



交通部中央氣象署
Central Weather Administration



初步評估同化菲律賓 PAGASA 阿帕里 (Aparri) 雷達資料對於颱風預報之影響:杜蘇芮颱風(2023)

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第 39 屆天氣分析與預報研討會 A2-13 @ 中央氣象署 (September 3, 2025)

Background

International collaboration in **weather data sharing** is essential **among countries that face common threat** from Tropical Cyclones (TCs) to expand observational coverage for improved understanding, forecasting, and early warning of TCs.

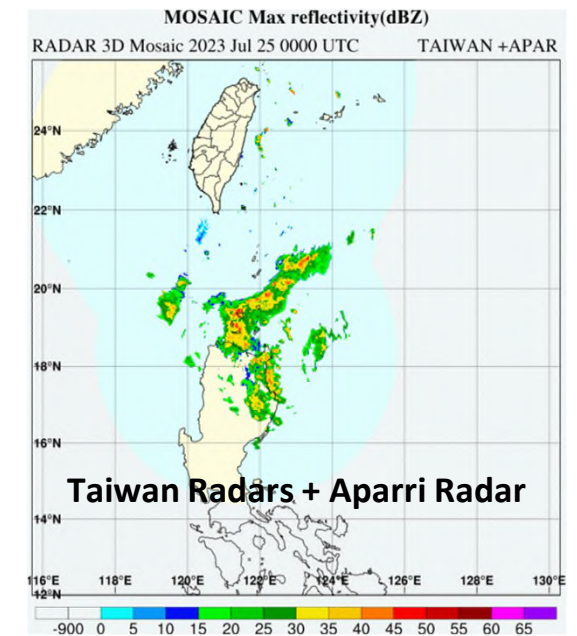
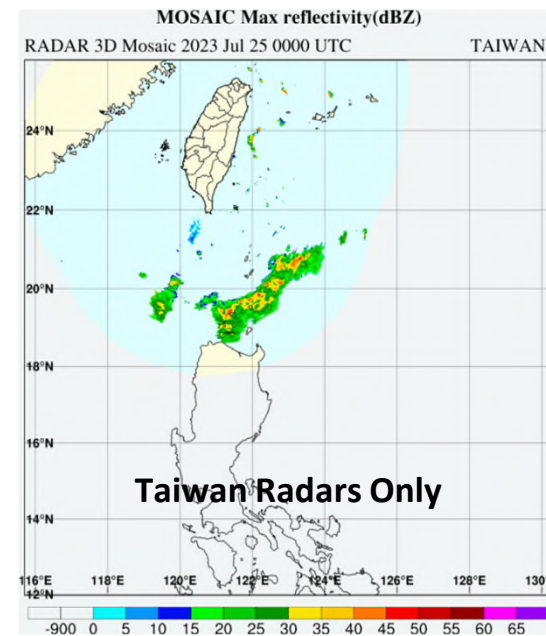
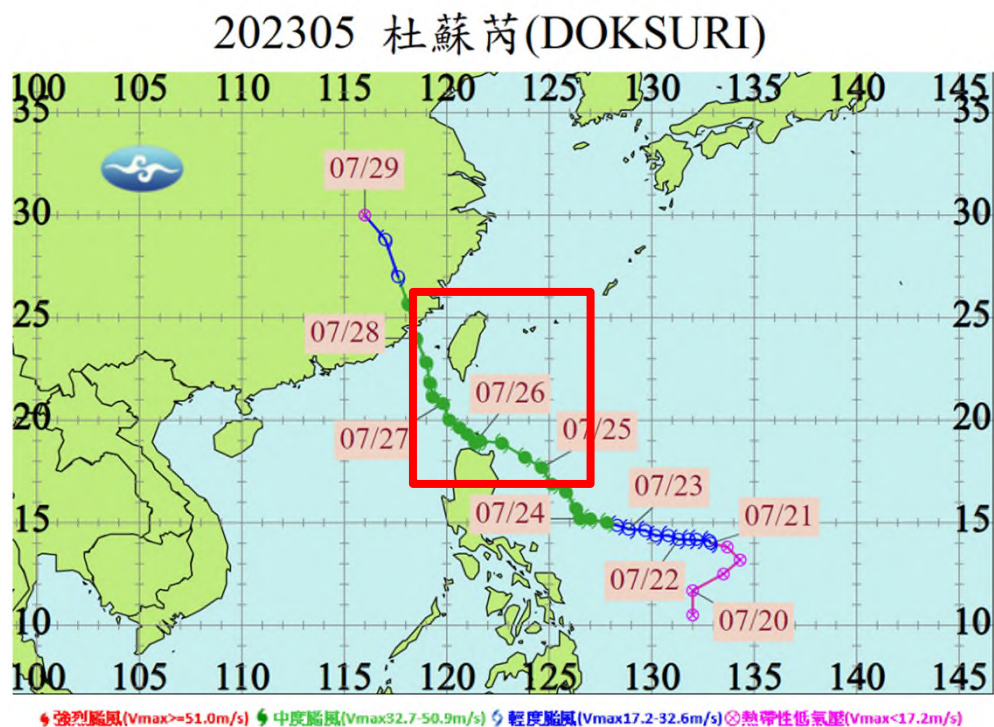
CWA of Taiwan receives **C-band ISHI radar data from Japan** and **C-band Basco and S-band Aparri radar data from the Philippines** via international collaboration.

VOTE is a Taiwan-Philippines collaborative research project supported by MECO-TECO and jointly funded by DOST and NSTC, focusing on research related to Volcanoes, Oceans, Typhoons, and Earthquakes - area of shared interests where both parties aim to deepen their scientific understanding

動畫來源: 方偉庭 (中央氣象署)

Objective

- Incorporate the PAGASA radar data with the Taiwan radar network expands observational coverage over the Luzon Strait and the Philippine Sea—key areas where many TCs develop and intensify before impacting both Taiwan and the Philippines.
- This study aims to improve TC forecast via assimilating radar data from both Taiwan and the Philippines.

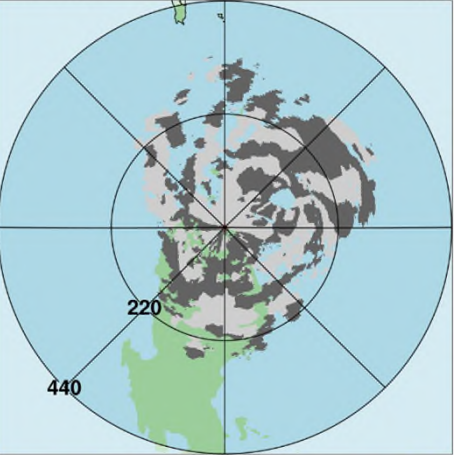


Aparri radar data provided by **PAGASA**:
2023/07/24 06 UTC - 2023/07/25 16 UTC

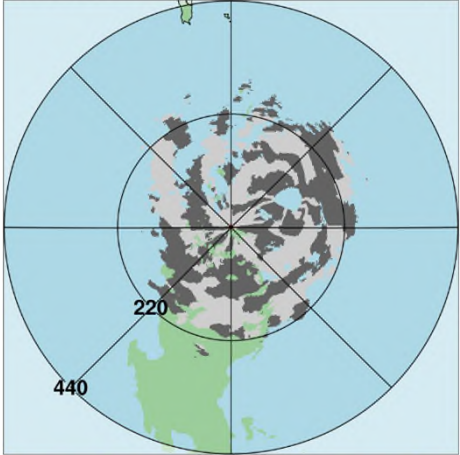
Aparri Radar Data

Radial Velocity (Vr)

0.0 PPI



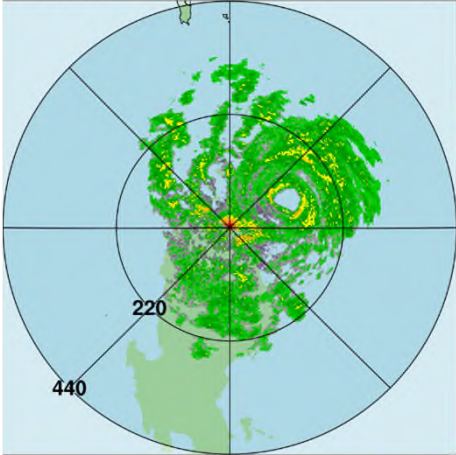
1.0 PPI



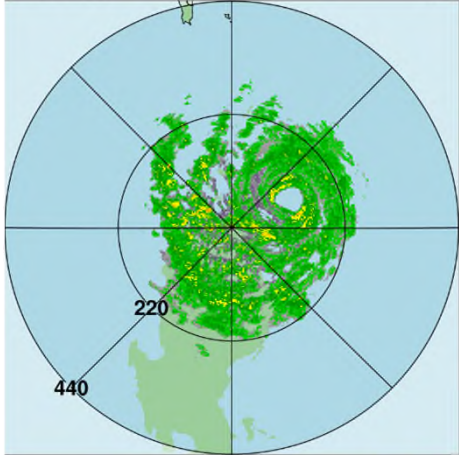
Surveillance mode
(sweep 1-4, 9-13)

Reflectivity (Zh)

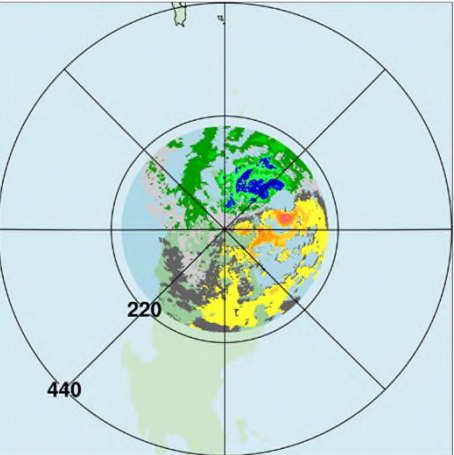
0.0 PPI



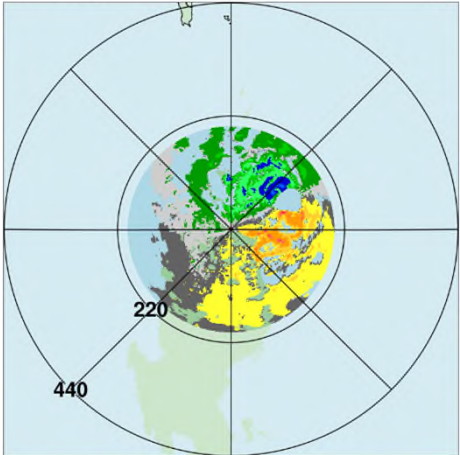
1.0 PPI



0.0 PPI

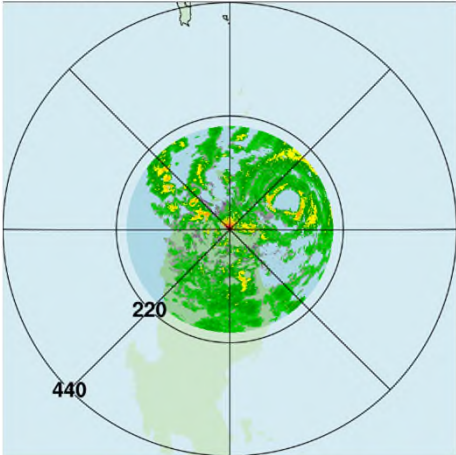


1.0 PPI

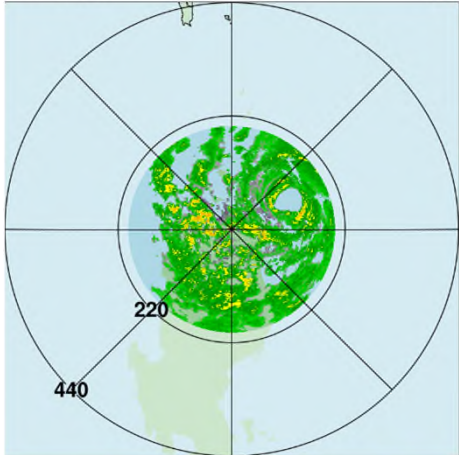


Doppler mode
(sweep 5-8, 9-13)

0.0 PPI



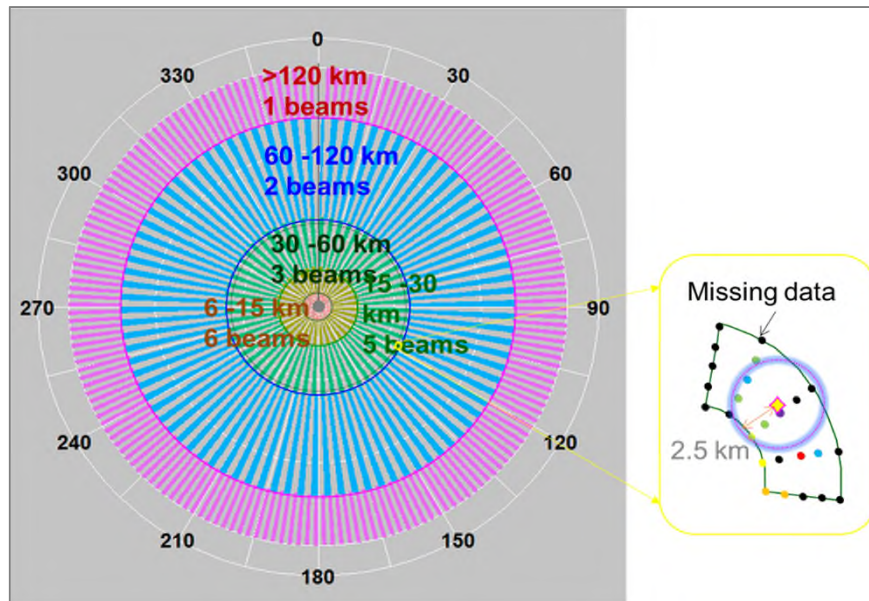
1.0 PPI



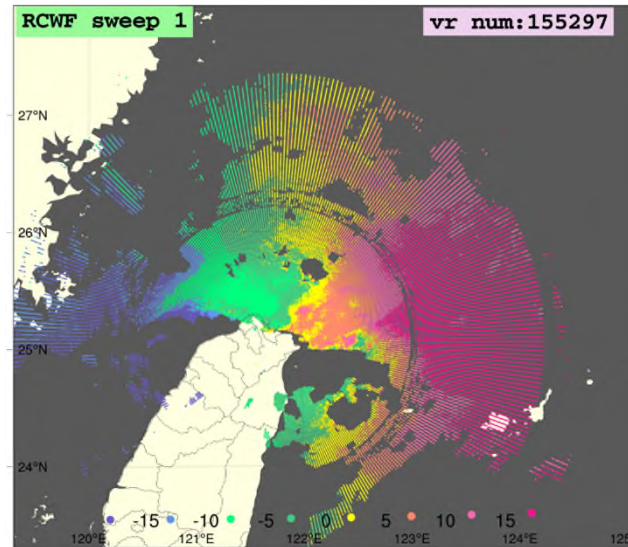
Pre-process of radar data (1/2)

Radial velocity (V_r)

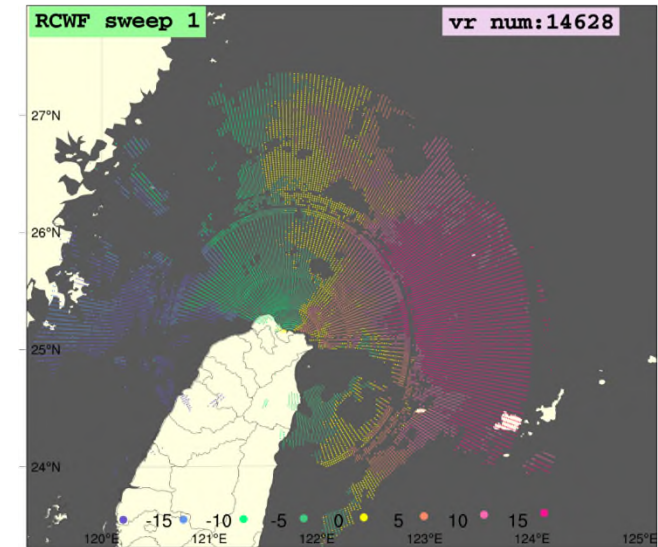
- Follow the super-obs strategy by *Alpert and Kumar (2007)* and *Chen et al. (2017)* for data thinning
- For each PPI, thinning is formed over a 5 azimuthal x 5 radial unit area ($\sim 2.5 \times 2.5$ km fan-shaped area) by discarding missing values and outliers followed by assigning value of data point closest to the center



Before thinning



After thinning



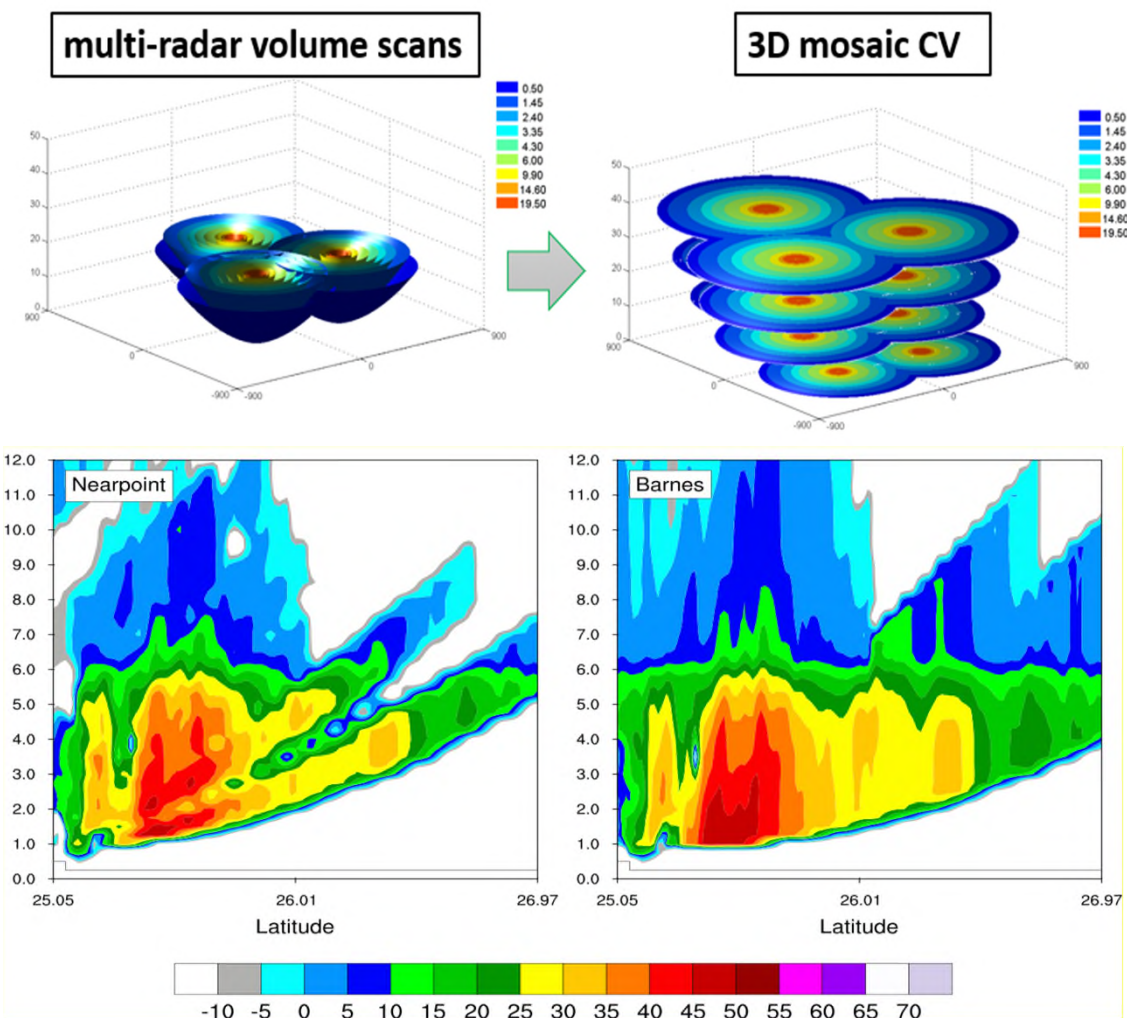
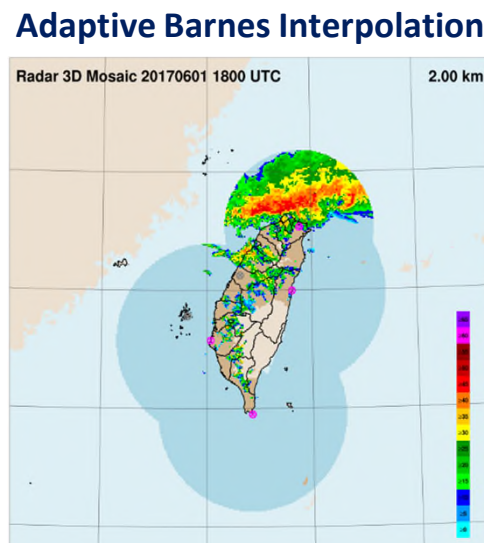
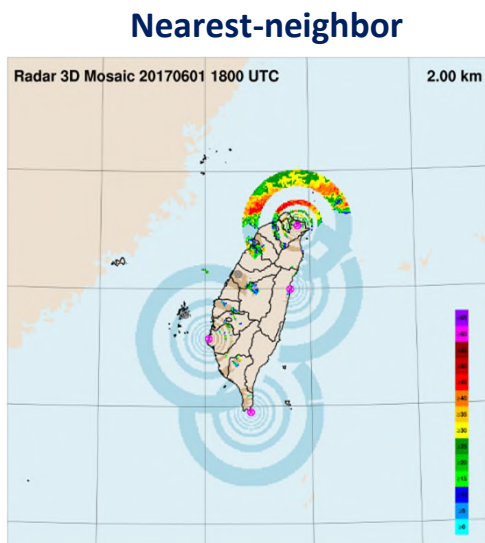
- 1) Alleviates the large computational cost needed to process large number of observations during data assimilation
- 1) Reduces impact of representative errors and avoids over-fitting to observations

詳情請參考 蔡雅婷等 (2019, 大氣科學) *WRF 三維變分雷達資料同化個案研究*

Pre-process of radar data (2/2)

Reflectivity (Ref)

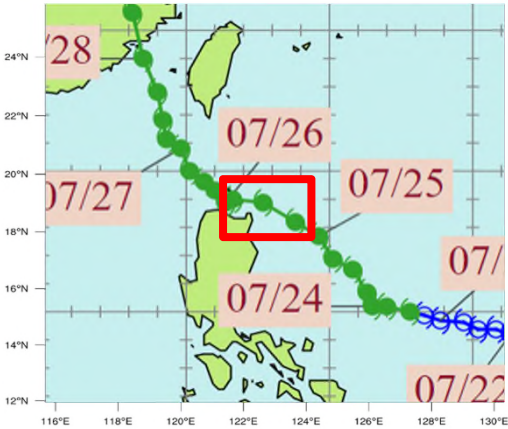
- Use adaptive Barnes interpolation scheme (*Askelson et al. 2000*) to construct Constant Altitude PPI (CAPPI) with resolutions at 2 km in horizontal and 500 m in the vertical from each volume scan per radar
- Form multi-radar composite (3D MOSAIC): for overlapping areas, we pick the maximum value



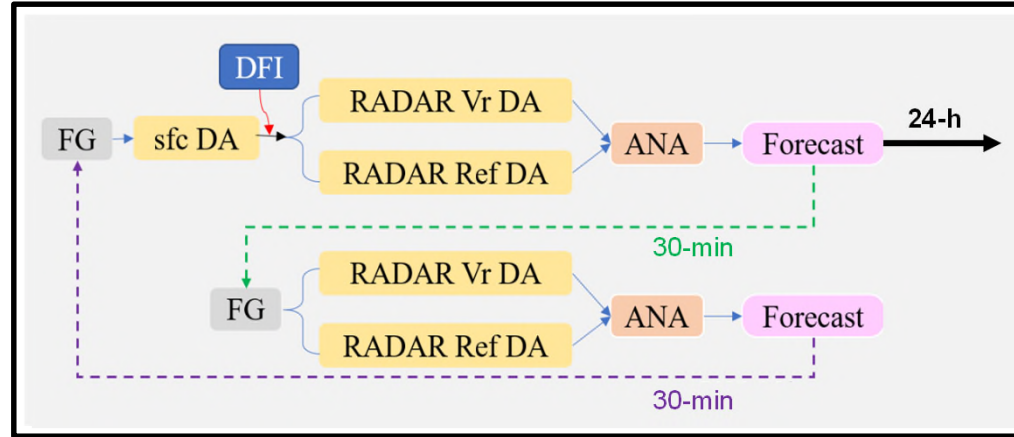
➤ Less data gaps and smoother composite of reflectivity field

Configuration & Experimental Design

grid = 801 x 801 x 52



Modified CWA RWRF Workflow



✓ Configuration:

- CWA RWRF with modified workflow and domain coverage (shifted to cover majority of the Philippine)
- Horizontal grid spacing = 2 km
- Vertical levels = 52

✓ Assimilation strategy:

- 30-min continuous cycling of 3DVar (cv7)
- 1-hourly sfc DA: updates U, V, T, Ps, pseudo RH
- 30-min radar Vr DA: updates U & V
- 30-min radar Ref DA: updates Qr, Qs, & Qg

Experiment	SFC DA	Radar DA
NoDA	X	X
woAPAR	O	Taiwan radar (Ref & Vr)
wAPAR	O	Taiwan radar (Ref & Vr) + Aparri_Ref_Vr
wAPAR_Ref*	O	Taiwan radar (Ref & Vr) + Aparri_Ref

✓ NoDA is initialized from 2023/07/25 00 UTC

✓ Warm-up period:

- 2023/07/25 00 UTC to 2023/07/25 06 UTC (total of 13 cycles)

✓ Examining period:

- 2023/07/25 06 UTC to 2023/07/25 16 UTC
- 24-h forecast initialized hourly (total of 11 forecast cases)

Analyses from wAPAR_Ref

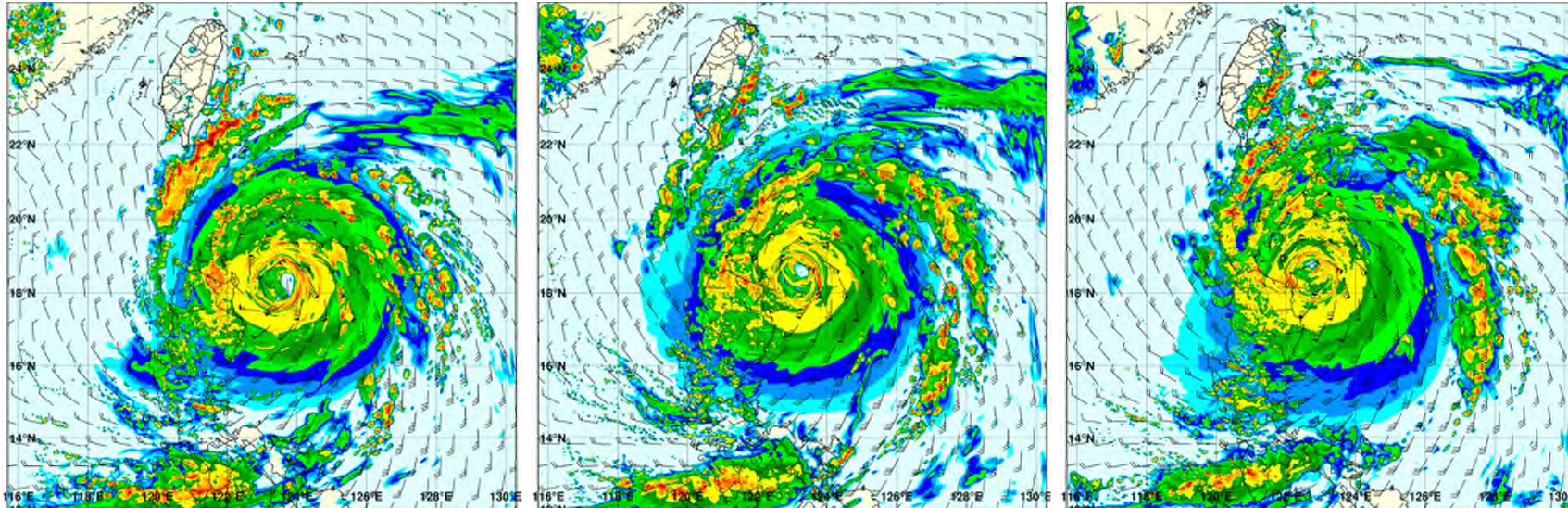
Max reflectivity (dBZ) and Wind vector at 3 km above ground

0600 UTC July 25, 2023

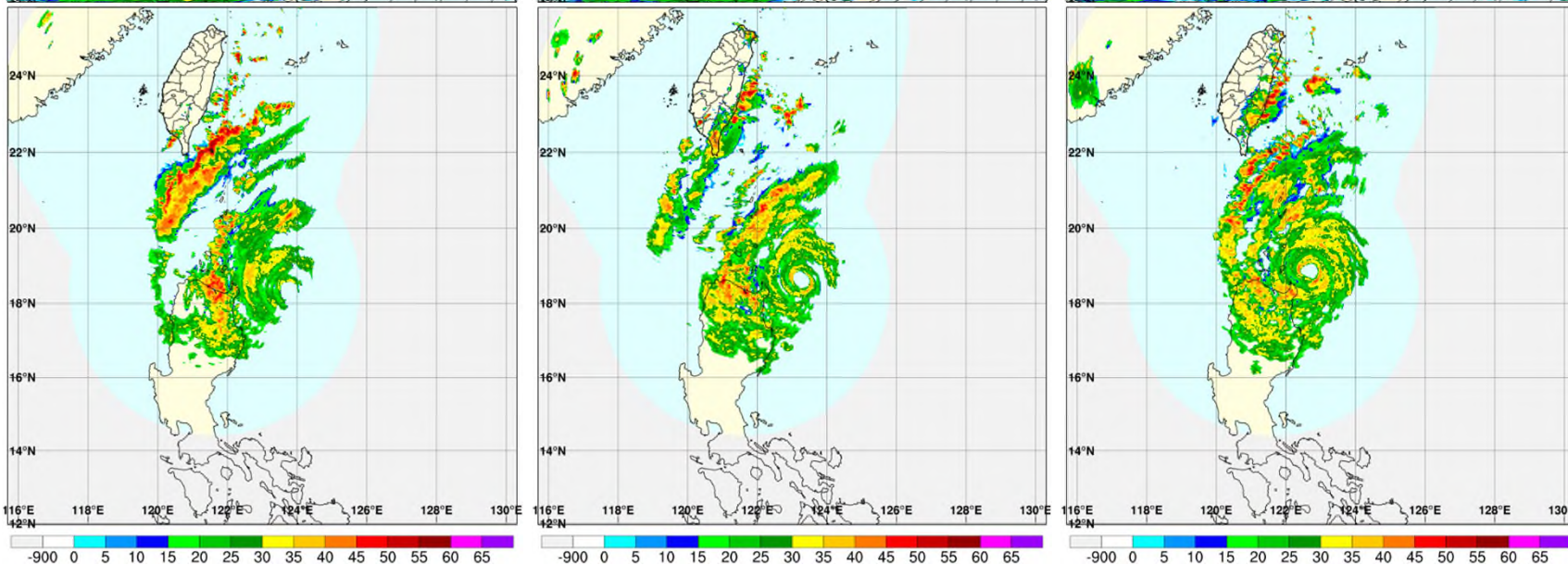
0900 UTC July 25, 2023

1200 UTC July 25, 2023

Analysis



Observation



- The analysis tends to result in a typhoon with a larger spatial extent.
- An unrealistic double eyewall feature appears in the **wAPAR_Ref** reflectivity analysis, which is likely attributed to the lack of a dynamically consistent wind field to support the corresponding hydrometeor distribution (even over multiple cycles of assimilation of radar reflectivity).

Analyses from wAPAR

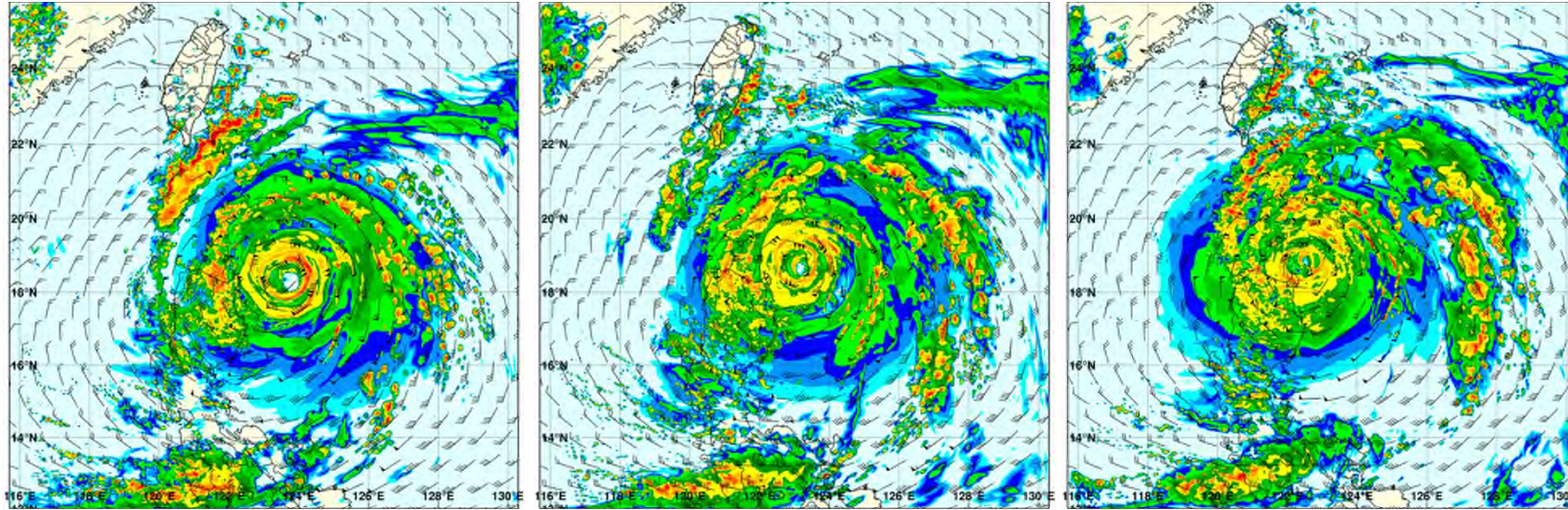
Max reflectivity (dBZ) and Wind vector at 3 km above ground

0600 UTC July 25, 2023

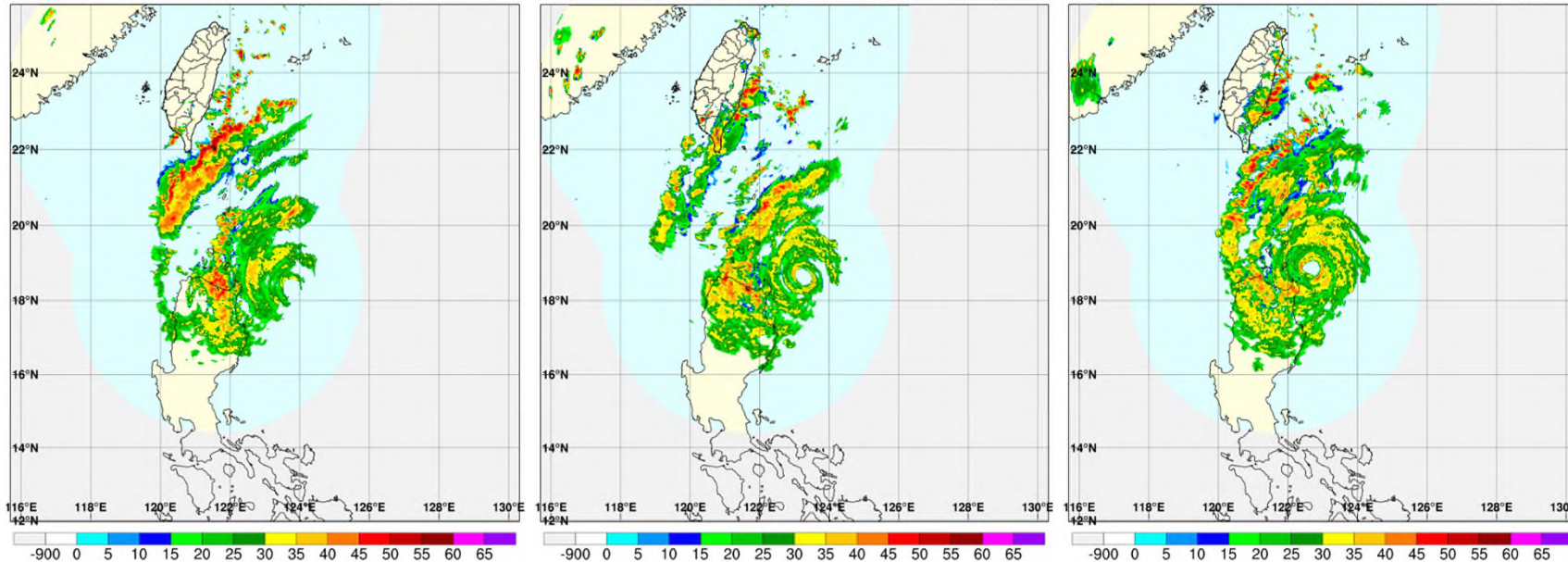
0900 UTC July 25, 2023

1200 UTC July 25, 2023

Analysis

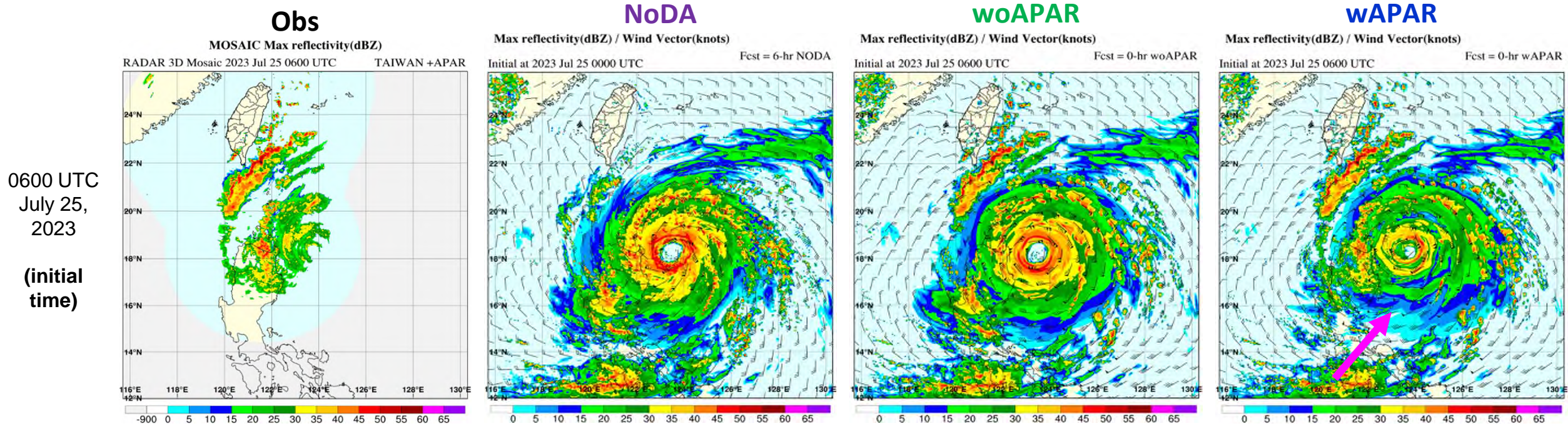


Observation



- After assimilating both radar reflectivity and radial velocity from Aparri, the unrealistic double eyewall feature is mitigated, and the reflectivity field becomes better aligned with the wind field.
- This highlights the importance of updating both dynamic and hydrometeor fields using radar reflectivity and radial winds, particularly in a 3DVar configuration.

Results from all experiments (1/2)

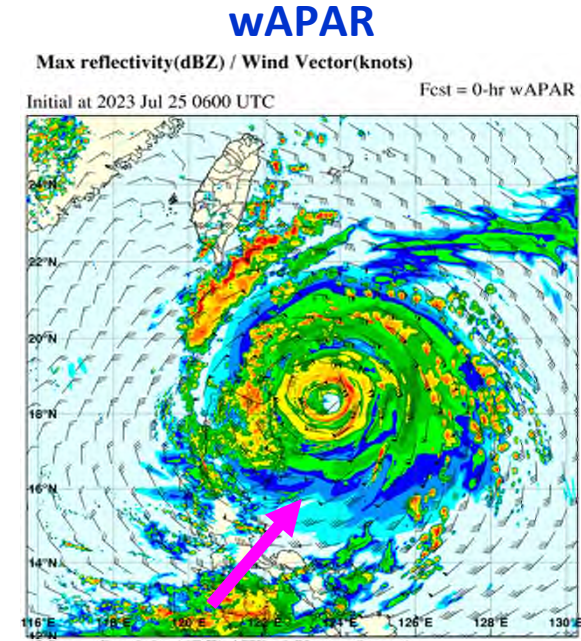
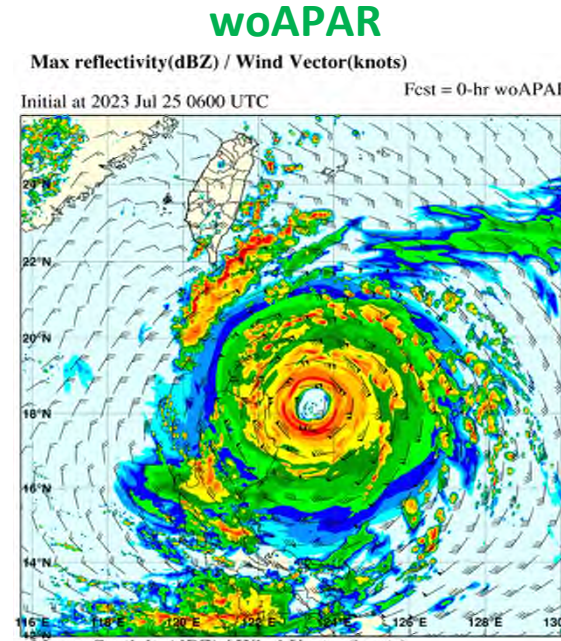
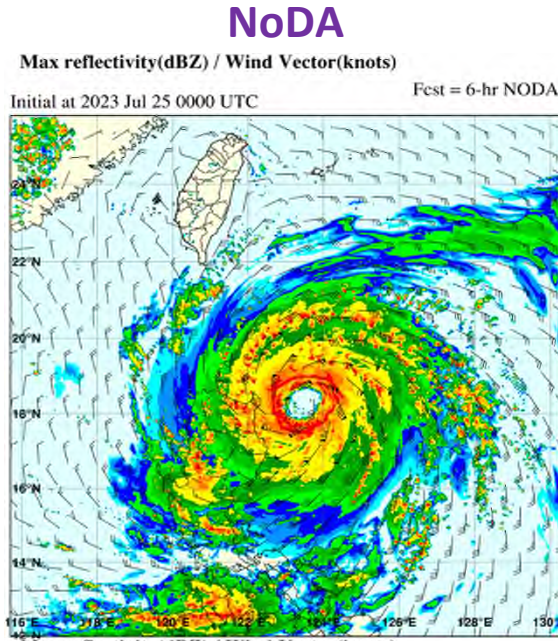
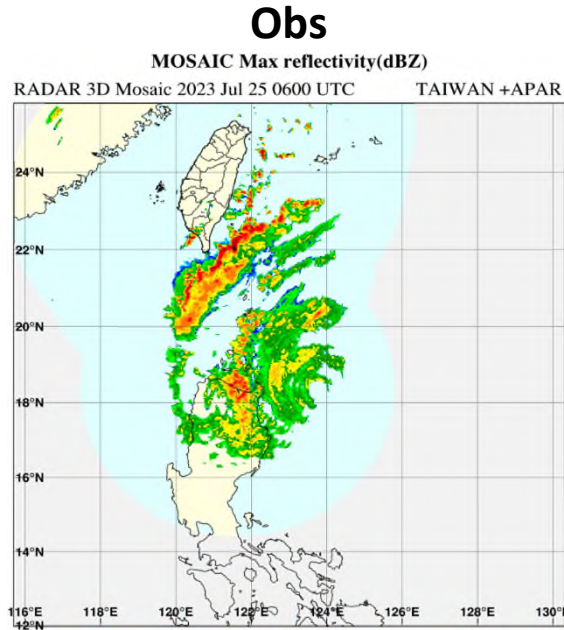


- **woAPAR** appears very similar to **NoDA**, with both showing higher inner-core reflectivity (dBZ > 40) than observed. However, **NoDA** lacks the outer rainbands just offshore of the Pingtung/Taitung coast, which are retained in **woAPAR**.
- By assimilating both reflectivity and radial velocity from the Aparri radar, the **wAPAR** analysis of maximum reflectivity better resembles the observed reflectivity.
- Interestingly, the radar reflectivity in **wAPAR** over the southern portion of Typhoon Doksuri is much reduced. This is suspected to be a consequence of the frequent assimilation of no-rain obs (perhaps should be treated as no obs instead).

Results from all experiments (2/2)

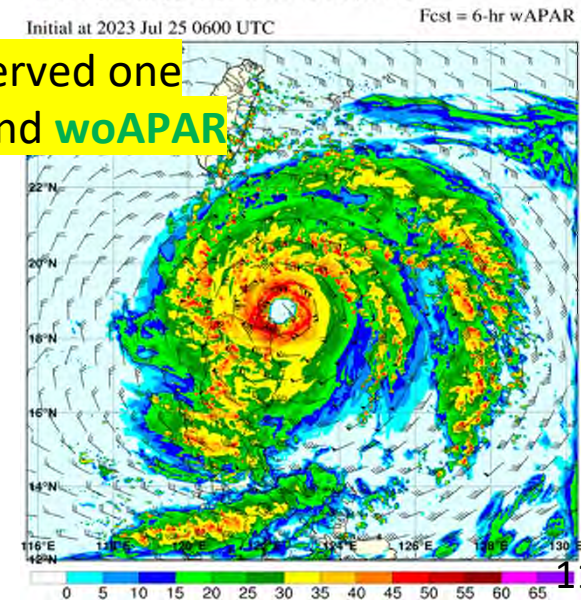
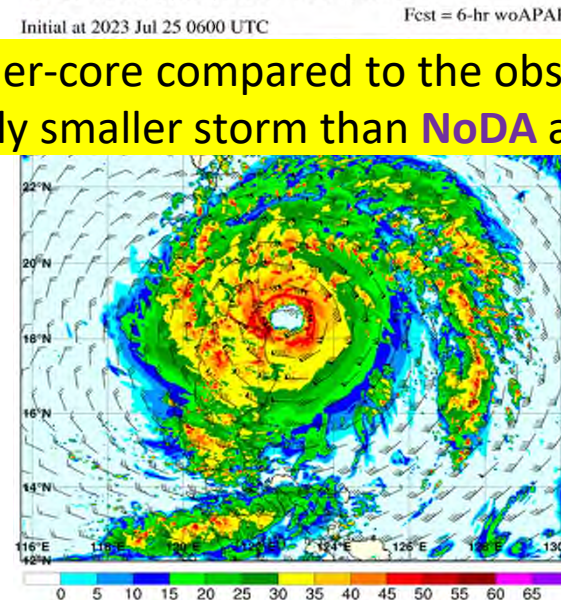
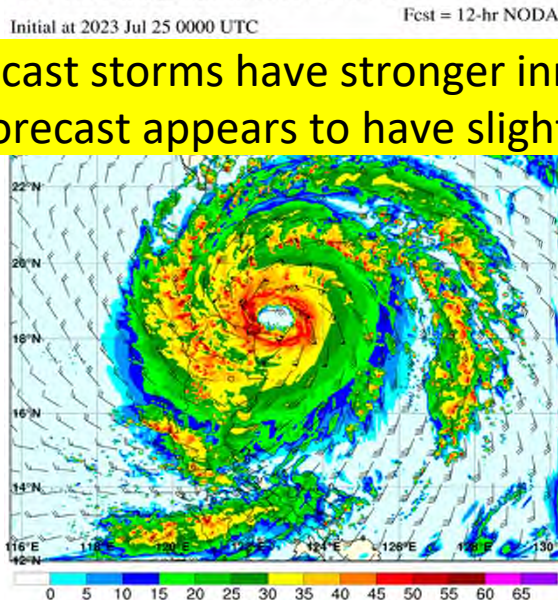
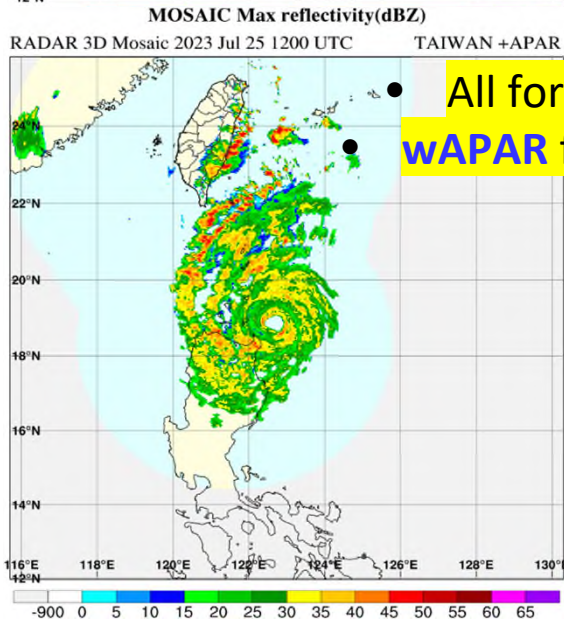
0600 UTC
July 25,
2023

(initial
time)



1200 UTC
July 25,
2023

(6-h
forecast)



• All forecast storms have stronger inner-core compared to the observed one
• wAPAR forecast appears to have slightly smaller storm than NoDA and woAPAR

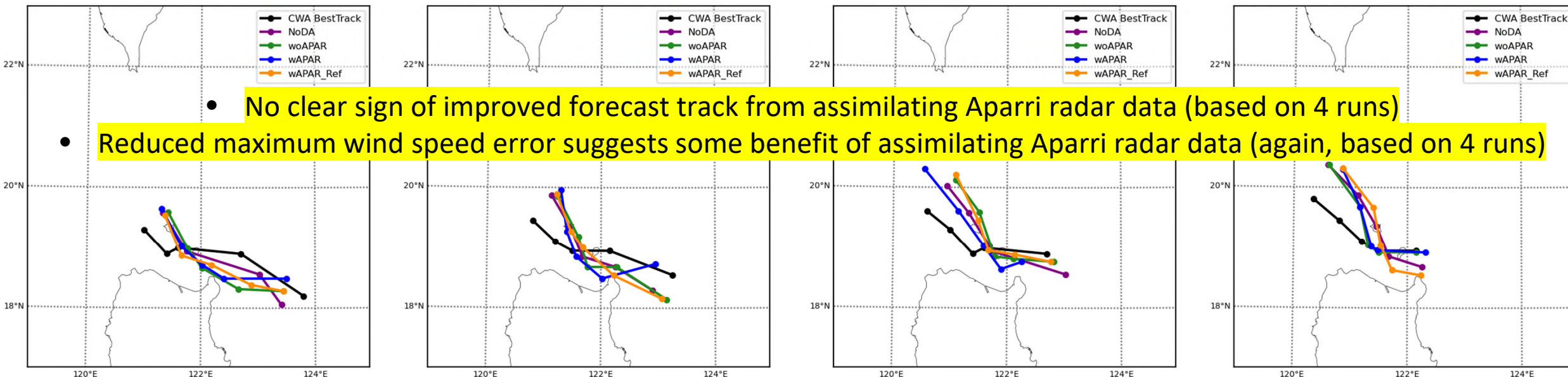
24 h Typhoon Track Forecasts

Initialized from 2023/07/25 **06 UTC**

Initialized from 2023/07/25 **09 UTC**

Initialized from 2023/07/25 **12 UTC**

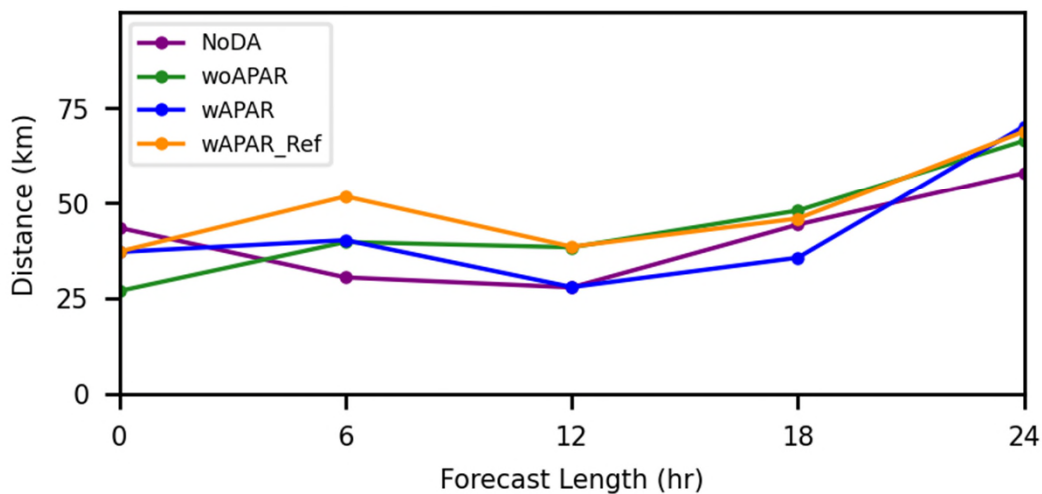
Initialized from 2023/07/25 **15 UTC**



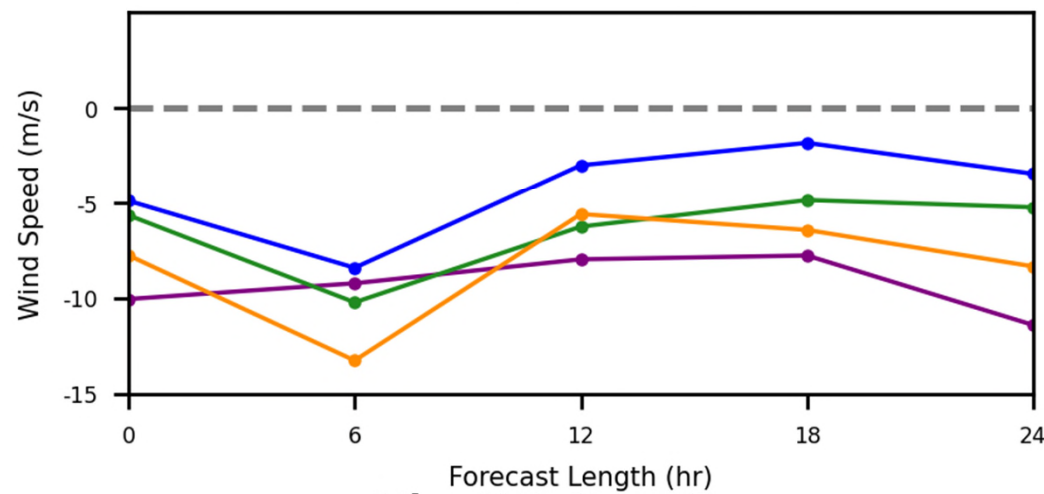
- No clear sign of improved forecast track from assimilating Aparri radar data (based on 4 runs)
- Reduced maximum wind speed error suggests some benefit of assimilating Aparri radar data (again, based on 4 runs)

DOKSURI RWRf Exps: 06 UTC 25 Jul 2023 ~ 15 UTC 25 Jul 2023 (4 runs)

(a) **Track: Mean Error**



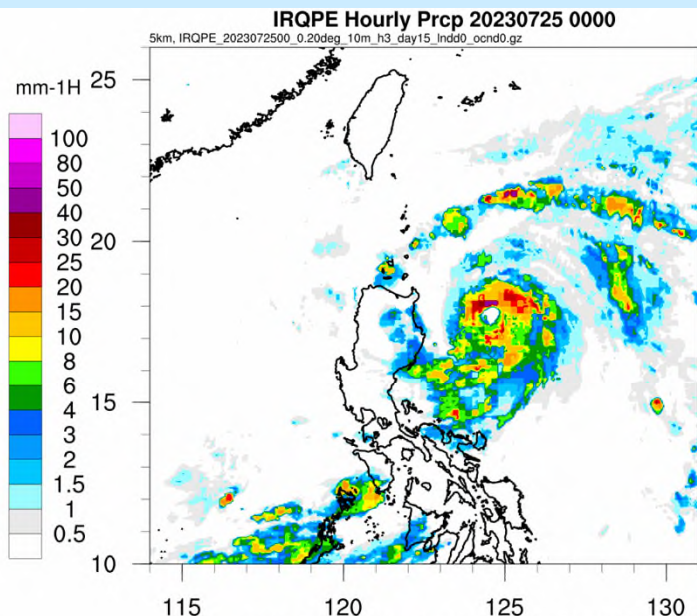
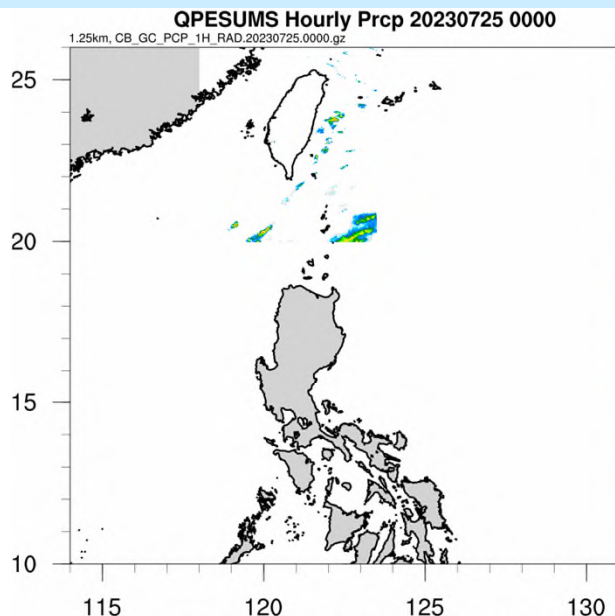
(b) **Max. WSPD: Mean Error**



Rainfall Estimation Products

資料來源:
科技發展組衛星團隊

Domain extent is beyond
the coverage of Taiwan
QPESUMS
(Radar + Rain Gauge)

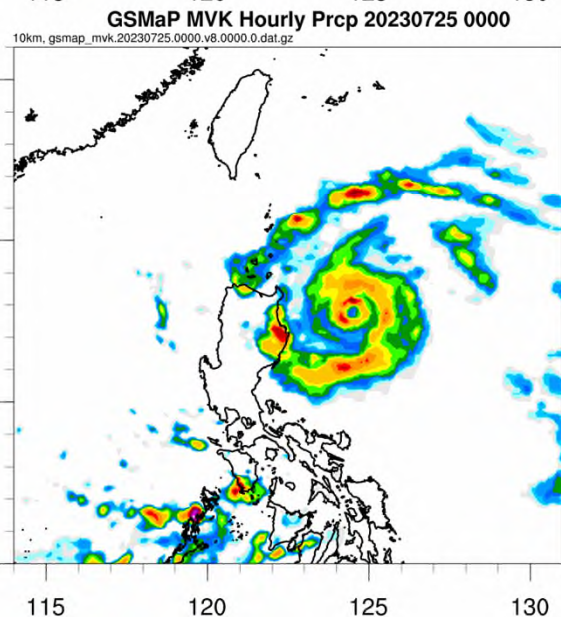
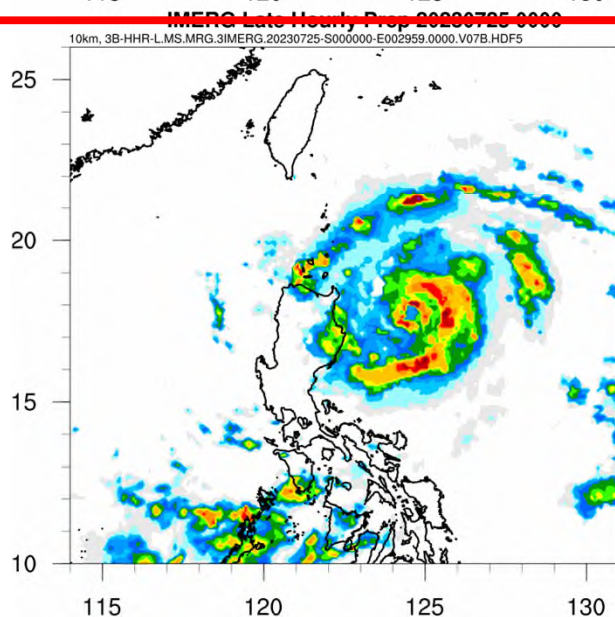


IRQPE

**Integrated Multi-Satellite
Retrievals for GPM
(IMERG)**

*calibrated with GPM DPR
(Dual-frequency
Precipitation Radar)

Temporal res: 30 min
Spatial res: 0.1 deg



**Global Satellite Mapping of
Precipitation (GSMaP)**

*calibrated with rain gauge
data, but not GPM DPR

Temporal res: 1 hr
Spatial res: 0.1 deg

6-h Accumulated Rainfall: Gauge, Sat-estimates, Fcst

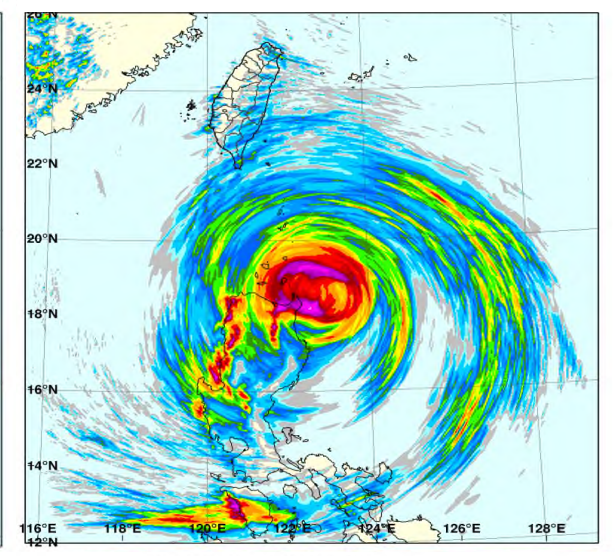
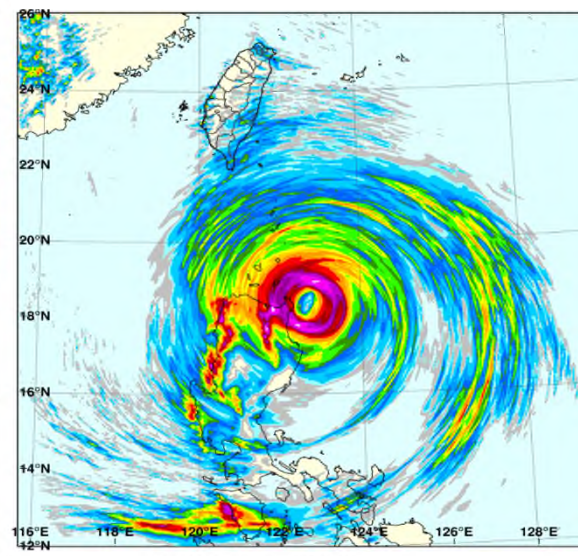
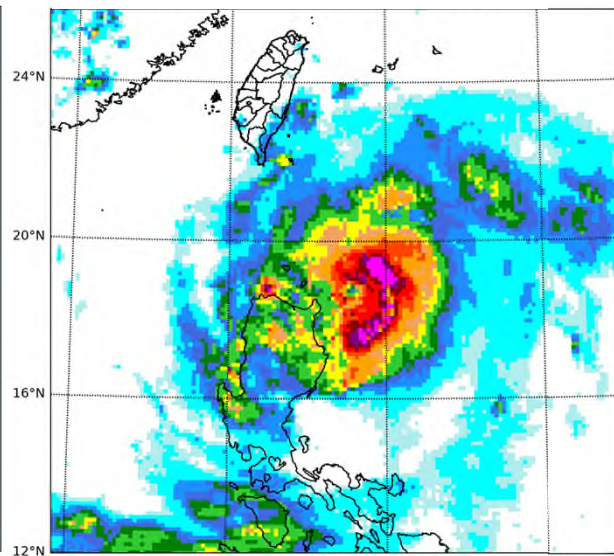
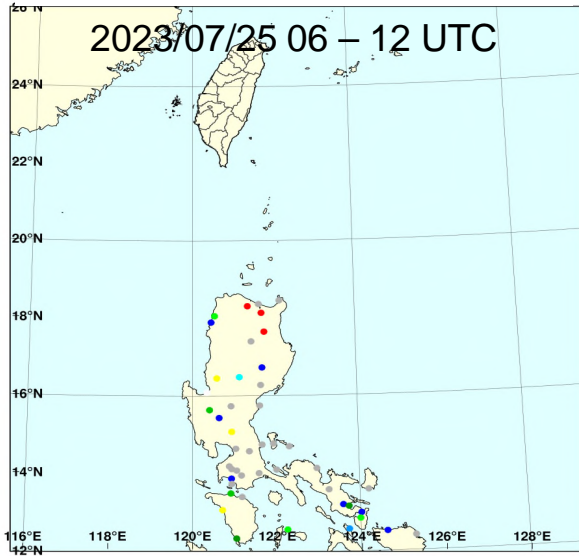
PAGASA Rain Gauge

IMERG Retrieval

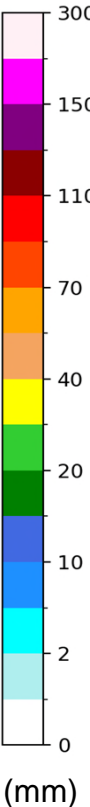
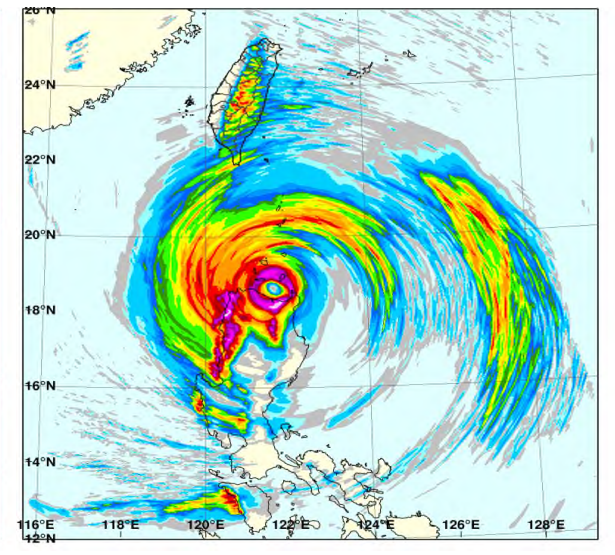
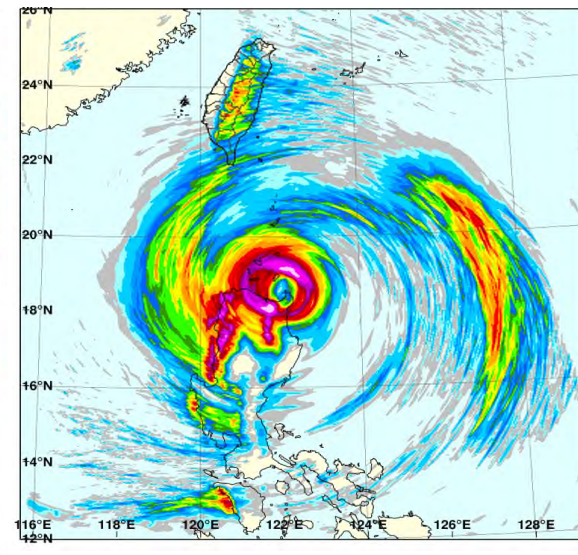
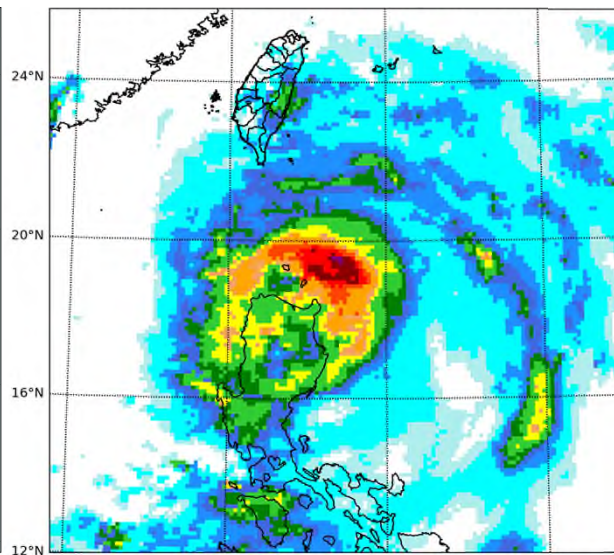
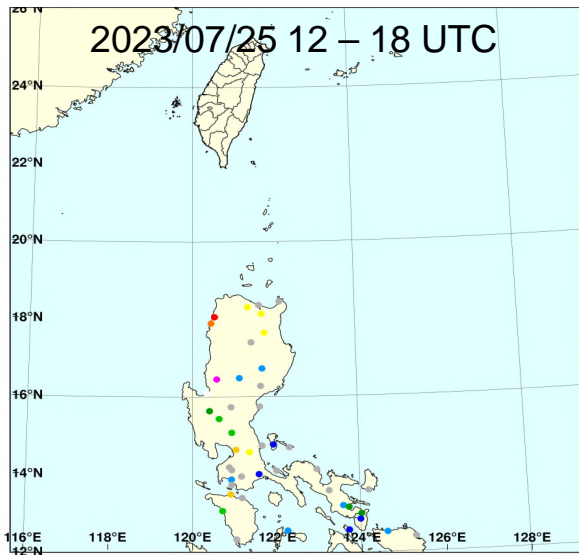
woAPAR RWRP Forecast

wAPAR RWRP Forecast

2023/07/25 06 – 12 UTC

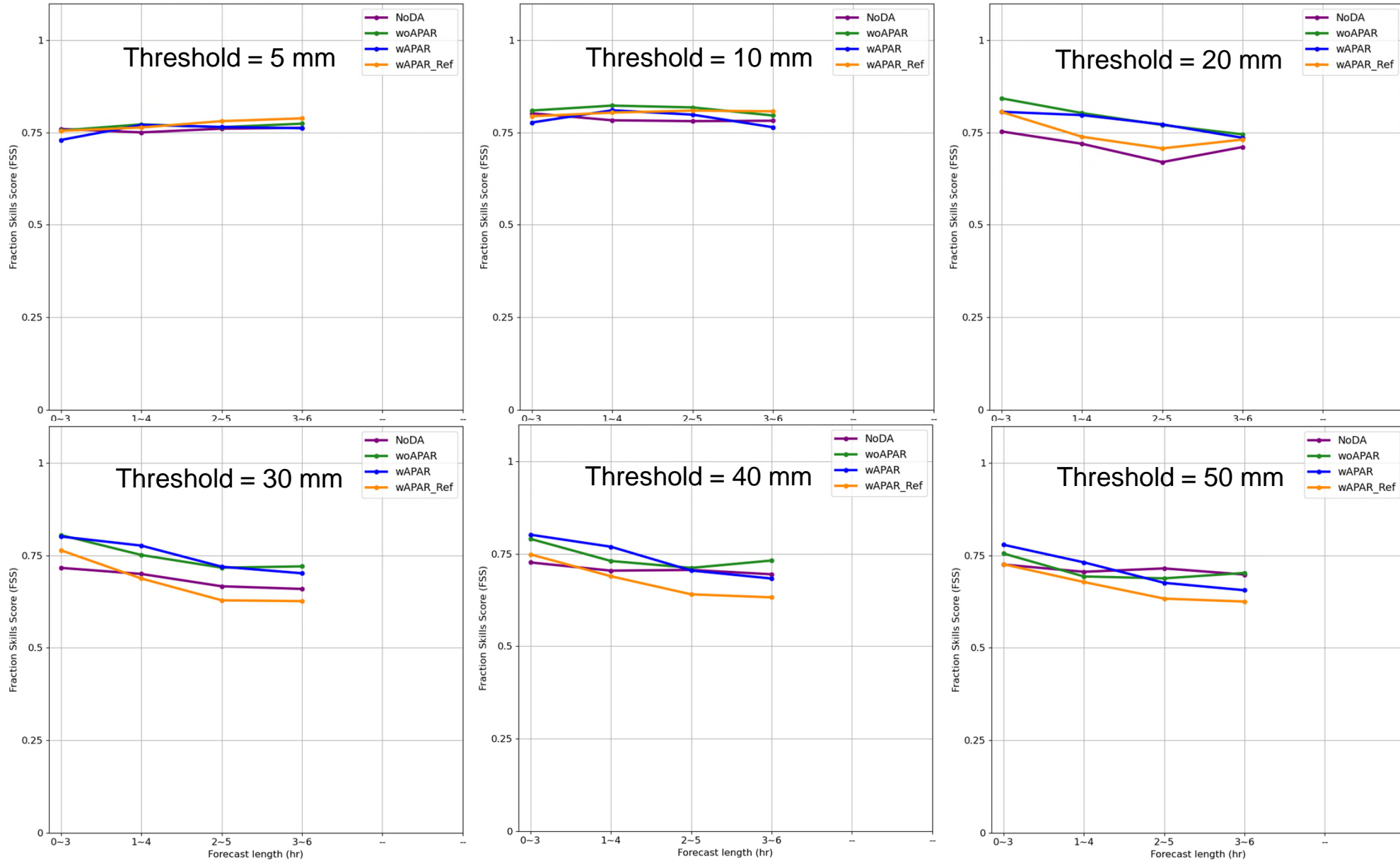


2023/07/25 12 – 18 UTC



Rainfall Forecast Skills (Verified against IMERG)

2023/07/25 06, 09, 12, 15 UTC (4 runs): Averaged 3-h Accum. Rainfall FSS (Neighborhood length scale = 50 km)



- There is no clear impact of assimilating Aparri radar data on 3-h accumulated precipitation forecast for light rain (below 10 mm).

- There is some evidence suggesting that assimilating Aparri radar data leads to improvement in forecasting medium to heavy rainfall events.

Summary & Future Work

- Radar data from Aparri radar is successfully assimilated using the modified CWA RWRF system.
- A case study of Typhoon Doksuri (2023) was conducted to assess the benefit of assimilating combined radar data from Taiwan and the Philippines for TC forecasting. Preliminary results from this study suggests the following:
 - ✓ By including the Aparri radar data, the storm structure in the analysis becomes more realistic, especially during the early stage when the storm is outside the coverage of CWA radar stations.
 - ✓ Assimilating both radar reflectivity and radial wind fields is essential in improving the position and structure of TC in the analysis (consistent with our previous experience using RWRF)
 - ✓ There is no clear impact of assimilating Aparri radar data on TC track forecasts
 - ✓ There is some evidence showing benefits of assimilating Aparri radar data to rainfall forecasts
- More case studies should be conducted to further understand the added value of PAGASA radar data.
- We look forward to continuing collaborative research with PAGASA under the VOTE program to deepen our understanding of tropical cyclones. That said, maintaining a long-term partnership requires high-quality data and a reliable and continuous data supply.

Thank you!

Other cases

- 2016 莫蘭蒂(MERANTI):
 - 只有 Aparri 站有提供資料，Basco 雷達遭莫蘭蒂破壞後尚未能修復
 - Aparri 僅有回波資料，沒有逕向風場資料
 - 僅 09/12: 16 UTC – 09/13: 16 UTC 這段期間有完整的仰角掃描資料
 - ~ 09/14: 00 UTC 僅有前三層仰角的資料)
- 2021 燦樹(CHANTHU):
 - 同樣只有 Aparri 雷達資料，沒有 Basco 站
 - 僅 09/10 08:00 UTC – 09/10 22:15 UTC 這段期間有資料
 - 雷達回波與逕向風場皆有資料

