Comparison of WRF Simulations and Polarimetric RO Data for Hydrometeors around Tropical Cyclones

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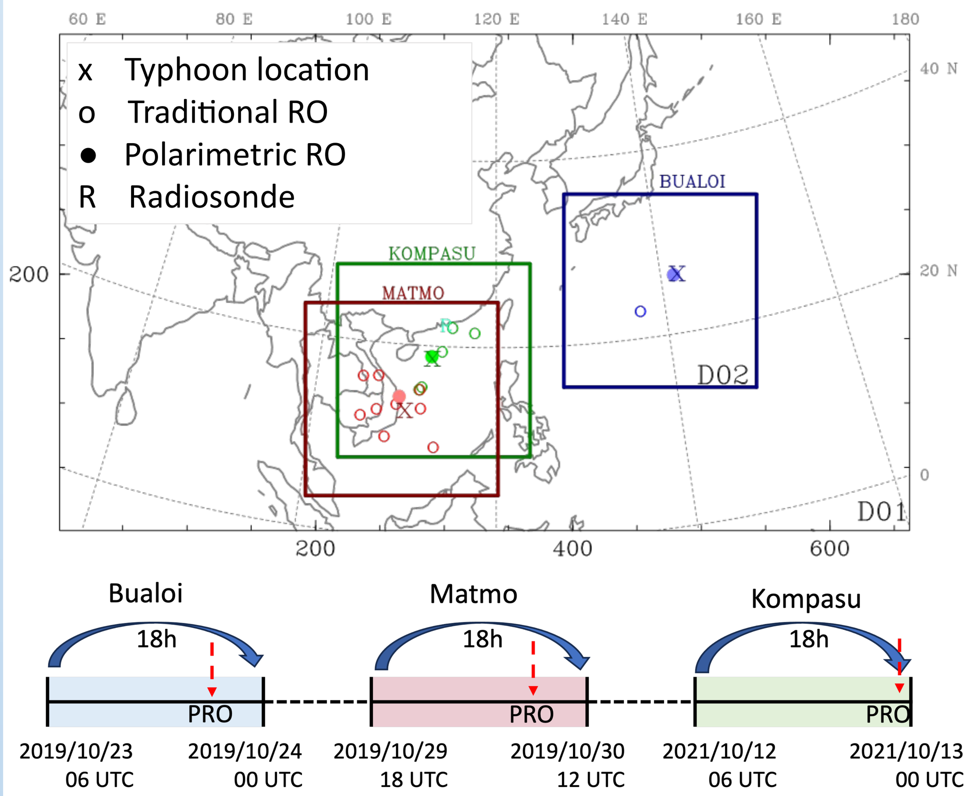
Introduction

Observing the development of typhoons over the ocean, particularly the vertical variation of hydrometeors, presents challenges. Many cloud microphysical parameterization schemes have been developed for weather and climate models. Most of these parameterizations are "bulk parameterizations", the evaluation of these parameterizations has shown uncertainty across different methods. The PRO observations offer a possibility for evaluating the performance of various cloud microphysics schemes. We performed high-resolution WRF model simulations for three typhoon cases and compared the simulated phase differences with PAZ PRO observations. Such comparison is subject to many uncertainties, including model initial conditions, the difference between the model and observed storm location, as well as details of the simulated cloud distributions.

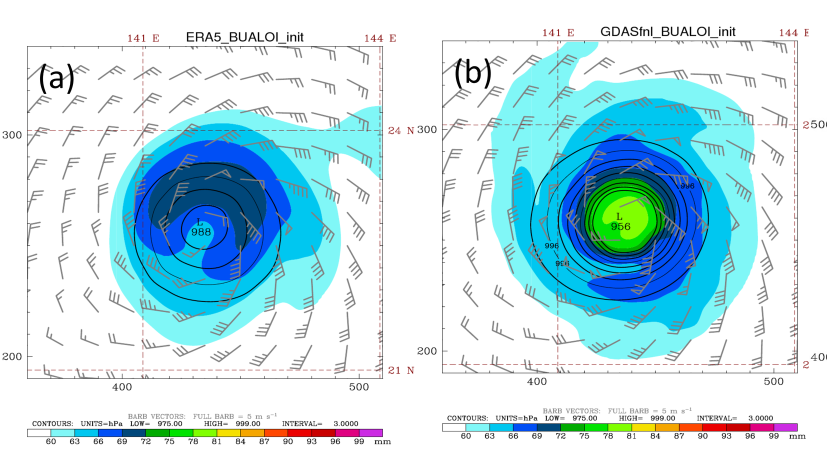
Model Configuration and Experimental Design



- Model : WRF model v4.2
- Domain : 15 km for D01, and 3 km for D02
- Vertical level : 52
- Model top : 20 hPa
- Kain-Fritsch cumulus convection scheme applied only for the D01
- RRTMG radiation physics scheme
- YSU PBL scheme
- No bogus vortex implementation
- Initial conditions : ERA5 0.25° resolution and GDAS FNL 0.25° resolution
- Microphysics : Purdue Lin, WSM6, Goddard, Thompson, Morrison
- Typhoon Cases: Bualoi (2019), Matmo (2019), Kompasu (2021)

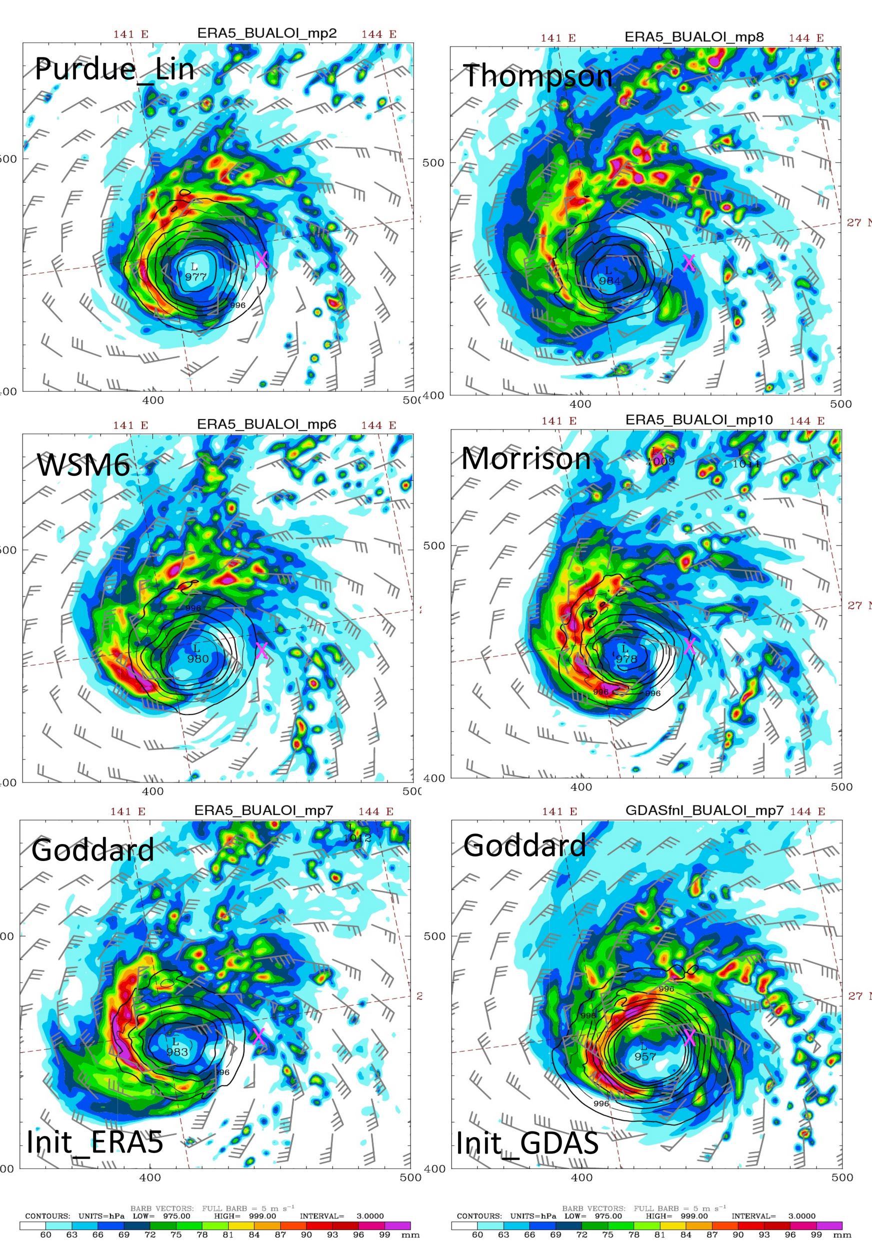
Simulated Results and Verifications

Initial conditions for TY Bualoi



Total precipitable water (in color), sea level pressure (in contour), and wind vectors for the WRF initial condition from (a) ERA5 and (b) GDAS Fnl for the Bualoi case.

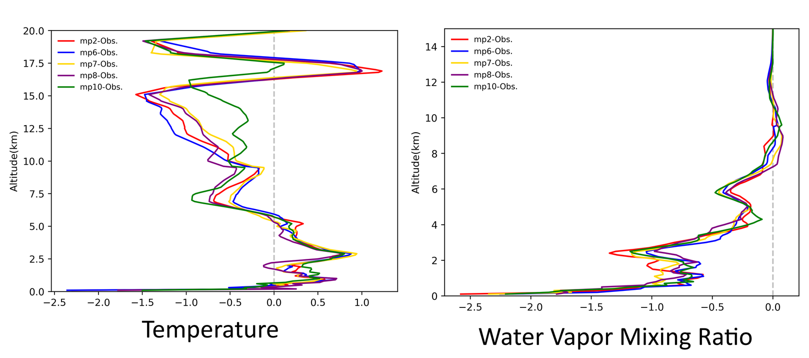
WRF 18h forecast for TY Bualoi



Total precipitable water (in color), sea level pressure (in contour), and wind vectors for WRF 18-hour forecast with different microphysics schemes. The cross sign in each panel indicates the observed location of Typhoon Bualoi.

Verifications for three typhoon cases

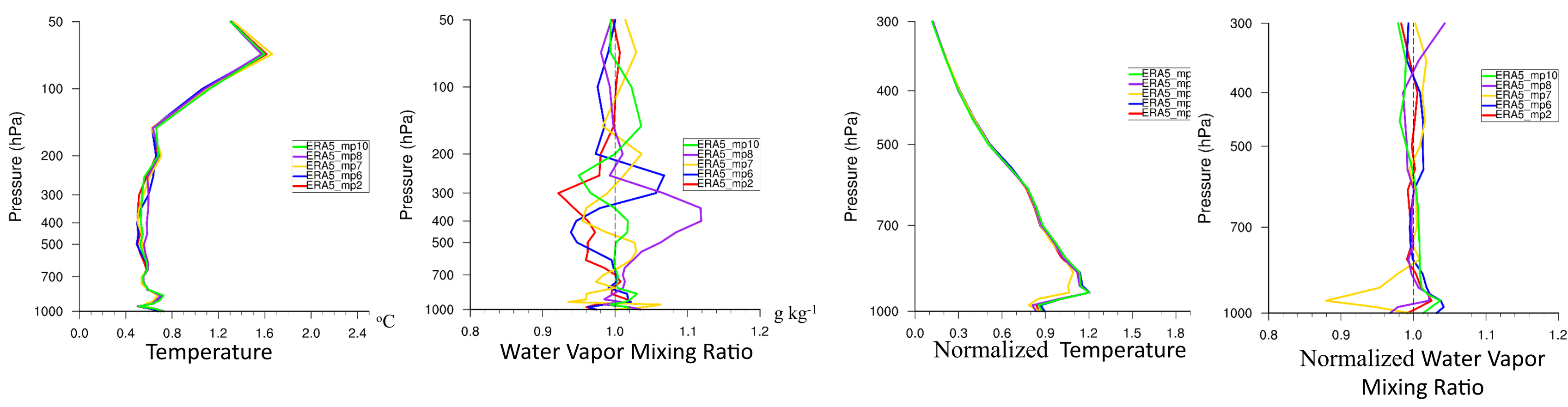
Against soundings (Bias)



14 Traditional GNSS RO profiles
1 radiosonde profile

Verifications for three typhoon cases

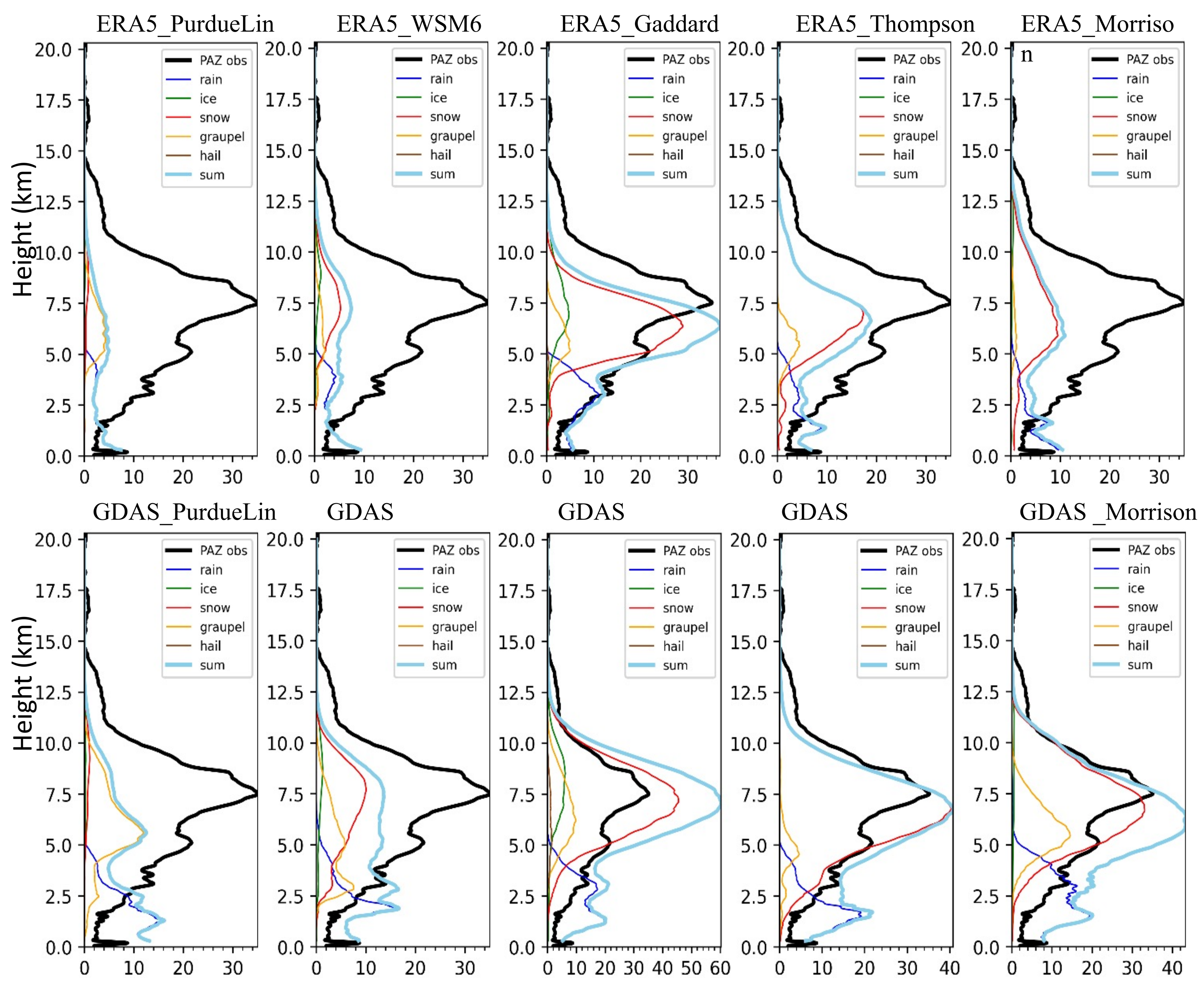
Against ERA5 (RMSE)



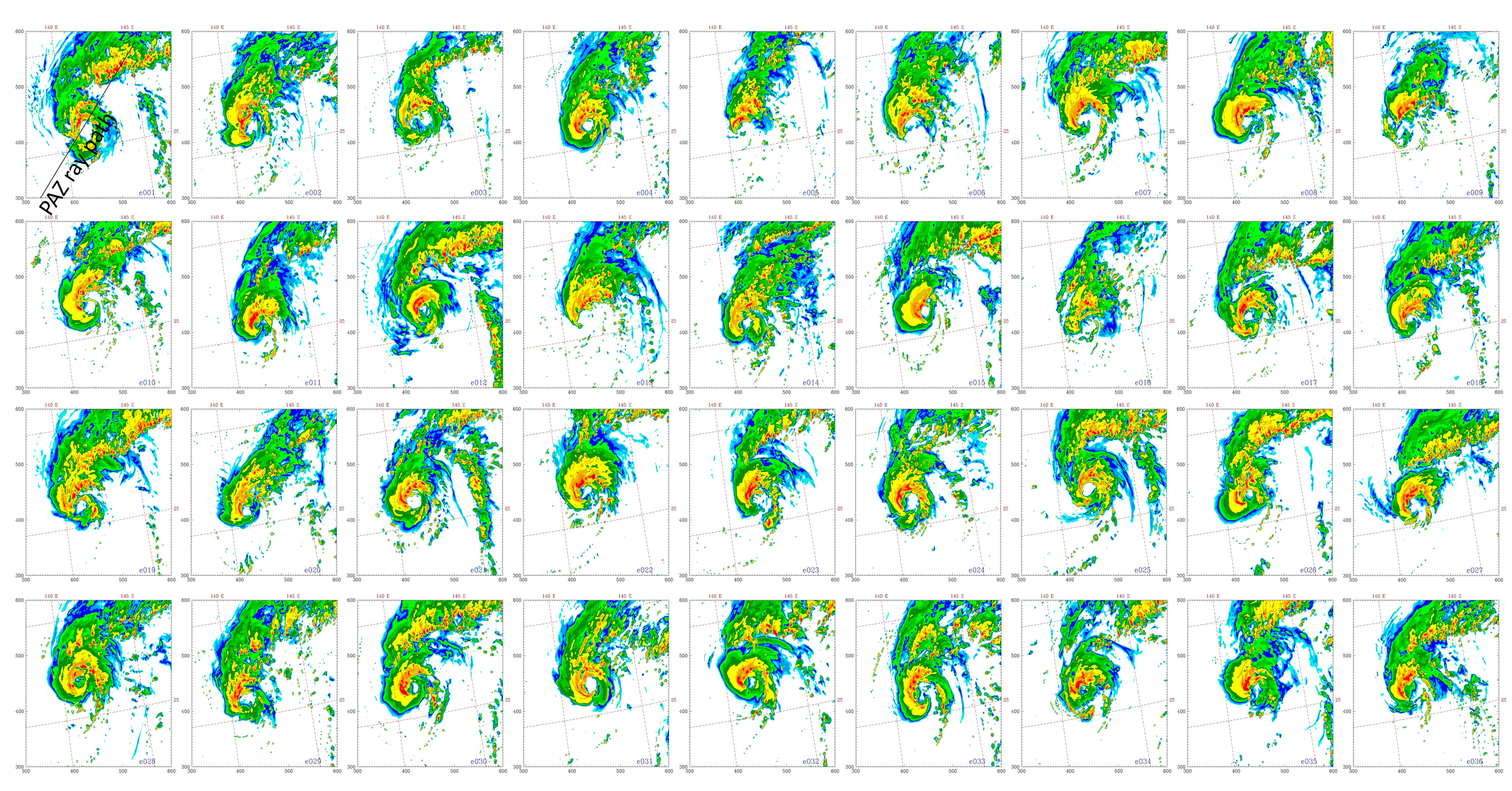
Verification against Polarimetric RO

Simulated $\Delta\Phi_{dp}$ and PAZ $\Delta\Phi_{dp}$ for TY Bualoi

Simulations are adjusted for TC best track and then spatiotemporally interpolated along the PAZ ray path and time.



Simulated radar reflectivity for 36 ensemble members



PRO forward operator

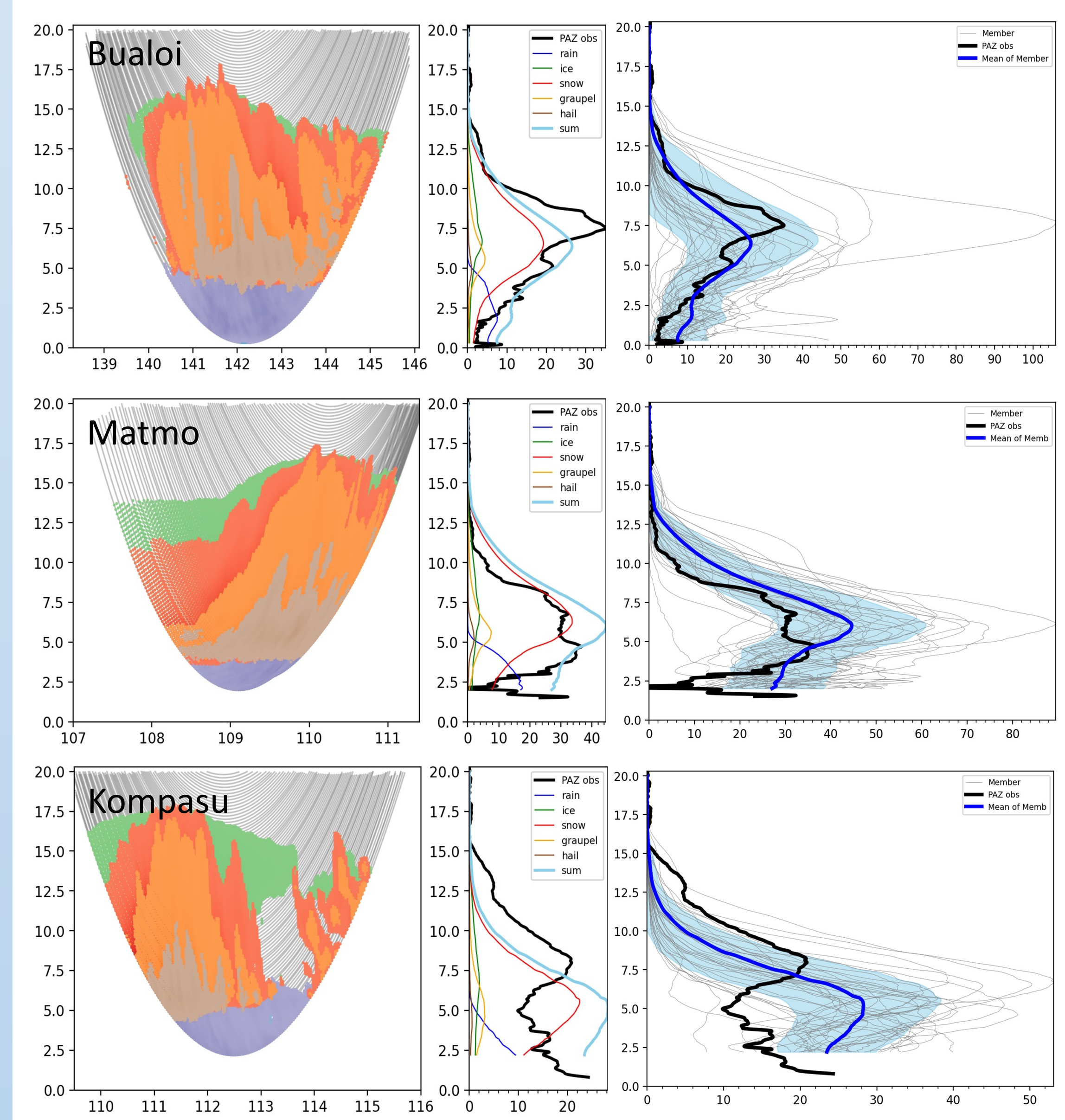
$$\Delta\Phi_{dp} = \Phi_H - \Phi_V = \int K_{dp}\, dL$$

$$K_{dp}(WC) = ½\, C\rho \times WC \times (1 - ar)$$

$\Delta\Phi_{dp}$: Differential phase shift
K_{dp} : the specific differential phase
WC (water content): rain, cloud, ice, snow, graupel, hail from WRF model
C : Rayleigh scattering at L-band
ρ : particle density (g cm^{-3})
ar : axis ratio of the hydrometeor

Each WRF hydrometeor variable is interpolated along the PAZ ray path.

Ensemble Mean



Left : Distribution of simulated hydrometeors along the PAZ ray path.
Middle : Simulated $\Delta\Phi_{dp}$ and PAZ $\Delta\Phi_{dp}$
Right : differential phase shift for each member, and light blue shadow described the range for one standard deviation.

Conclusion

- The results show large variability in the distribution of the model's hydrometeors, which could be influenced by factors such as initial conditions, microphysics parameterization, typhoon location, and the diversity of cloud fields in ensemble forecasts.
- PRO data can potentially be used to evaluate the performance of different microphysics schemes for typhoon cases.
- Generally, PRO observations provide an opportunity to assess the performance of model microphysics schemes.