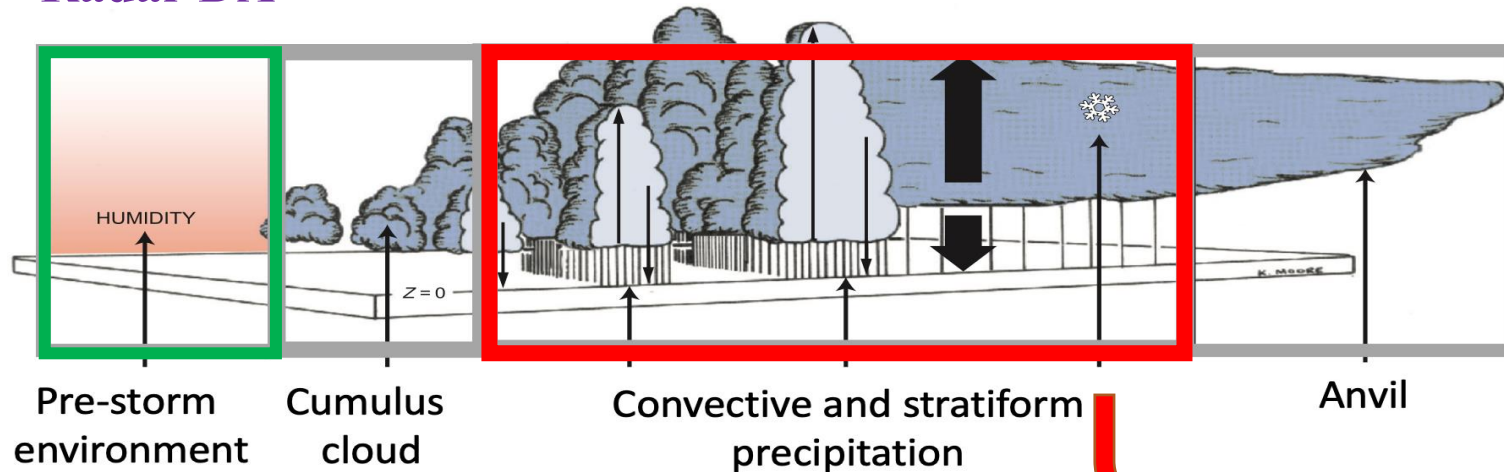


Assimilating Z and V_r prove to improve the NWP performance of severe weather. However, the info is available after the convection begins and develops. Besides, a variation of moisture within 1 g kg^{-1} can determine the occurrence or nonoccurrence of storm initiation -> **water vapor info is important**



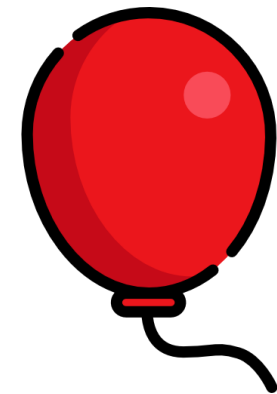
Various studies made efforts to overcome these limitations by **assimilating different sources of moisture** information (Lai et al. 2019; Sun et al. 2020; Ke et al. 2022)

Radar DA



3D Temperature & Q_v

Conventional observation
- radiosonde



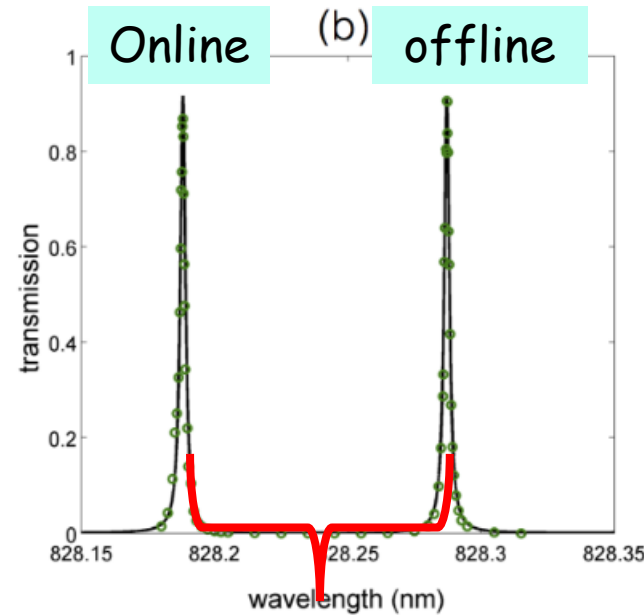
low spatiotemporal resolution
X mesoscale environment

MicroPulse Differential Absorption Lidar (MPD)

3



Micropulse laser



$$n_{wv}(r) = \frac{1}{2\Delta\sigma_{wv}} \frac{d}{dr} \ln \frac{N_{on}(r)}{N_{off}(r)}$$

$n_{wv}(r)$: the range resolved water vapor number density (molecules/m³)

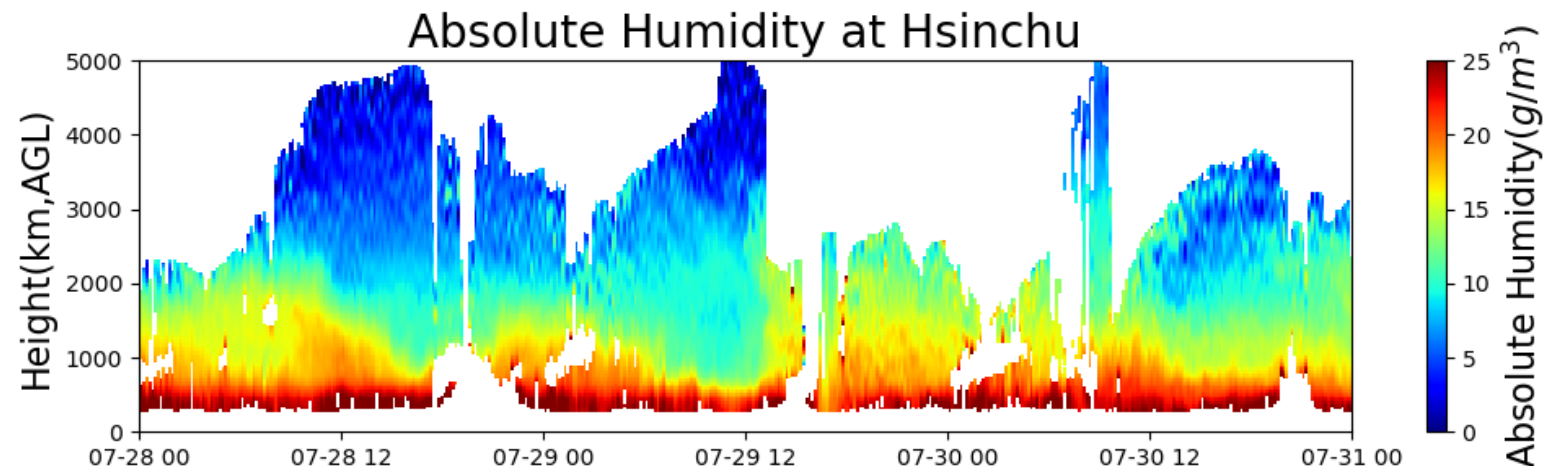
$\Delta\sigma_{wv}$: the difference of the online and offline wavelengths

$N_{on}(r)$: online wavelengths (max absorption)

$N_{off}(r)$: offline wavelengths (min absorption)

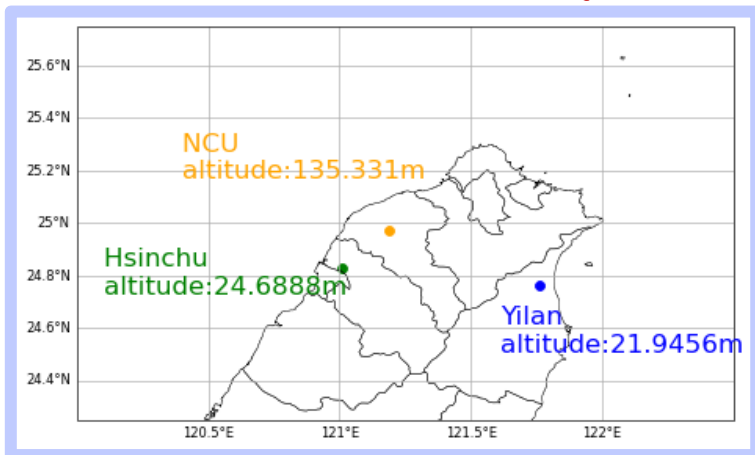
Return difference : water vapor absorption

MPD (NCAR & MSU developed)	Active remote sensing
pulse energy	3 μ J(Micropulse)
advantage	• Eye safe, low-cost, • High spatiotemporal resolution • No calibration



Objective of the research

- Taiwan-Area Heavy rain Observation and Prediction Experiment (TAHOPE) 2022



Three MPDs were deployed during 2022 TAHOPE campaign from May 28 to August 12

Goal

01

MPD data analysis to examine **water vapor characteristic** in northern Taiwan

Goal

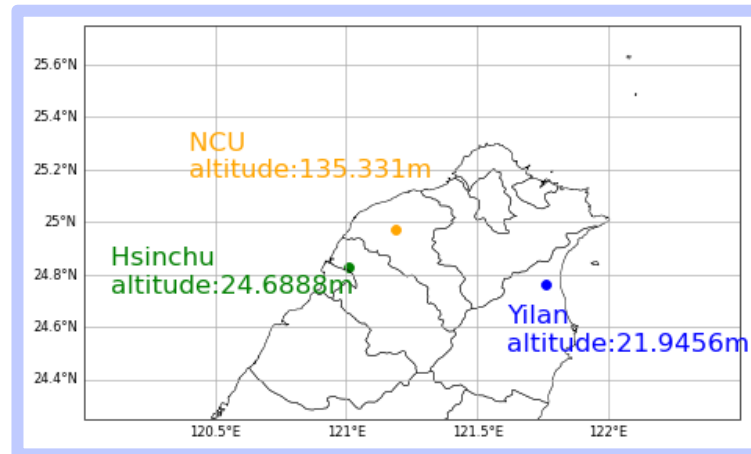
02

Impact of assimilating **water vapor from MPD and surface data** on the initial conditions and rainfall forecasts during different scale weather system

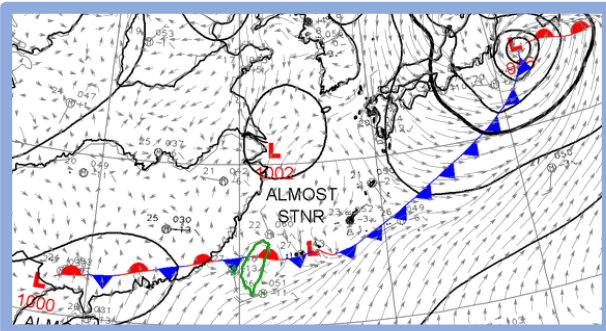
MPD during TAHOPE

- Absolute Humidity(AH) [g/m^3]
- temporal resolution=10minutes
- vertical resolution= 37.5m

Weather system

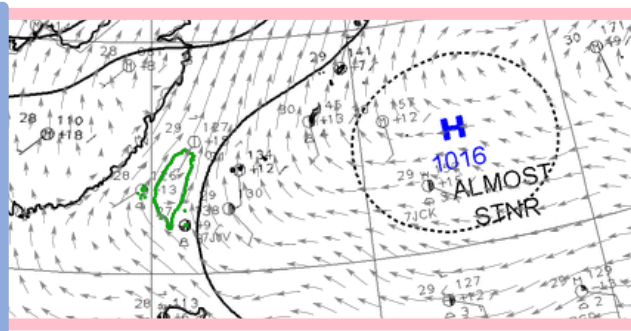


Mei-Yu



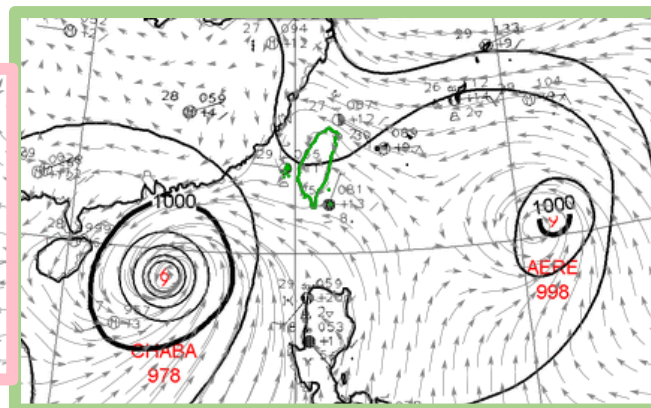
- 6/06 06Z - 6/12 12Z
 - 6/15 00Z - 6/16 00Z
- 174hours

Afternoon thunderstorm



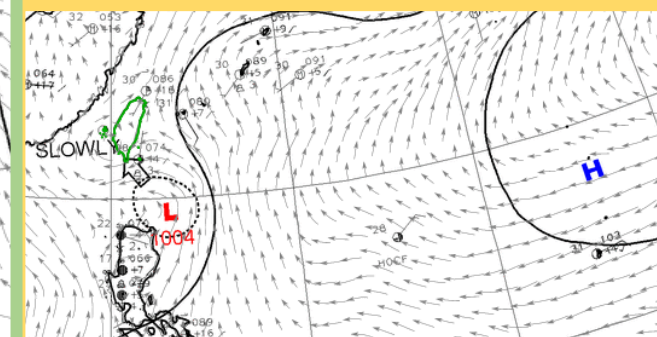
- 5/31 00Z - 5/31 12Z
 - 6/23 00Z - 6/24 00Z
 - 6/24 00Z - 6/25 00Z
 - 6/25 00Z - 6/25 15Z
 - 6/29 00Z - 6/30 00Z
- 207hours

Typhoon

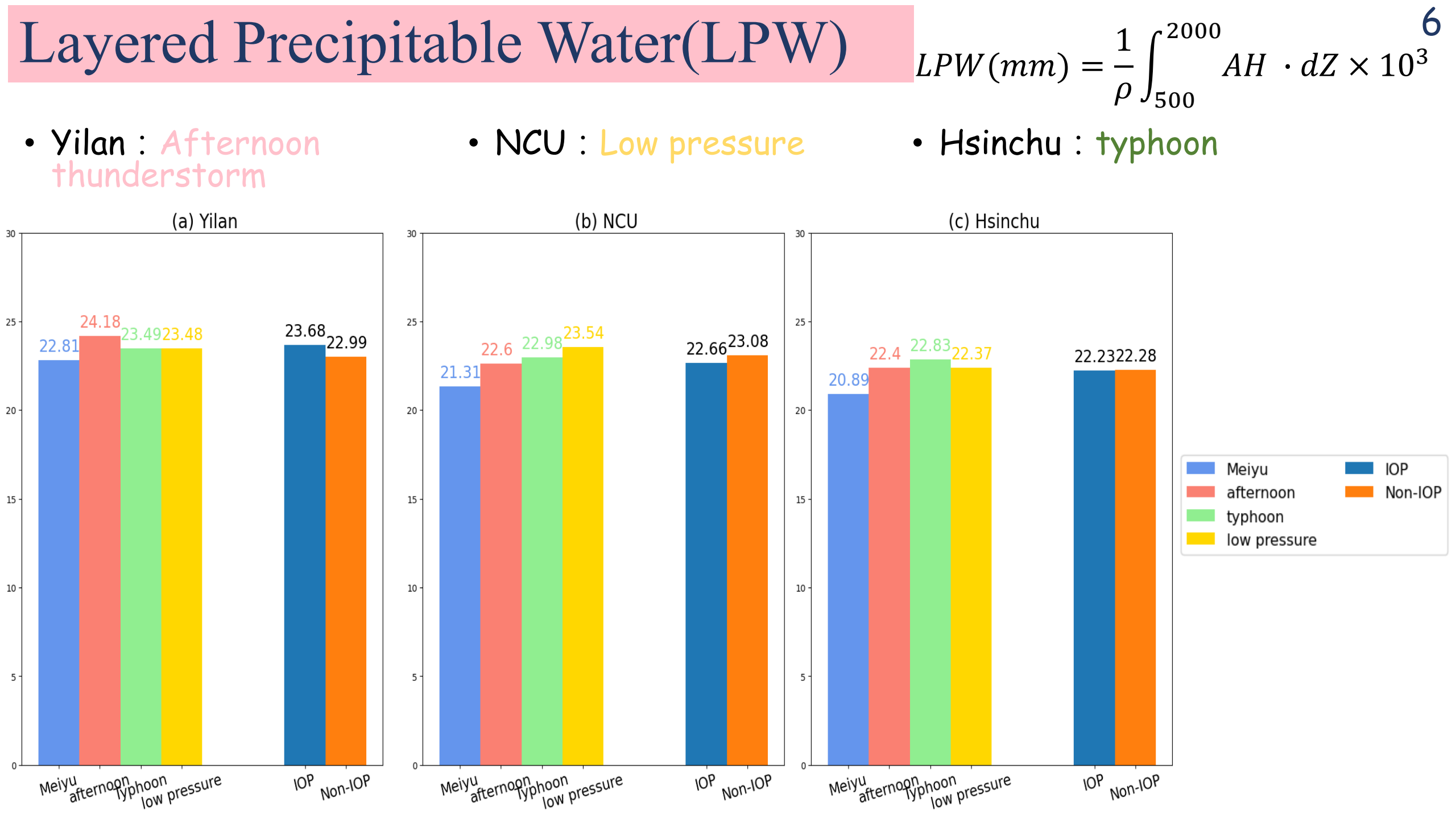


- 7/01 00Z - 7/04 00Z
 - 7/05 00Z - 7/05 04Z
 - 7/13 06Z - 7/16 06Z
- 148hours

Low pressure



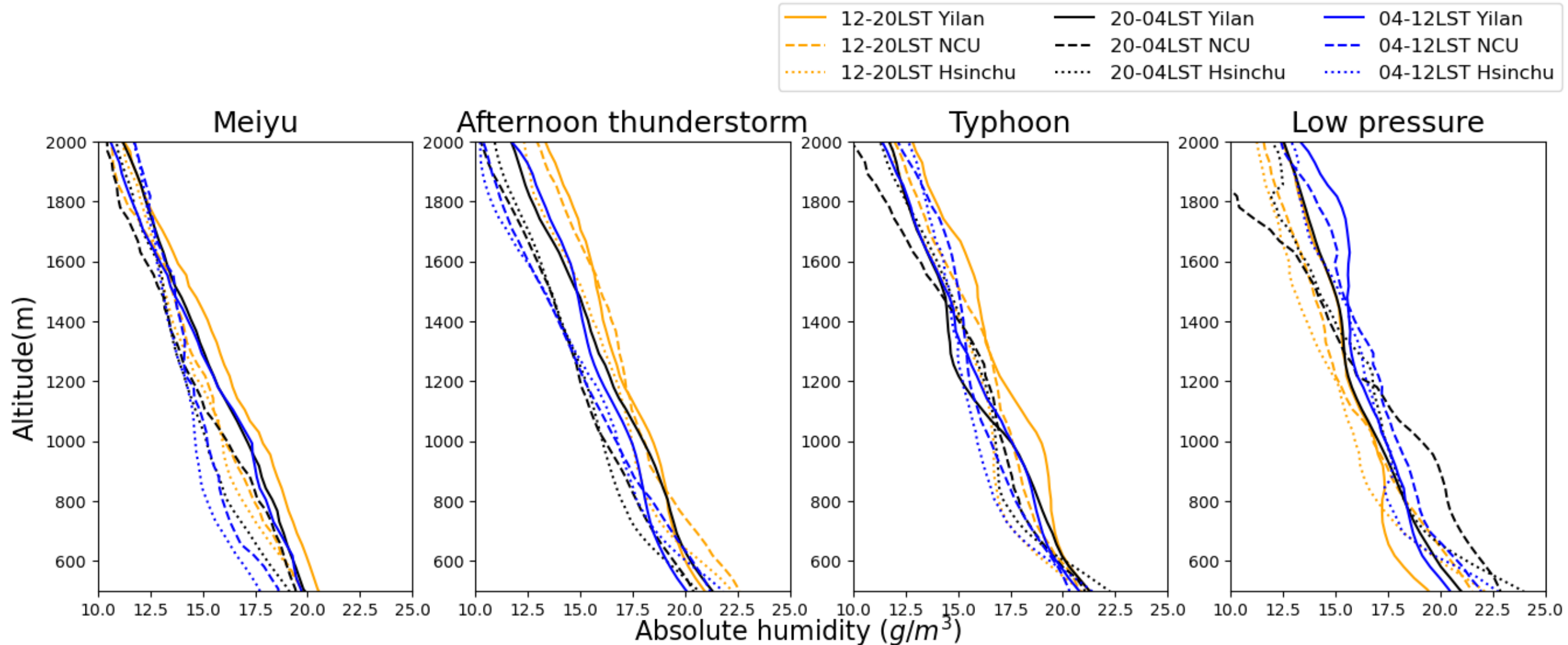
- 7/29 00Z - 7/29 12Z
 - 8/01 00Z - 8/03 18Z
- 78hours



MPD in diurnal variation

7

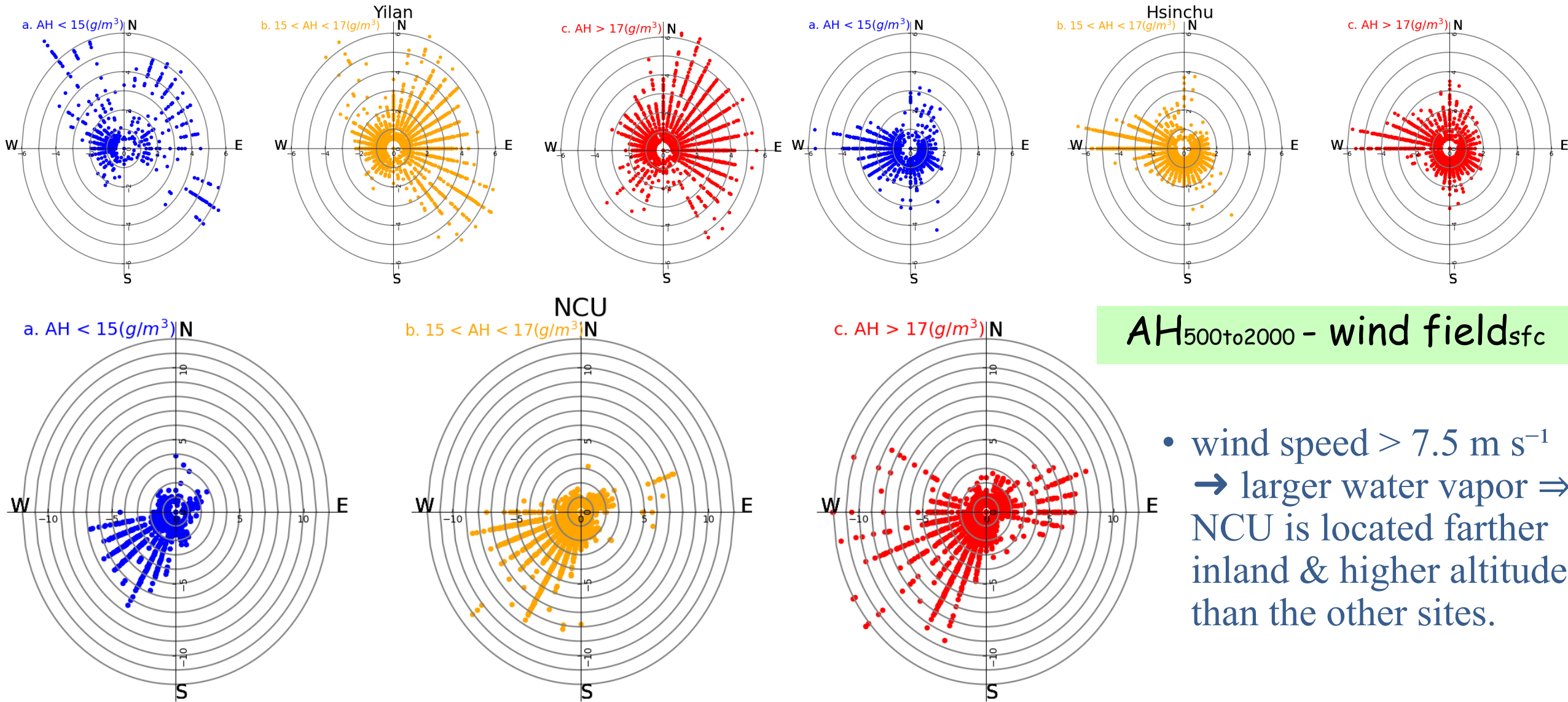
- Mei-Yu, Afternoon thunderstorm, typhoon : 12-20LST afternoon period
- Low pressure : 04-12LST morning period



Relationship between Water vapor & Wind

8

- Yilan、Hsinchu : wind speed & wind direction $\neq$ amount of water vapor

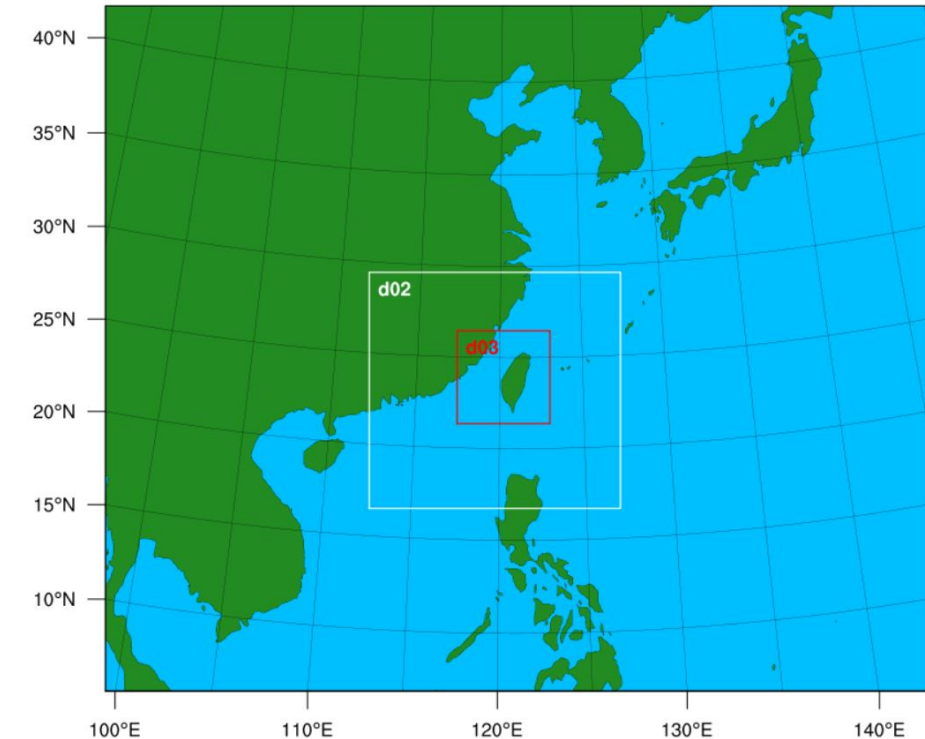


- wind speed $> 7.5 \text{ m s}^{-1}$
→ larger water vapor $\Rightarrow$ NCU is located farther inland & higher altitude than the other sites.

Model setting

9

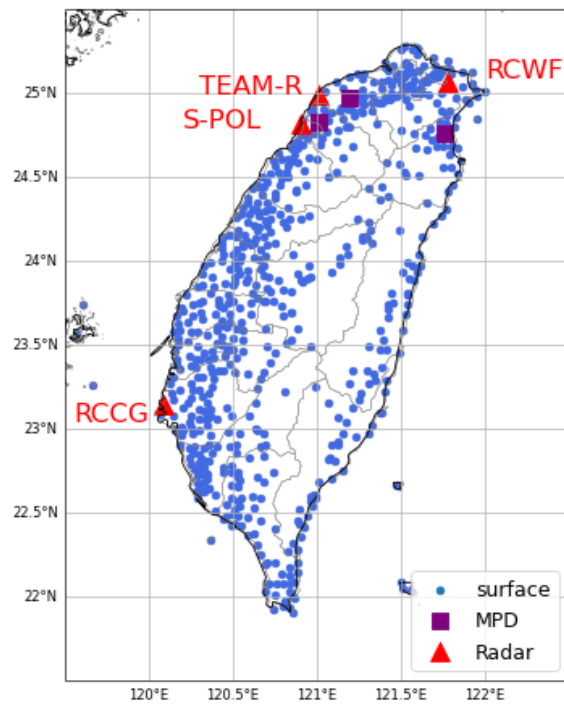
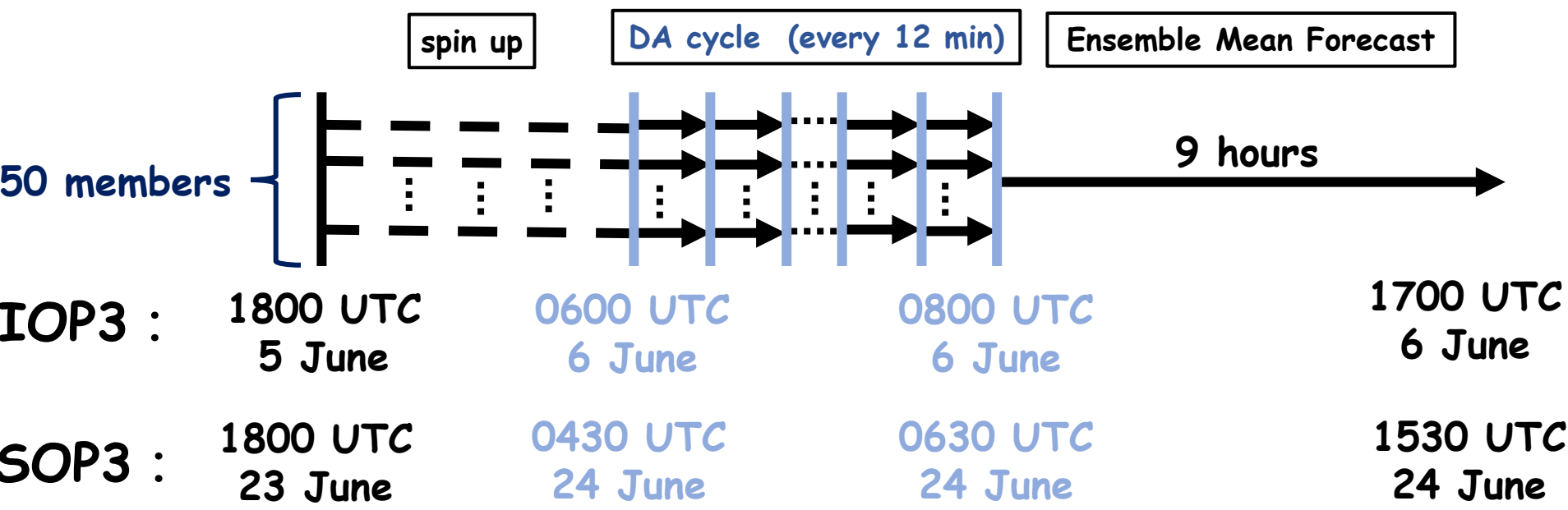
	WRFV3.9.1
Initial conditions	NCEP - FNL (0.25°*0.25°)
Horizontal resolution	d01 : 15km(325*271) d02 : 3km(496*466) d03 : 1km(550*550)
Vertical resolution	52 (p_top: 10hPa)
Microphysical scheme	GCE
Cumulus scheme	Grell-Devenyi (d01)
feedback	True



Observation Variable	Temperature	QVapor	Vr	Zh
error	1K	1(g/kg)	3(m/s)	5dBz

Experimental design

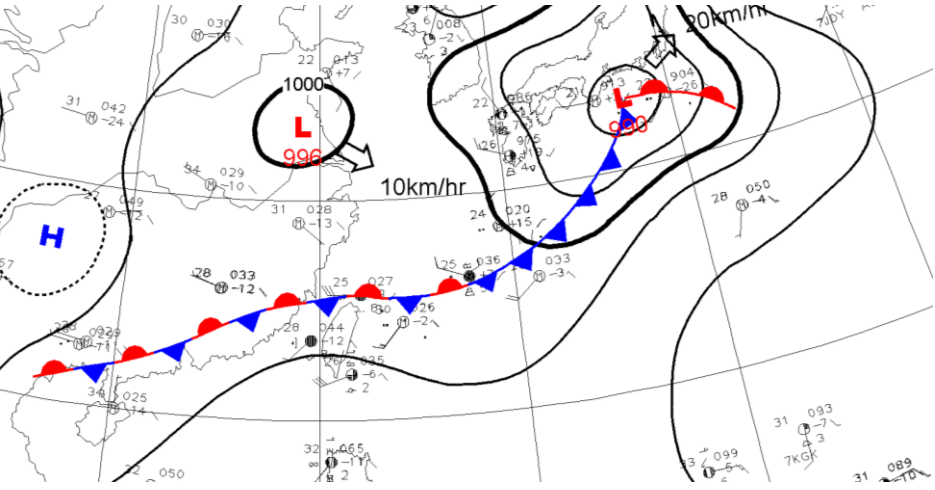
• WRF-LETKF Radar Assimilation System (WLRAS) Tsai et al. 2014 10



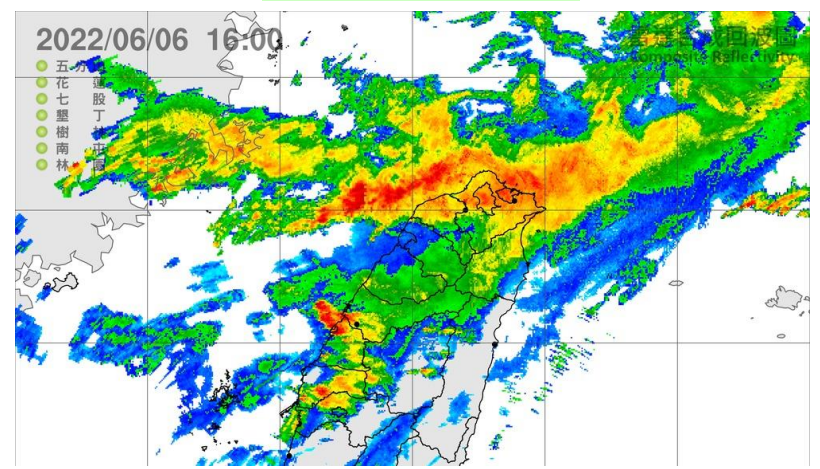
SOP3&IOP3 Experiment	Assimilated data - 12min			Localization
	Radar - Z,Vr	surface - T,QV	mpd - QV	QVmpd
ZVr	Yes	No	No	-
sTQV_ZVr	Yes	Yes	No	-
sTQVmQV48_ZVr	Yes	Yes	Yes	48km

➡ more local feature

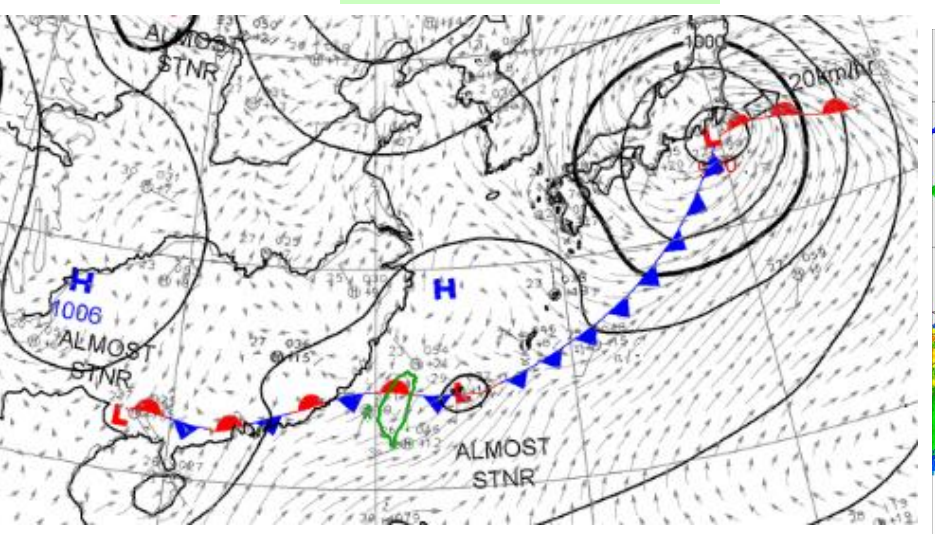
06UTC



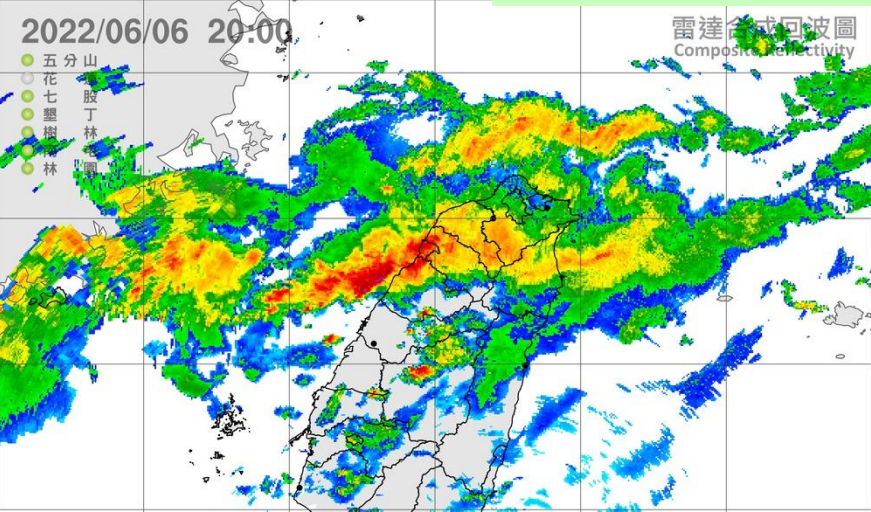
08UTC



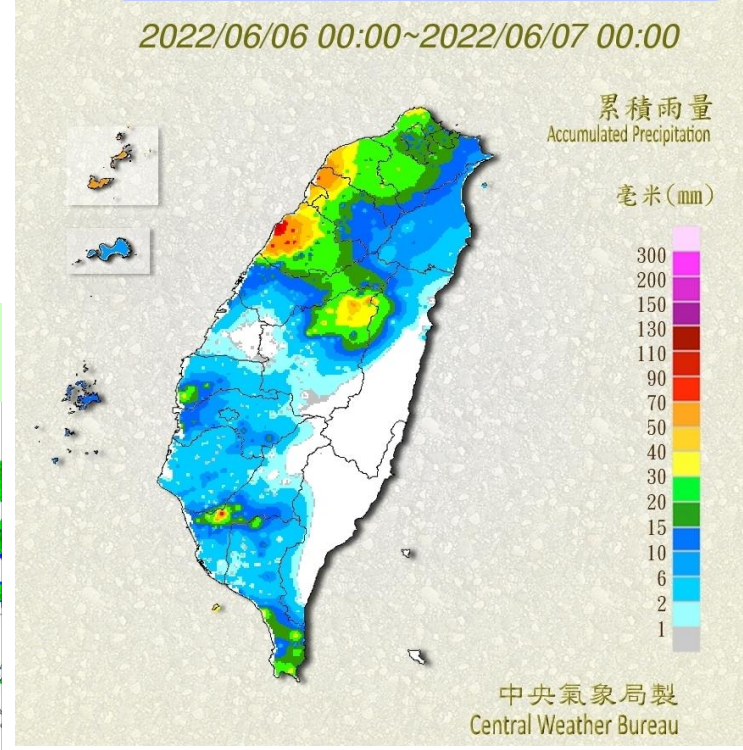
12UTC



12UTC

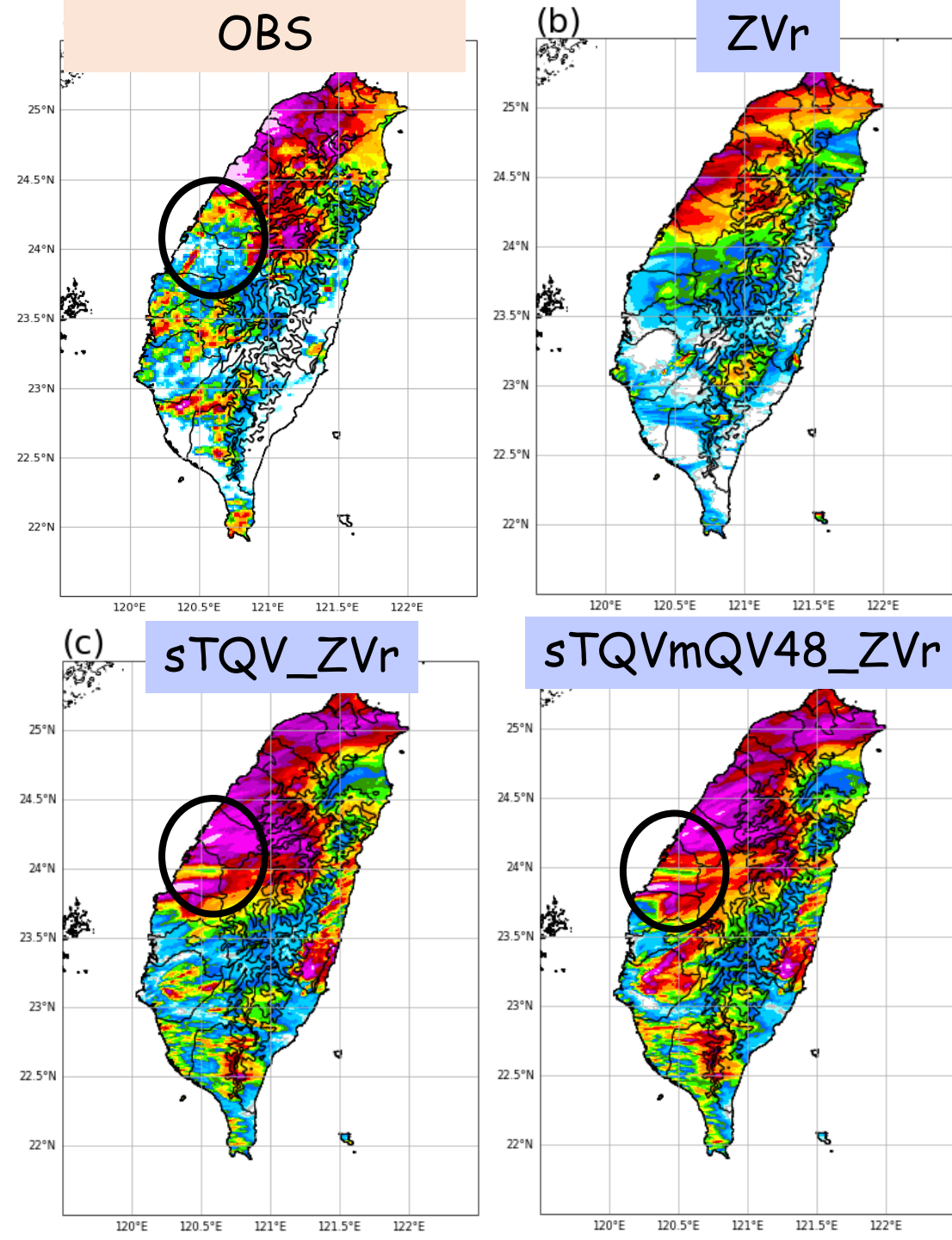
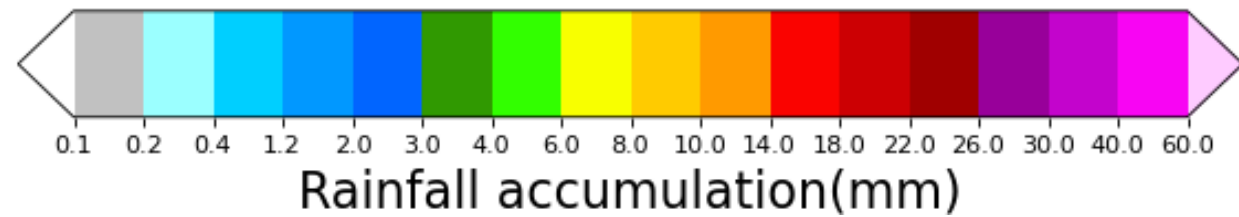


One-day accumulated rainfall

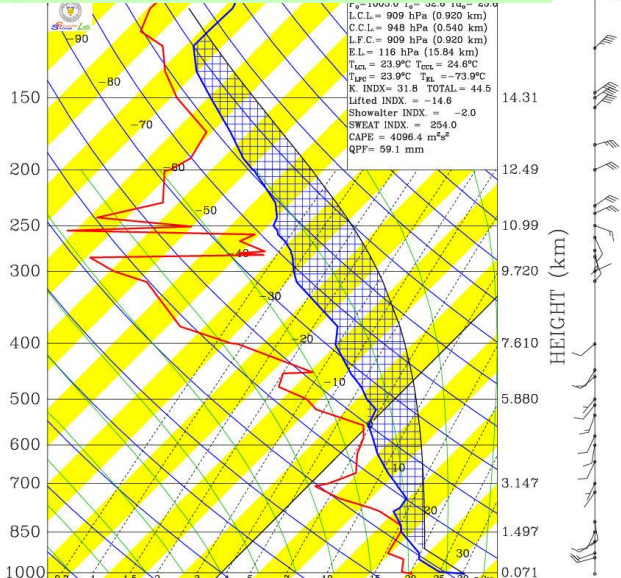
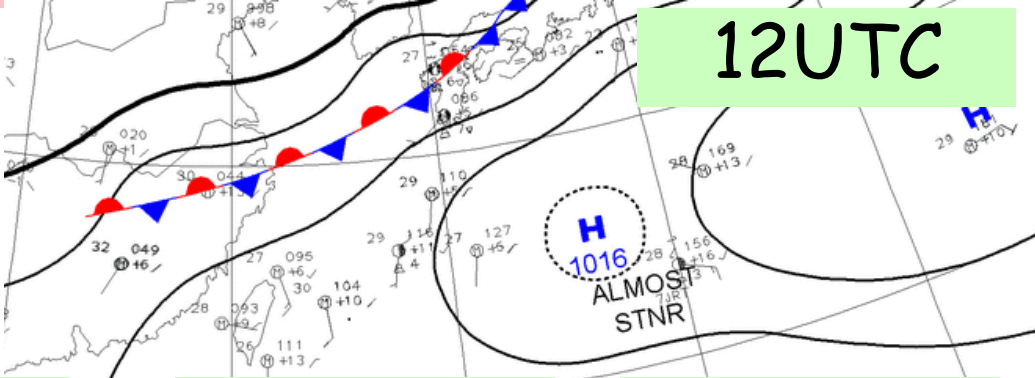


Rainfall Forecast - 9h (08-17UTC)

- ZVr shows the obvious underestimation.
- sTQV_ZVr and sTQVmQV48_ZVr overestimate over middle and southern Taiwan.

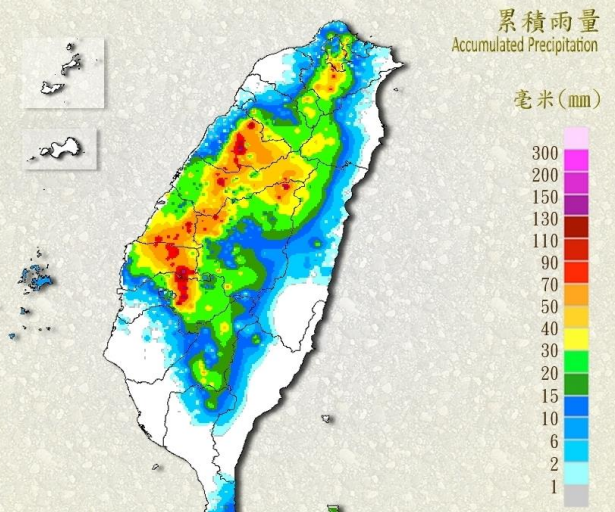


Case overview –SOP3 afternoon thunderstorm June 24 2022



CAPE=4096.4 m²s²

2022/06/24 00:00~2022/06/24 23:30



中央氣象局製
Central Weather Bureau

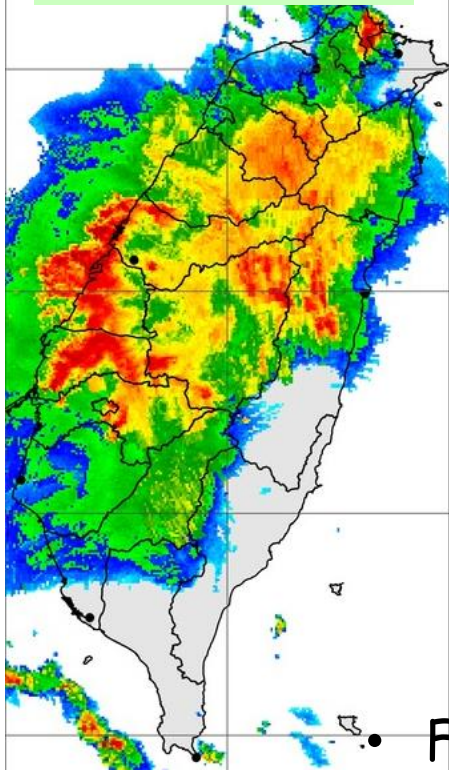
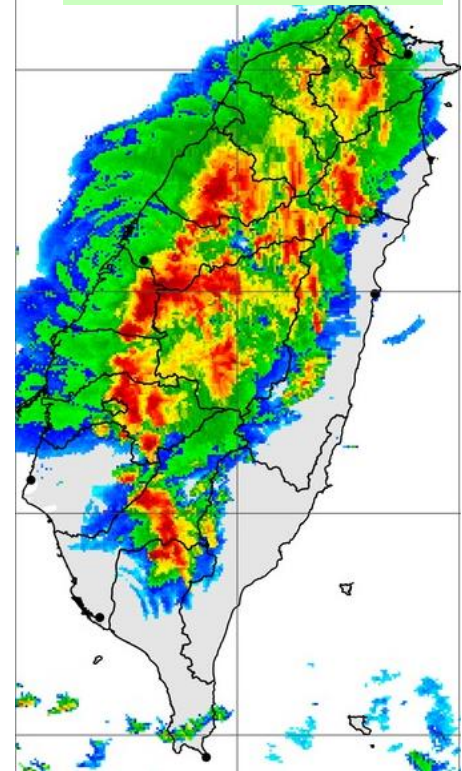
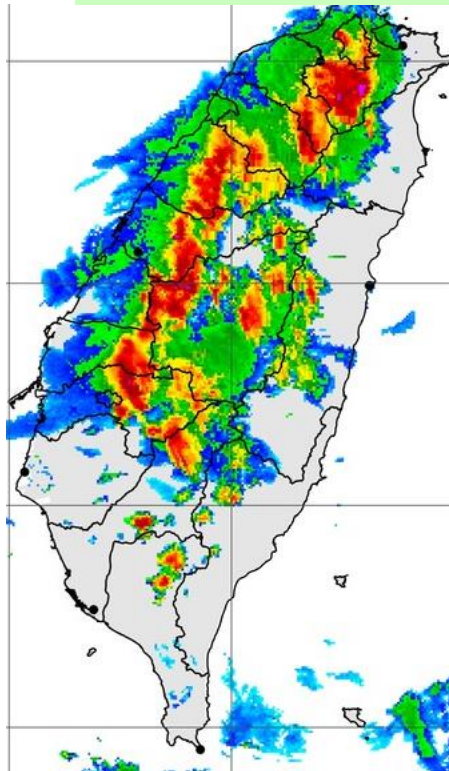
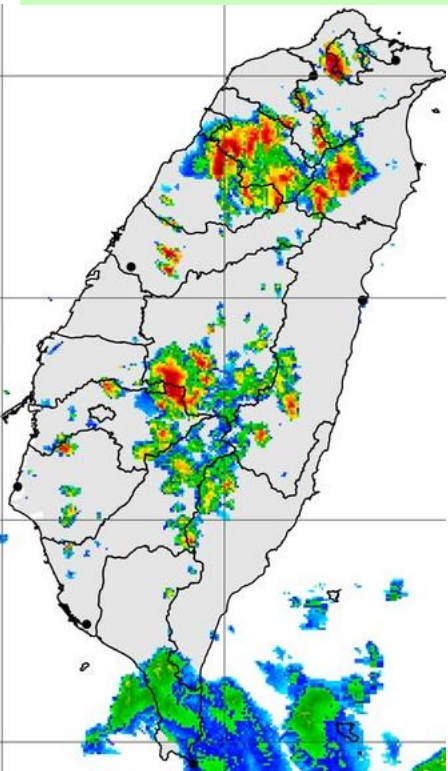
From CWA

0530UTC

07UTC

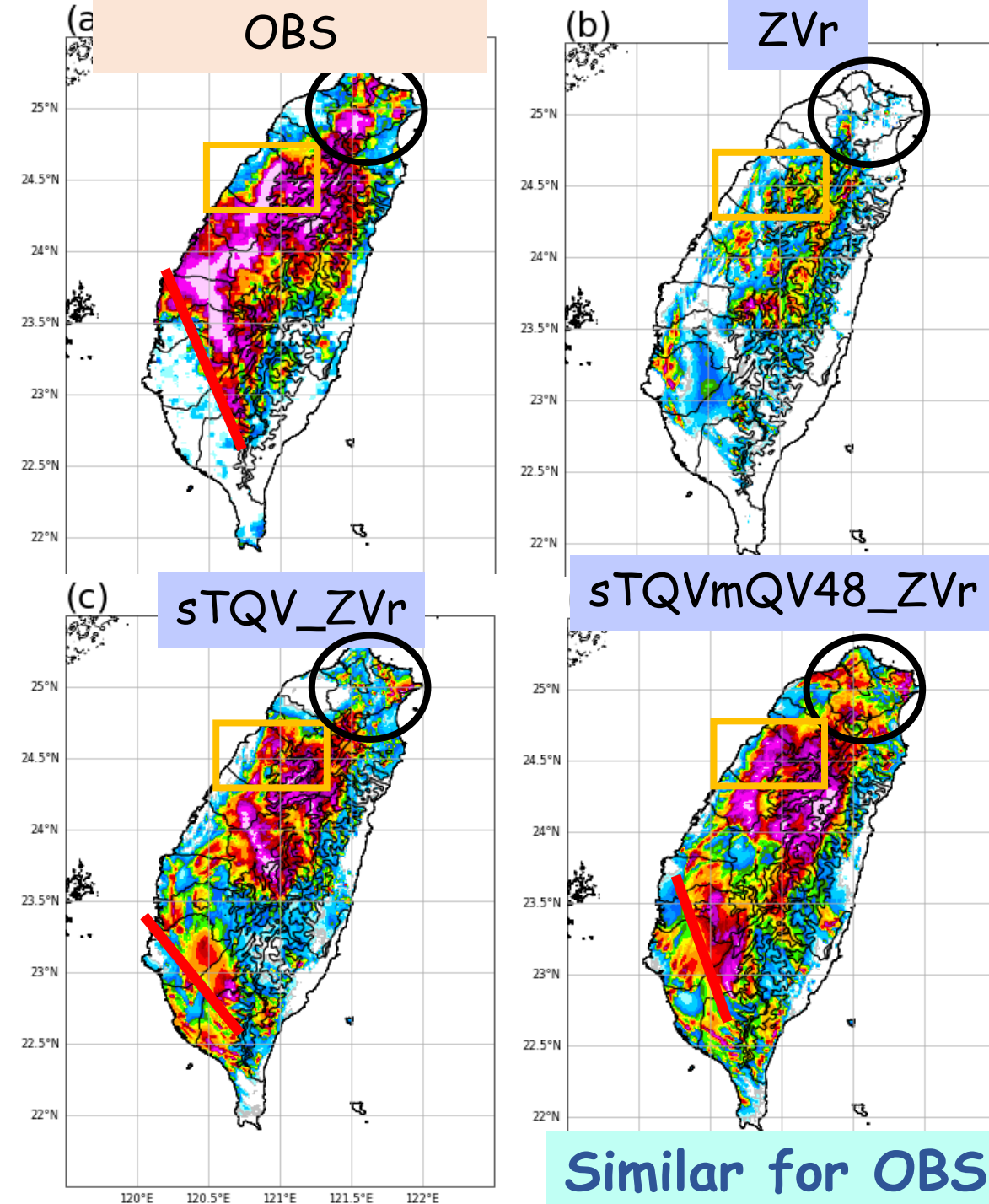
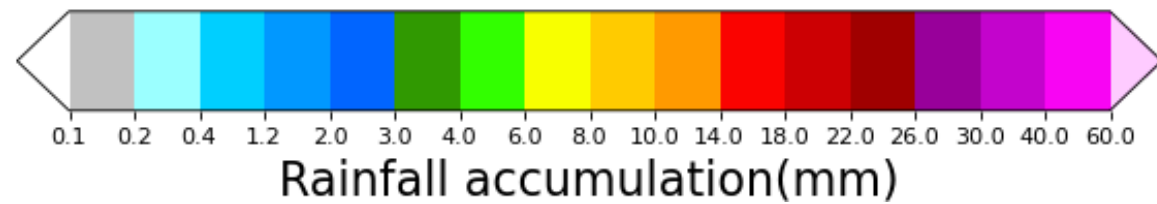
08UTC

10UTC



Rainfall Forecast -6h(0630-1230)

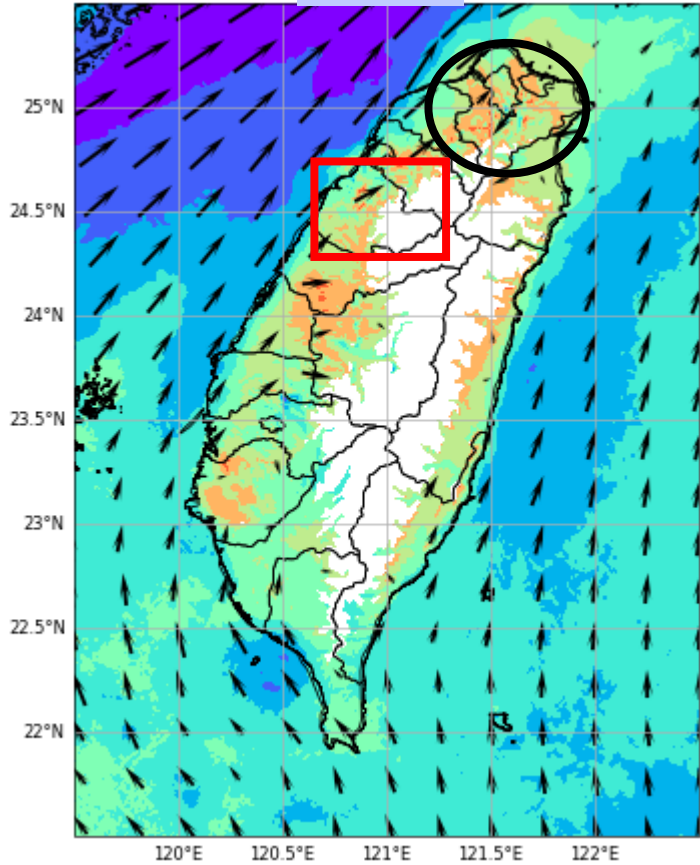
- Assimilating additional MPD and localization set to 48km captures the rainfall area similar for the observation.



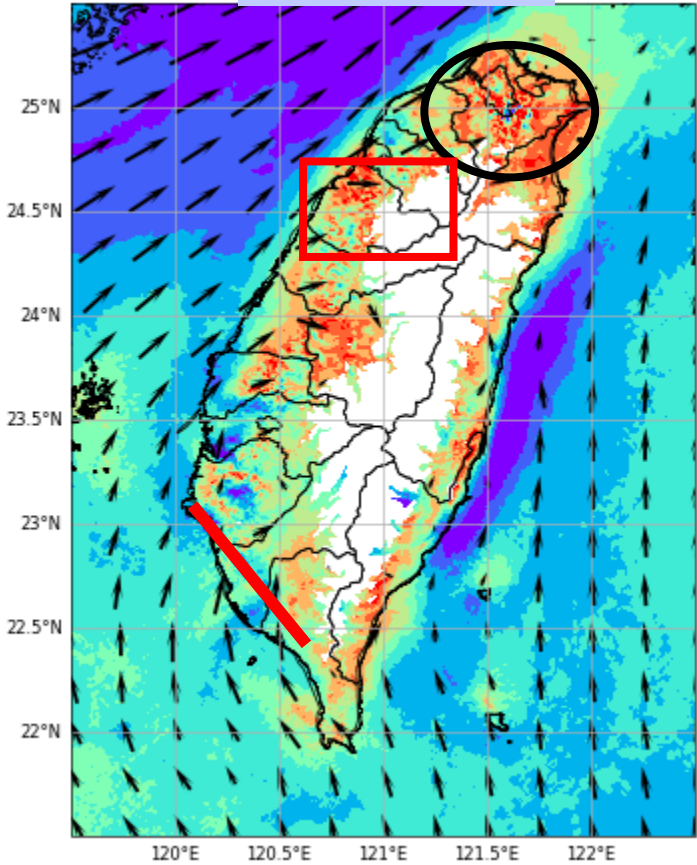
Water vapor & wind field at 900hPa

Final analysis - 0630 UTC

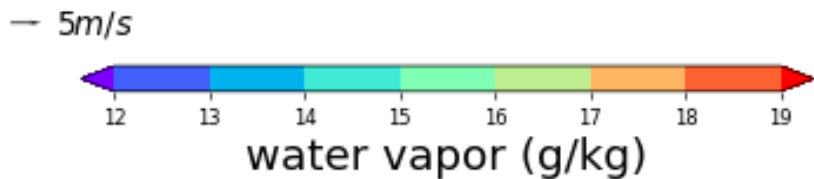
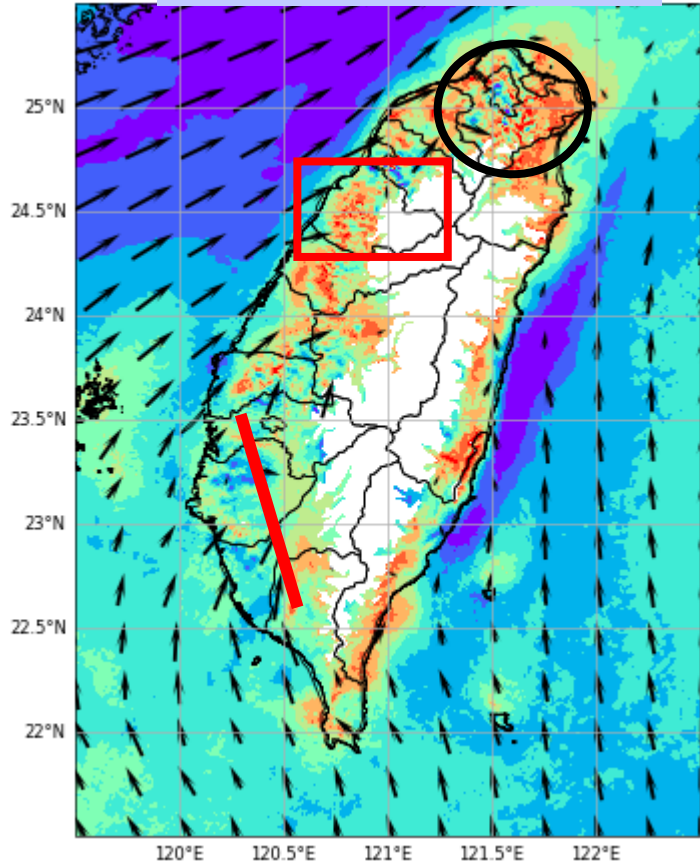
ZVr



sTQV_ZVr



sTQVmQV48_ZVr



QV(g/kg)	ZVr	sTQV_ZVr	sTQVmQV48_ZVr
RMSE	3.139	2.459	2.559
Bias	-1.910	-0.056	-0.358

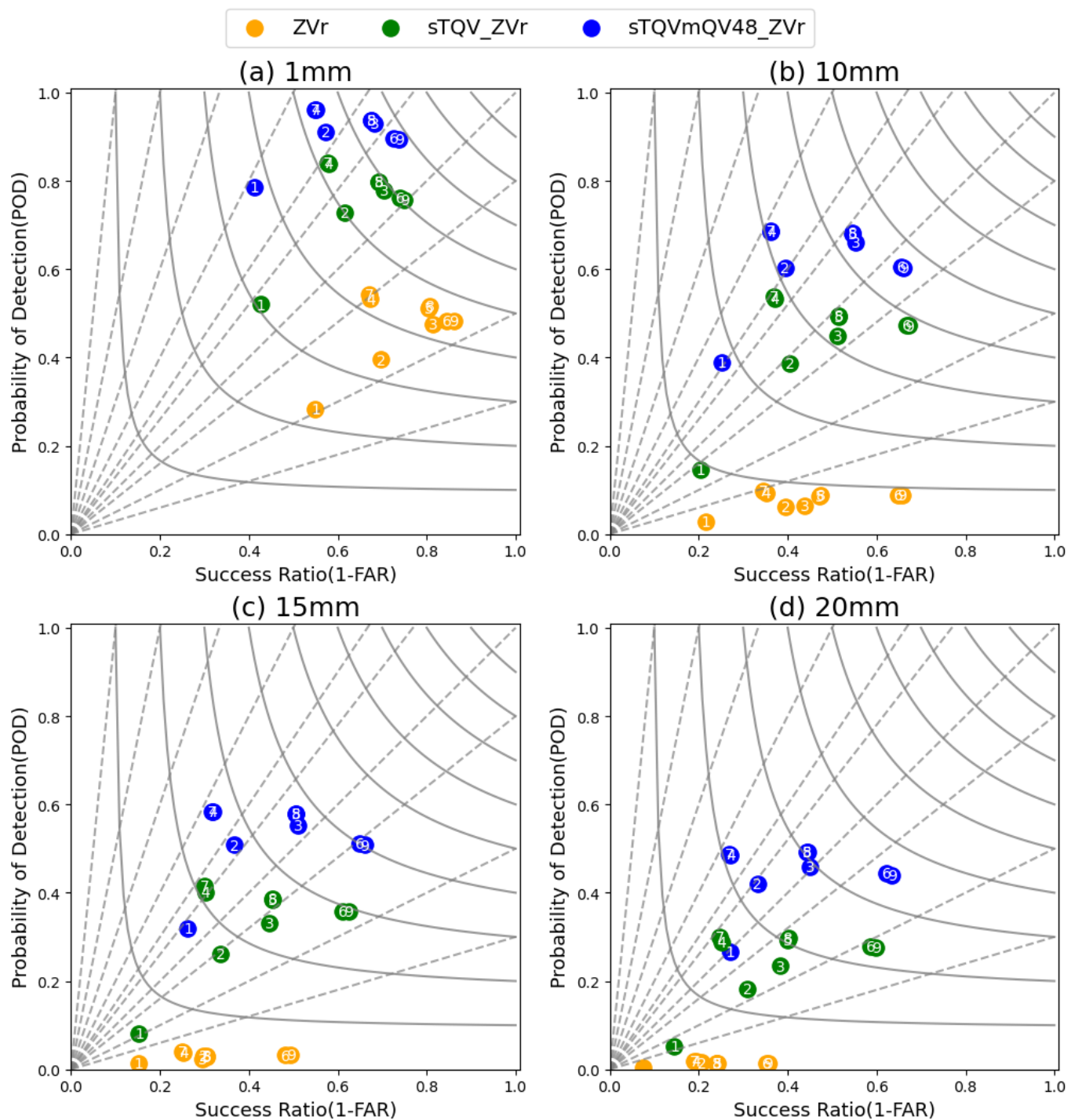
Performance diagrams for 9-hours rainfall forecasts

Contingency table		Event observed	
		yes	no
Event Forecast	yes	A	B
	no	C	D

$$POD = \frac{A}{A + C} \quad \text{Success Ratio} = \frac{A}{A + B}$$

$$\text{Bias} = \frac{A + b}{A + C} = \frac{POD}{\text{Success Ratio}} \quad \text{CSI} = \frac{A}{A + B + C}$$

- sTQVmQV48_ZVr gets highest POD at all thresholds.



Conclusions

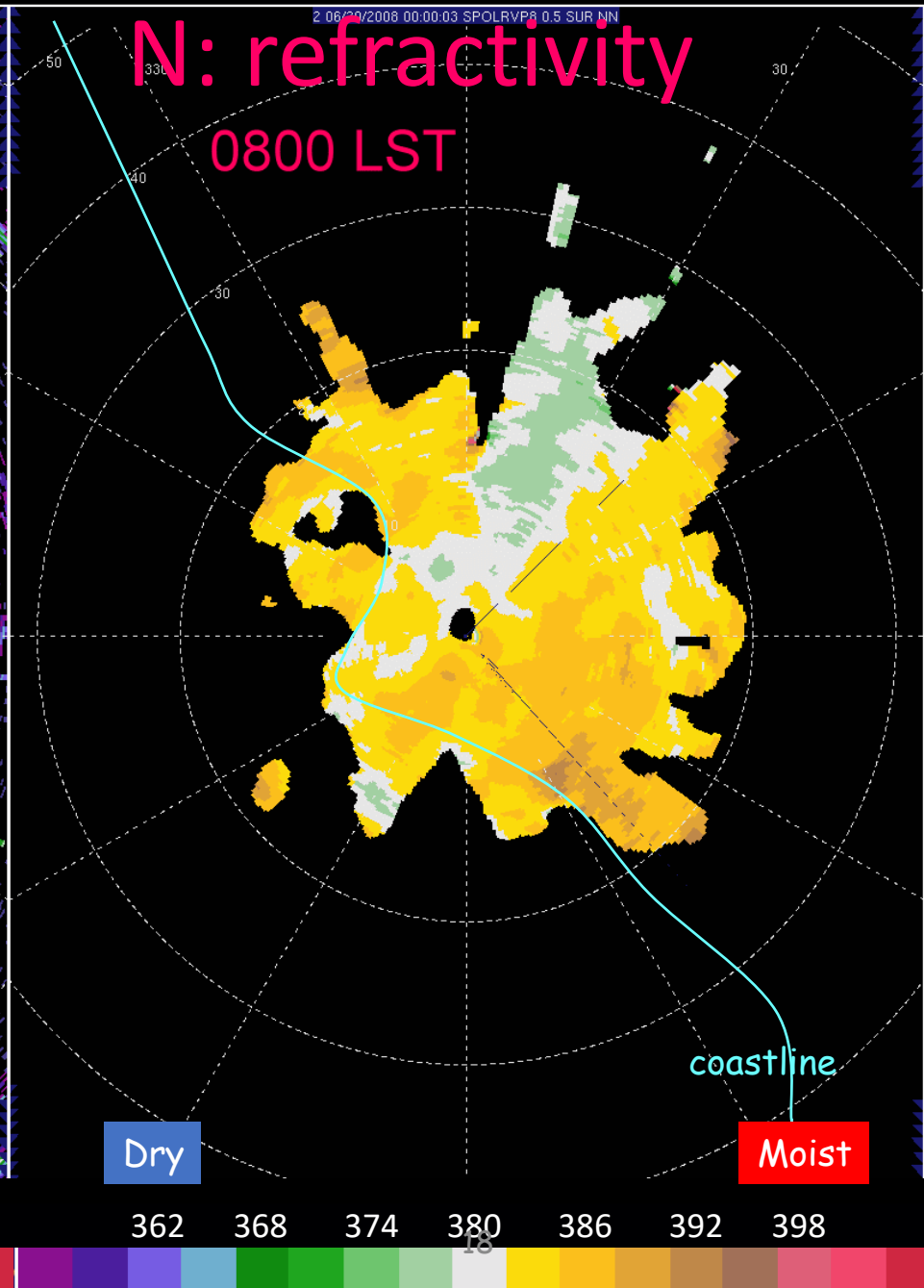
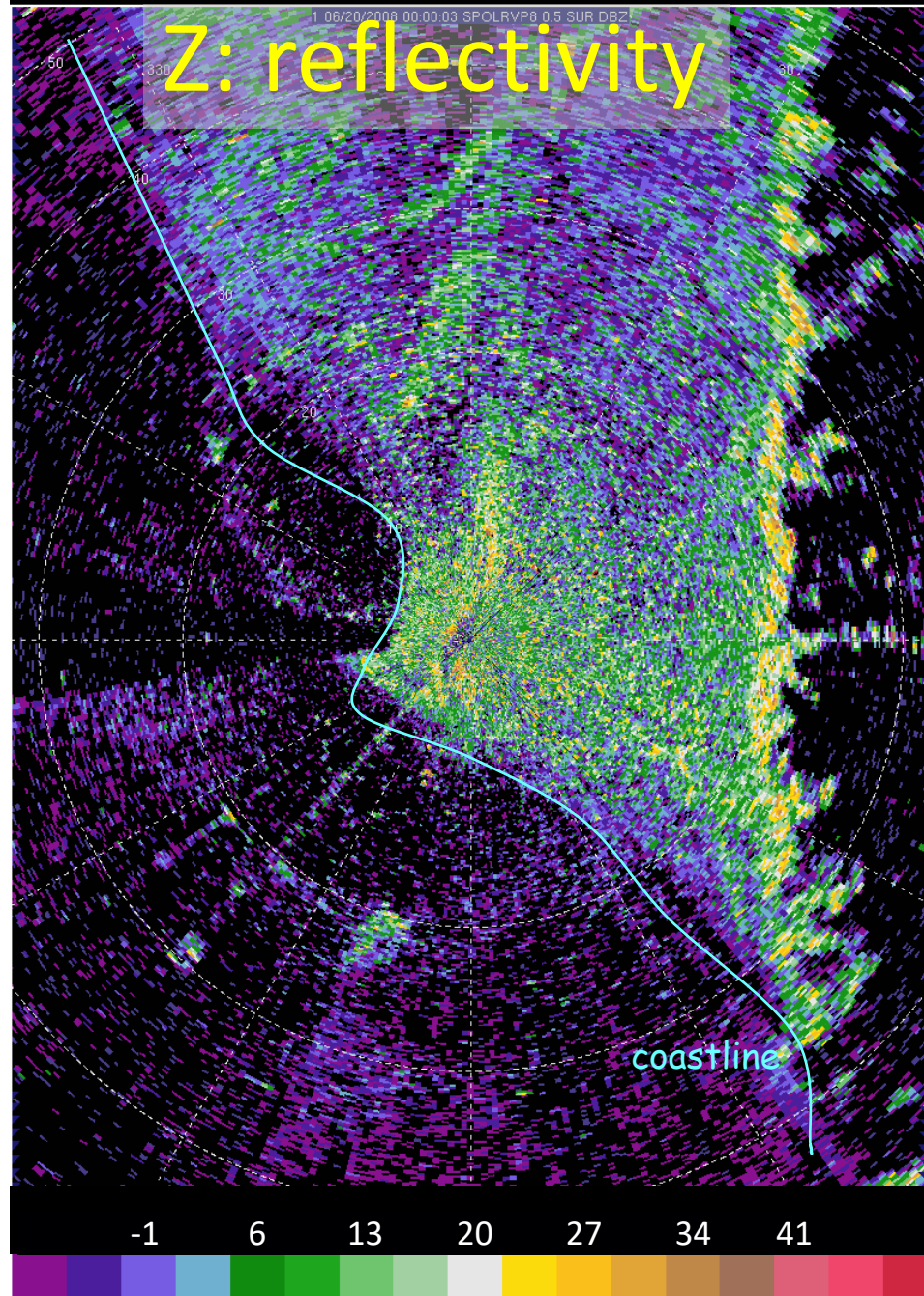
17

- LPW in afternoon thunderstorm, typhoon and low-pressure cases were higher than Mei-Yu.
- Water vapor in Mei-Yu, Afternoon Thunderstorm, and typhoon cases were higher during afternoon period.
- The larger wind speed ($> 7.5 \text{ m s}^{-1}$) led to higher water vapor at NCU because it's located at higher altitude and more inland area.

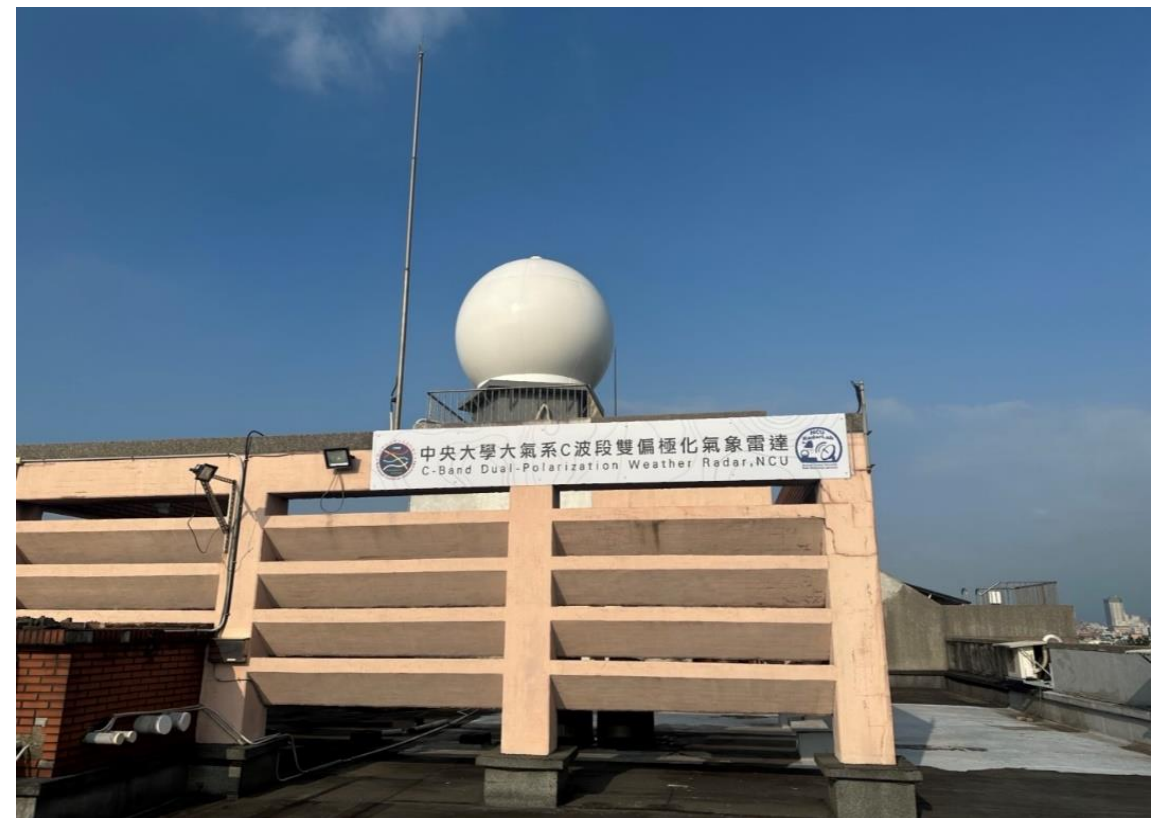
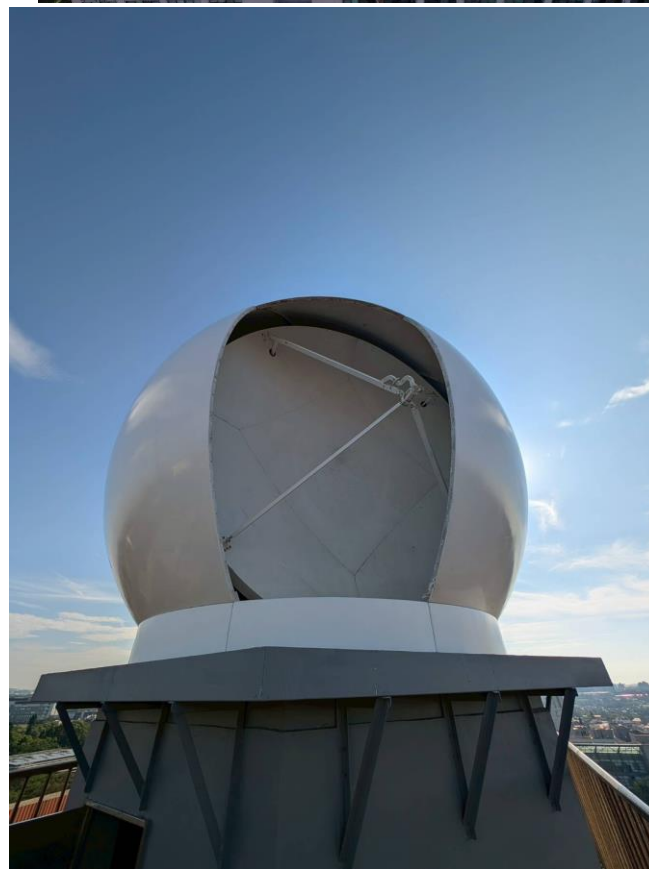
- Assimilating MPD + surface data provides better data on the thermodynamic environment.
 - Typically, MPD data improves rainfall forecast in northern Taiwan. However, it doesn't improve in Mei-Yu case.
- higher spatiotemporal resolution of MPD captures the local thermodynamic environment and has the positive impact in mesoscale weather system.

Future Work

Refractivity data is available both in **non-precipitation** and **precipitation** periods

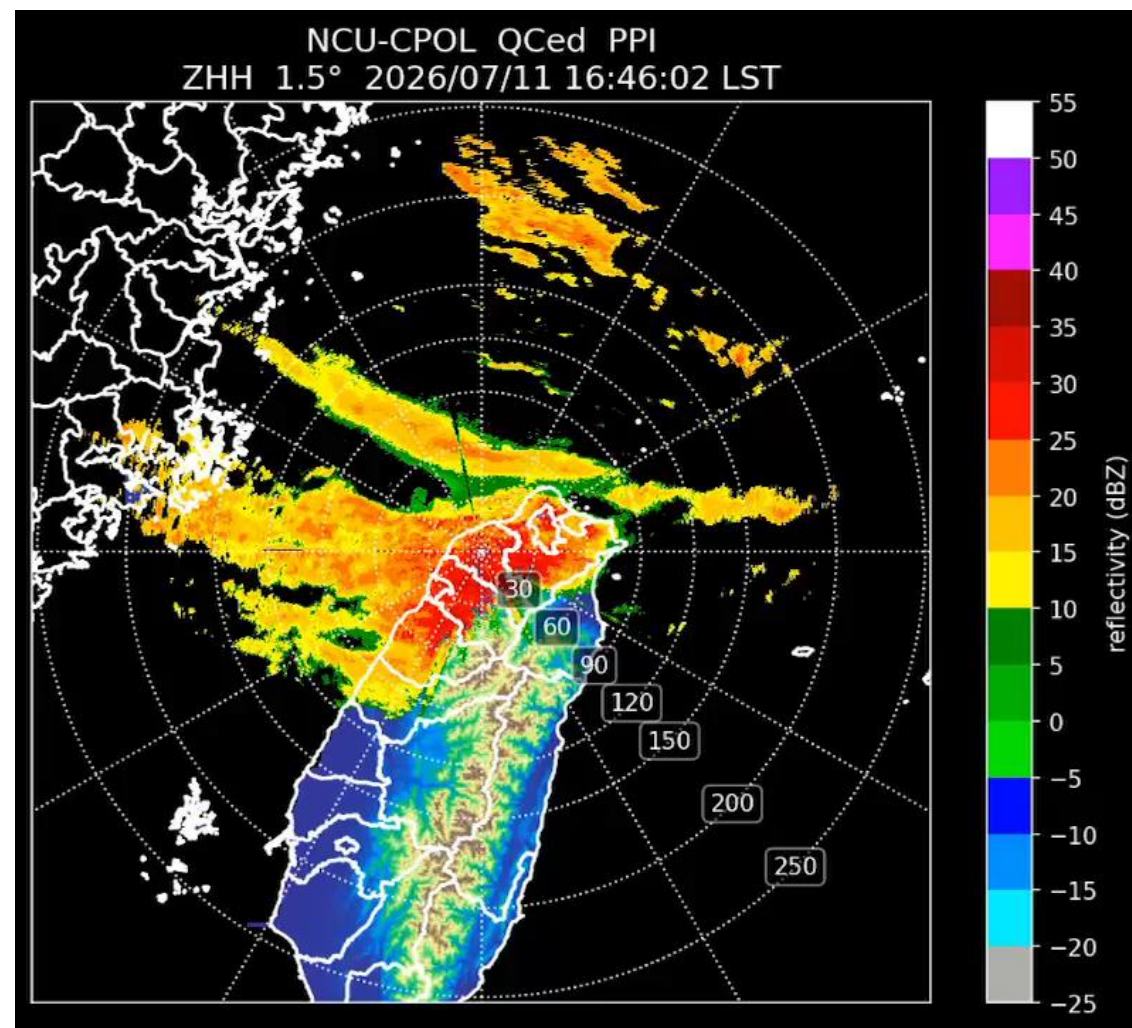
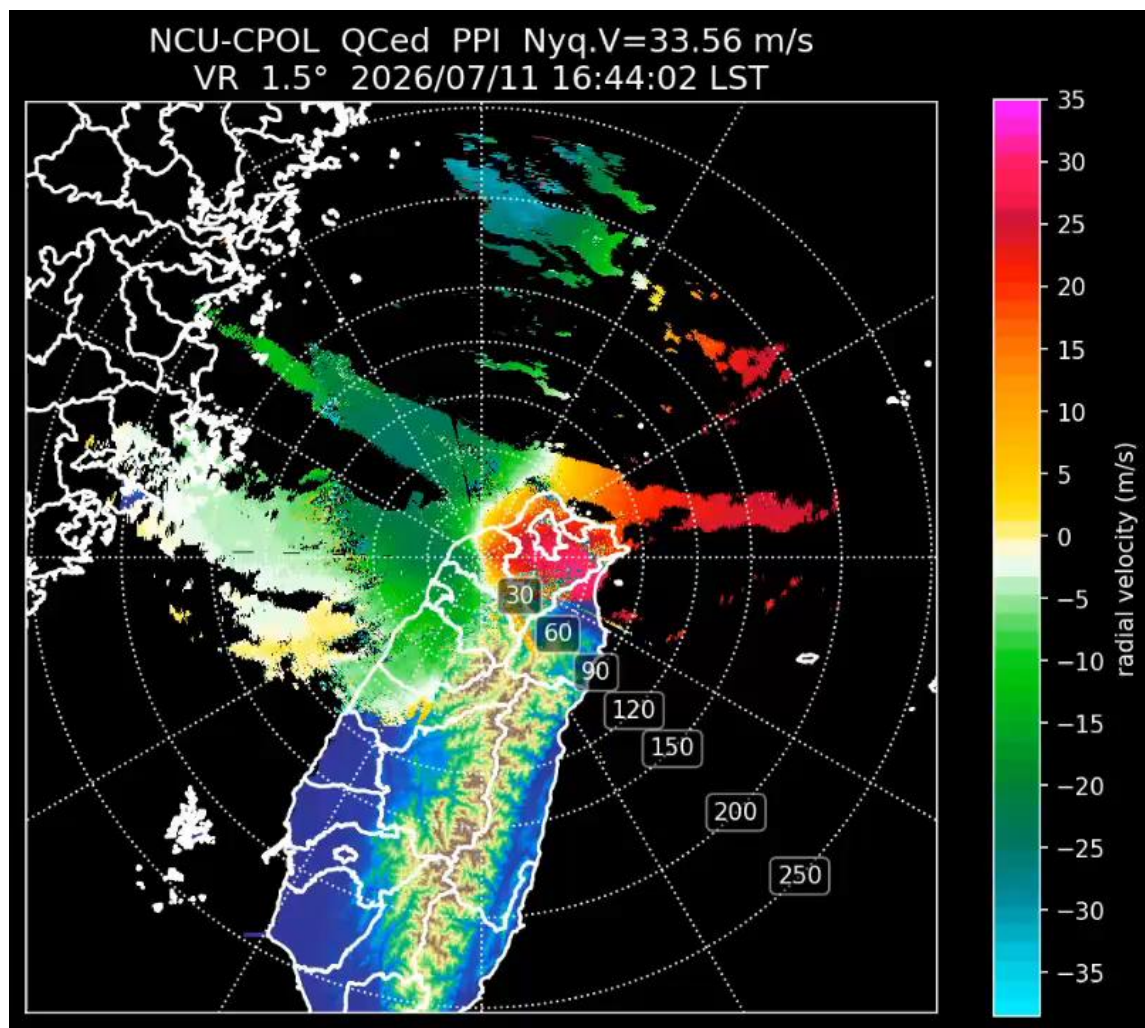


中大雷達換裝



中大雷達觀測動畫

2025/07/11巴威颱風



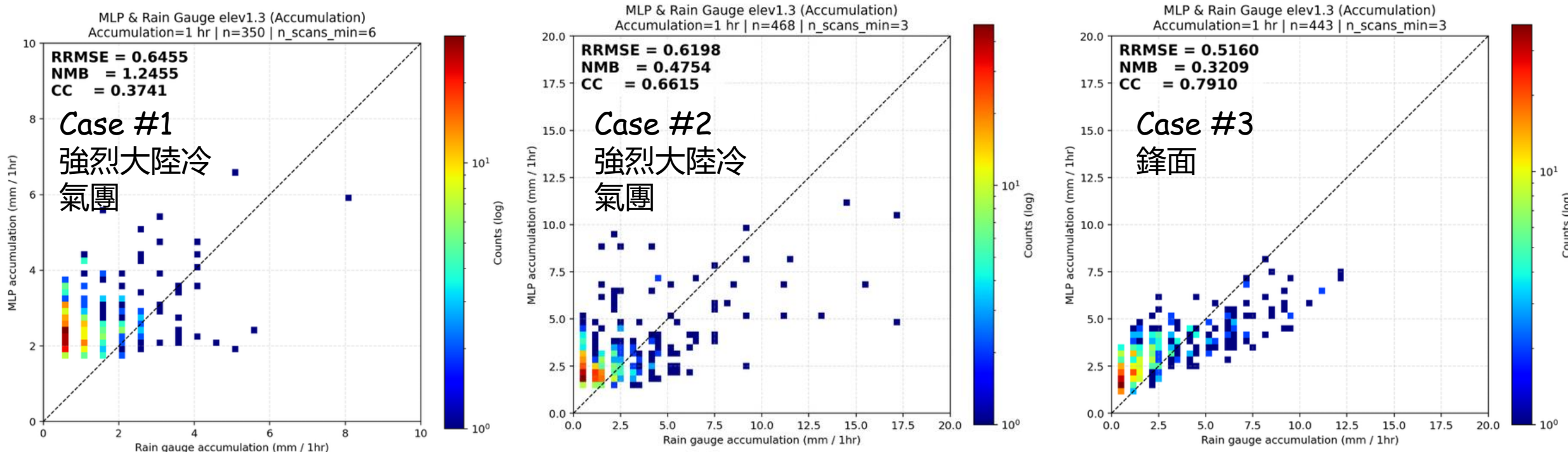
桃園市氣象雷達預測雨量及水理應用

廖宇慶、李明旭、楊舒芝、鍾高陞、張偉裕

雨量估計技術

目的：評估現行中大團隊開發之 QPE 技術針對 115 年 1 至 3 月間桃園市降雨估計。

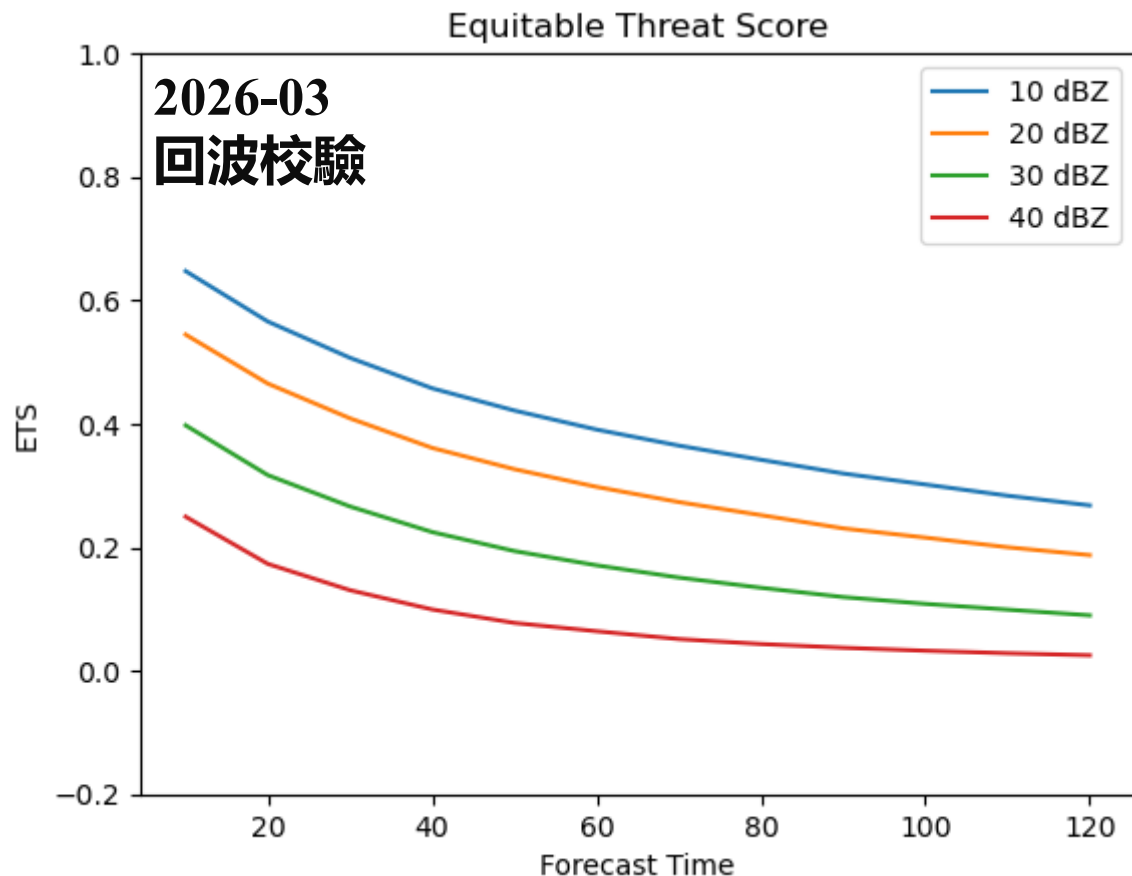
五分山雷達資料套用中大團隊開發的機器學習雷達定量降雨估計分法與氣象署雨量站校驗



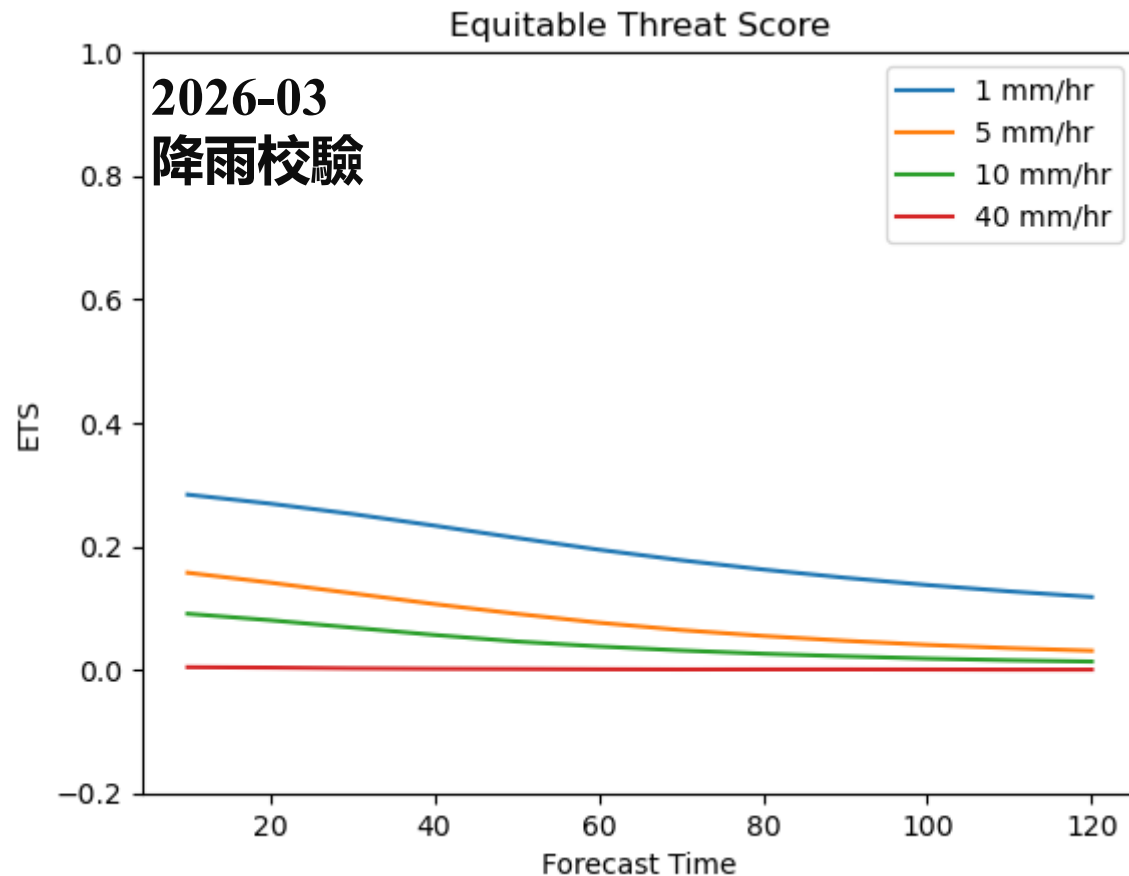
目前收集到的冬春季節降雨較弱，雷達定量降雨估計的優勢不易展現，將於後續計劃持續分析。

0~3小時雨量預測技術

目的：評估 MAPLE 對 115 年 1 月至 3 月間之降雨預報驗證。



10 至 30 分鐘內具最高的預報掌握度且對於大範圍降水回波的預測能力較佳

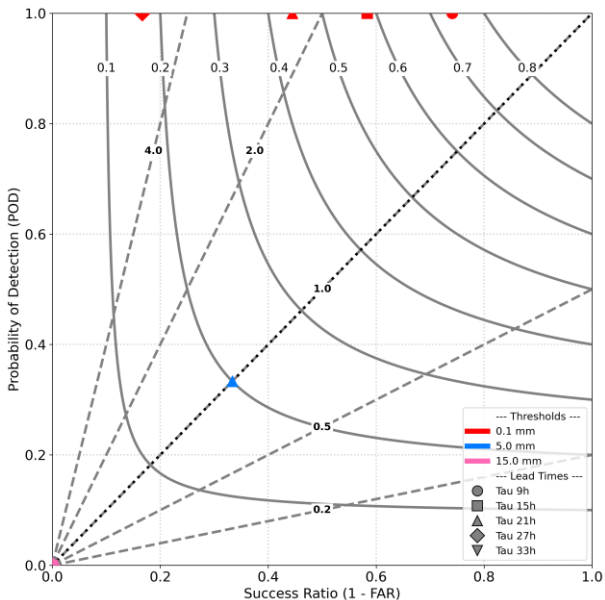


雨量為經由回波轉換，因此需考量其降水估計產生的誤差。1~3月極少出現40mm/hr以上的個案，因此40mm/hr校驗門檻宜調整。

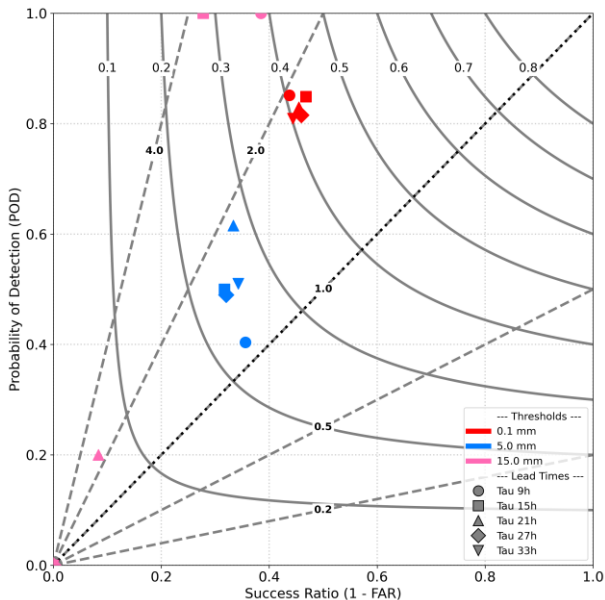
Performance diagram: POD, FAR, TS及BIAS

- 預報長度 9-15小時的表現較穩定

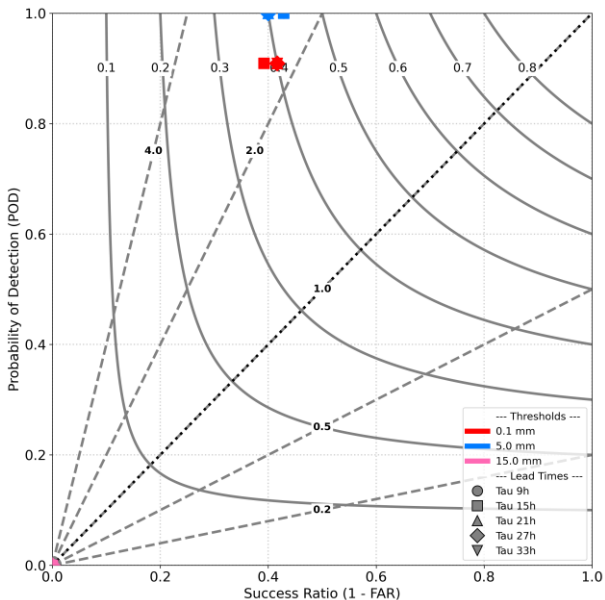
1/1~1/3



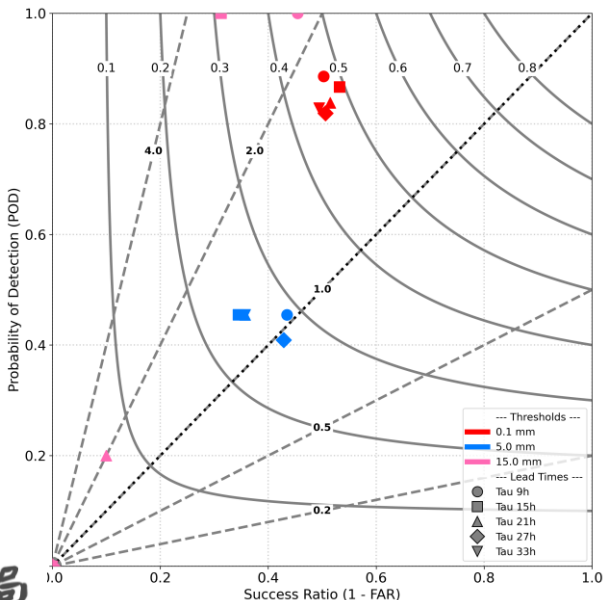
1/18~1/21



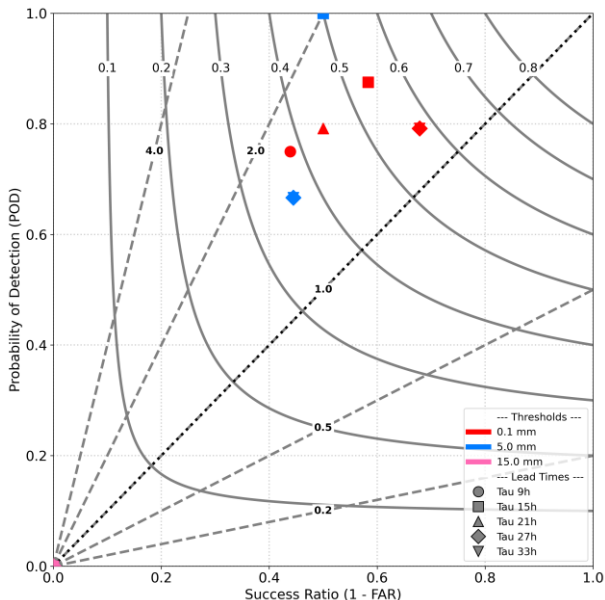
2/24~3/6



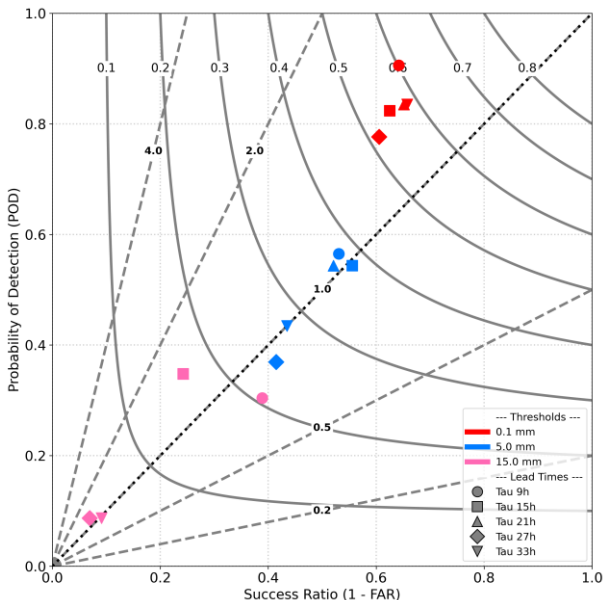
3/25~3/29



1/1~3/31

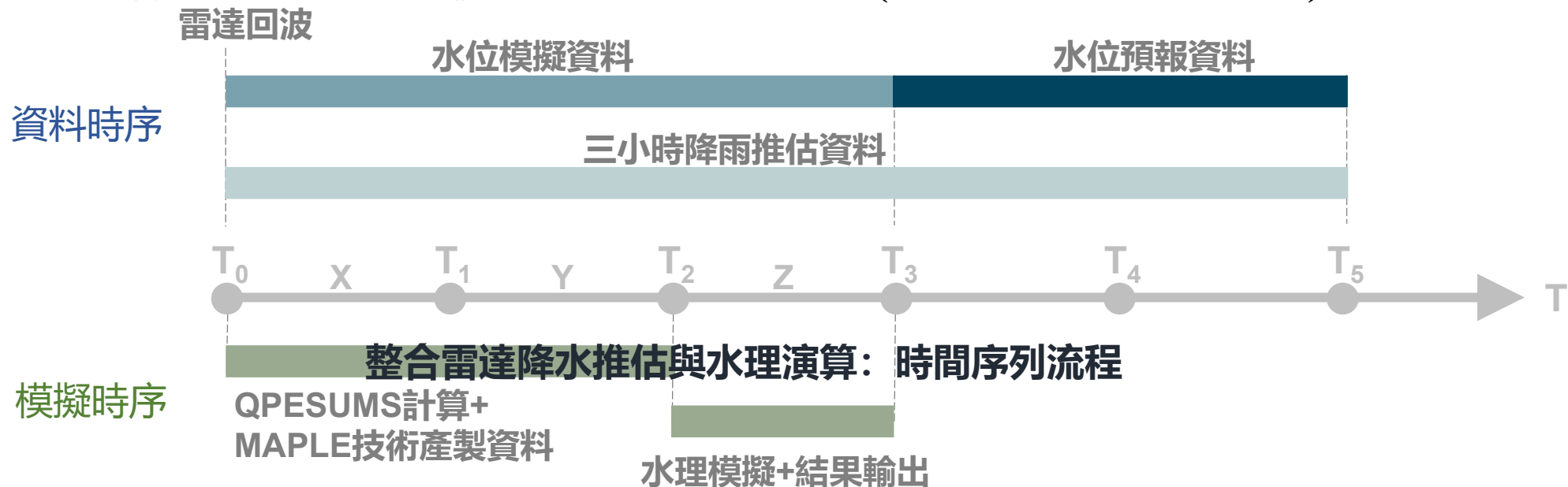


4/1~4/8



水理模式水位預報

目的：建立預測新街溪流域一處特定斷面的河道水位(或超過臨界水位的時間)之模式。



x 為雷達資料使用QPESUMS計算出第1筆時雨量所需時間

y 為前述第1筆雨量導入MAPLE技術產製未來3小時推估降雨資料以及傳給水理模擬團隊所需時間

z 為水理模擬團隊模擬且發布結果所需時間

T_2 為MAPLE資料產製完成及傳到水理模擬團隊時間點

T_0 為雷達資料觀測當下時間點

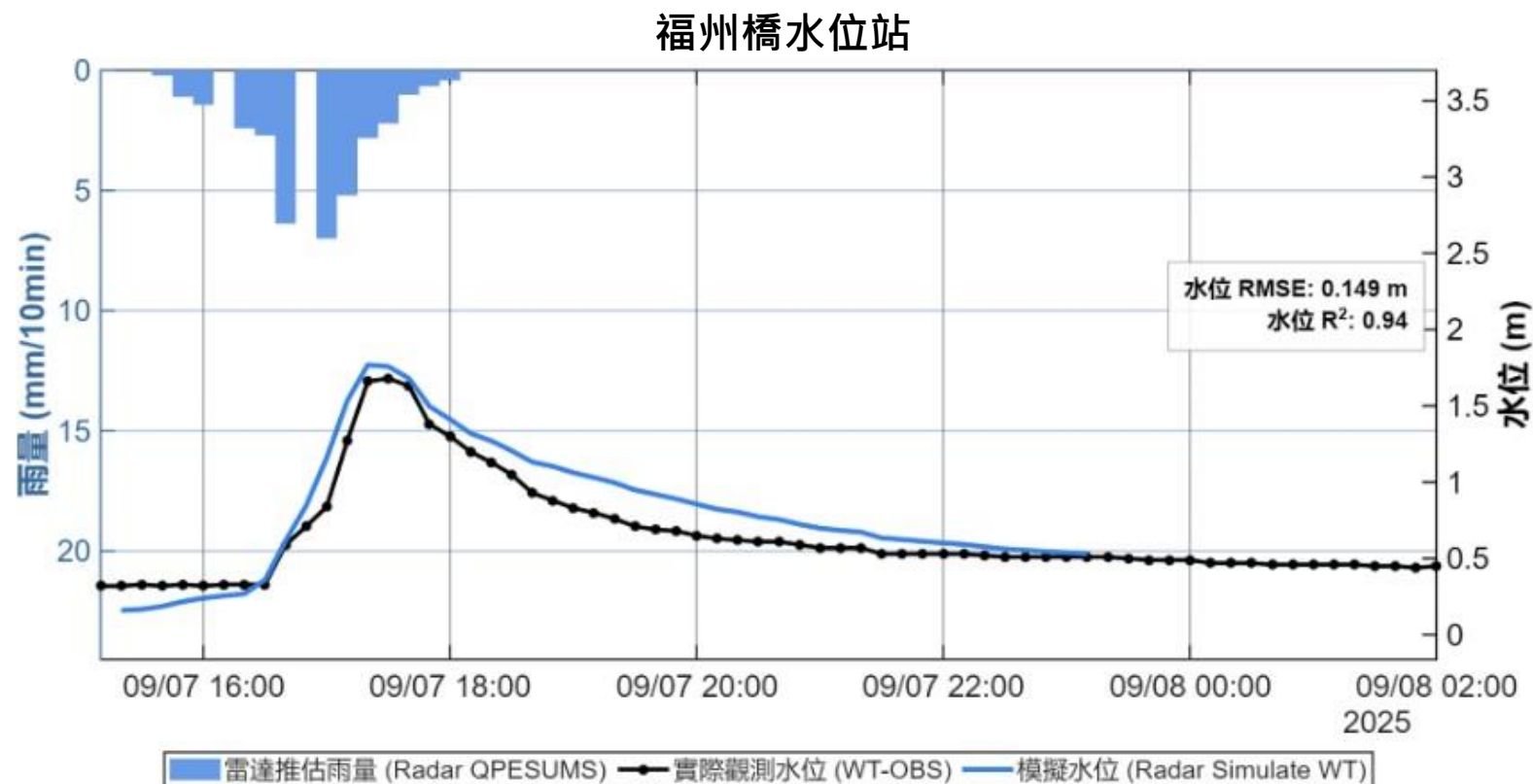
T_3 為水理模擬團隊發布結果時間點(預報起始時間)

T_1 為QPESUMS計算出第1筆時雨量時間點

T_4 、 T_5 為水位預報時間點(1-3小時水位預報)

水理模式水位預報

目的：建立預測新街溪流域一處特定斷面的河道水位(或超過臨界水位的時間)之模式。



- 模擬的水位歷線（藍線）與實際觀測水位（黑線）具備極高的吻合度。
- 模式能有效評估極端降水事件之洪災風險規模。



Thanks For Your
Attention !