Sensitivity of Doppler Radar and AWS Data Assimilation in WRF Microphysics Schemes

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Introduction

Weather radar detects 3-D distribution and intensity of precipitation and its motion that can be used as NWP model's initial condition or verification data at high spatio-temporal scales. For these reasons radar data assimilation has been conducted for the last 20 years. Most of these studies focus on simulated precipitation at the surface using microphysics schemes developed for U.S. continental precipitation, and there are not many studies for East Asian summer Monsoon where the cloud microphysical process can differ significantly (Min et al, 2015).

Hence, this study tests 6 different microphysics schemes in WRF with radar data assimilation in Korea during summer convective season. Sensitivity of radar data assimilation with respect to different microphysics schemes are shown and each scheme is evaluated with AWS observed precipitation and radar data.

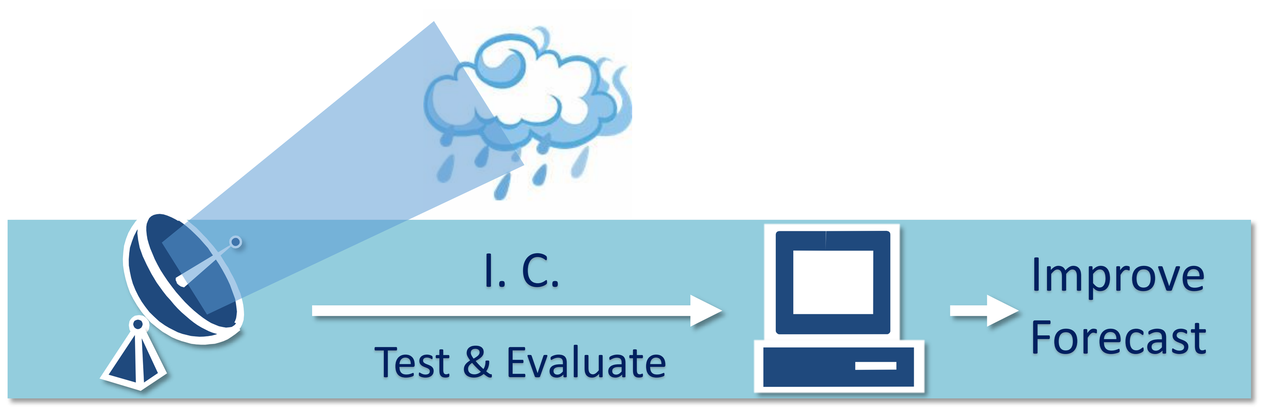


Fig. 1 Schematic diagram depicting the use of radar data in NWP model.

Data and Method

❖Radar data assimilation in WRFDA

Radar reflectivity and radial velocity is assimilated. Radar reflectivity is converted to hydrometeor mixing ratio based on model temperature using Z-q relation (Gao et al., 2012) and saturated humidity is assumed where observed reflectivity exceeds certain thresholds (30 dBZ) (Wang et al., 2013).

❖Model configuration

	D01(27km)	D02(9km)	D03(3km)
Cumulus	Kain-Fritsch scheme		
Microphysics	WSM6, WDM6, Thompson, Morrison, Milbrandt-Yau, NSSL		
PBL	YSU scheme		
Radiation	RRTM scheme / Dudhia scheme		
SFC/Land	MM5 similarity / Noah LSM		
I.C & B.C	NCEP Final Reanalysis (FNL)		

Table. 1. Used physics parameterization schemes

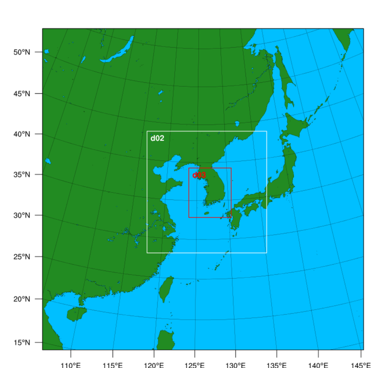


Fig. 2 WRF domain (27-9-3km) configuration

❖Data

Reflectivity and radial velocity of KMA S-band Doppler radar (GDK, KWK, KSN, JNI, GSN, SSP, PSN, GNG) are used. All of the data is quality controlled using KNU fuzzy logic algorithm (Ye, 2013) and thinned to model grid resolution (3km) with radar preprocessing system developed at KNU.

❖Case & experiment setup

From 1800UTC 12-08-2011 to 0900UTC 13-08, convective band developed in the warm sector of surface low. This system produced 40mm/hr precipitation over the western coast of Korea.

Hourly 3D-Var update cycles during 3 hour assimilation period were carried out for 6 microphysics schemes.

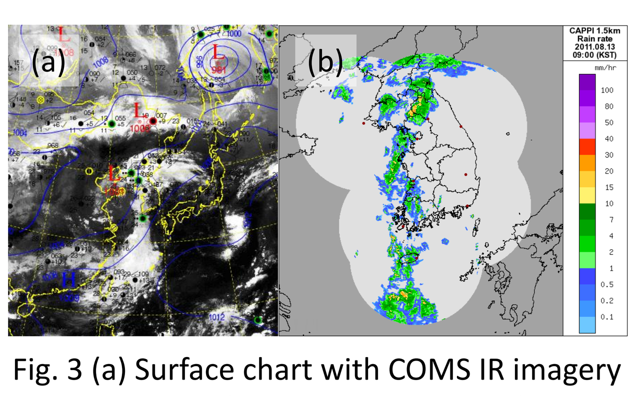


Fig. 3 (a) Surface chart with COMS IR imagery and (b) radar reflectivity composite of KMA radar network on 00UTC 13-08-2011.

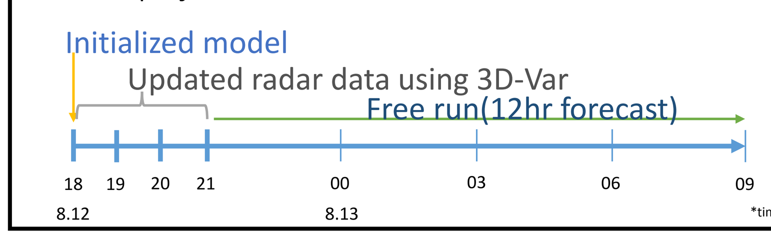


Fig. 4 Data assimilation and model experiment setup.

Results

All of the CTRL runs with 6 microphysics schemes failed to capture heavy precipitation on the western coast of Korea. Furthermore, CTRLs produced inland precipitation that was not observed by AWS. DA runs predicted main precipitation band near the coastline well. In addition, inland precipitation was suppressed in DA experiments. Particularly, Thompson scheme under-predicted rain band west of Seoul and NSSL scheme had much broader precipitation than observation.

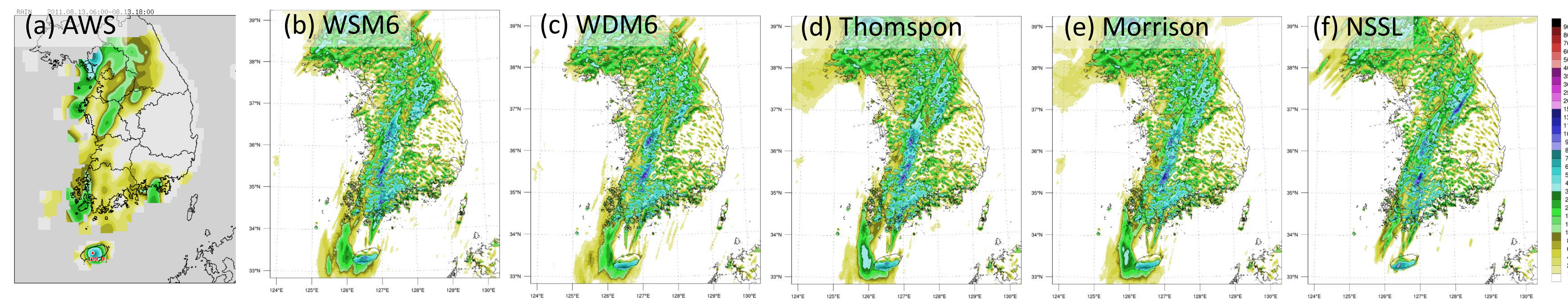


Fig. 5 12-hr accumulated precipitation from (a) KMA AWS network, (b)-(f) CTRL runs of each microphysics scheme.

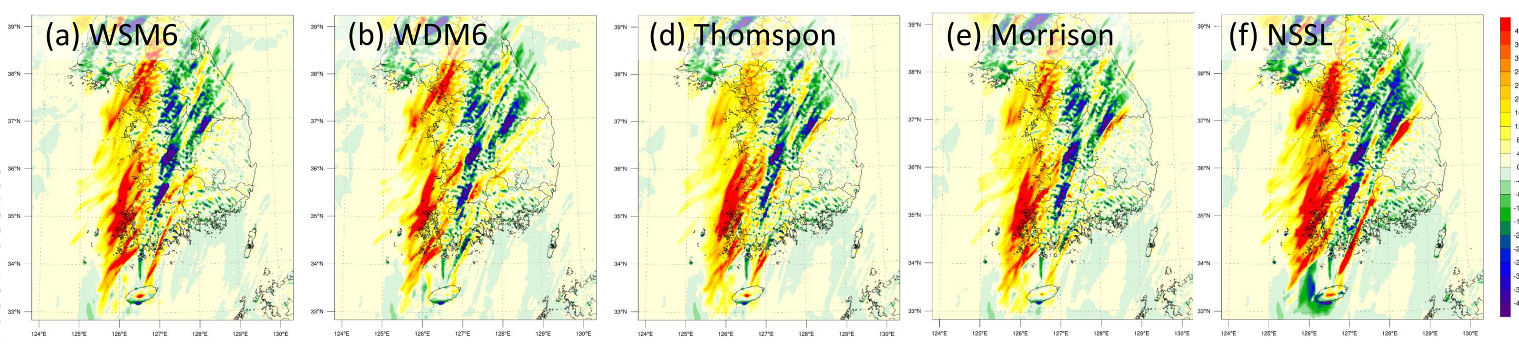
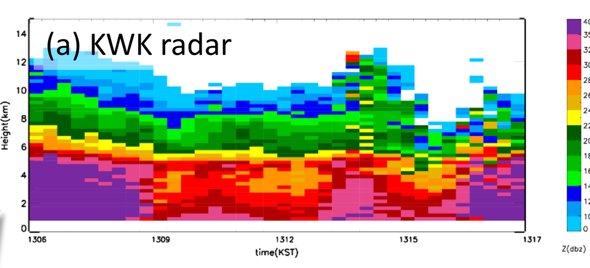
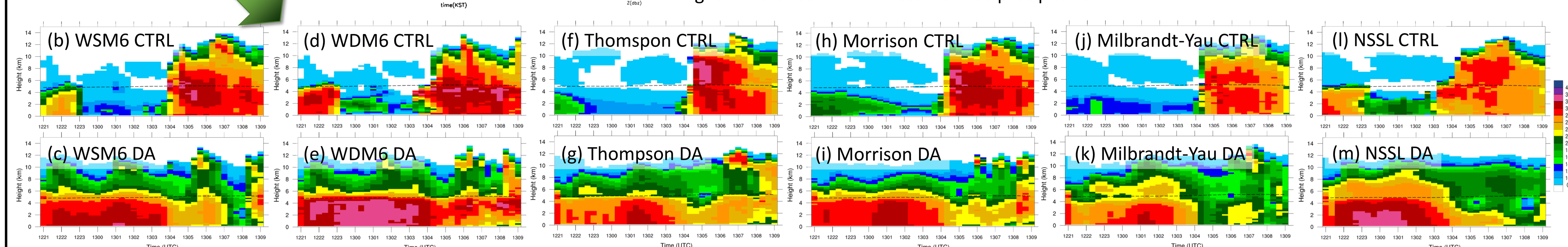


Fig. 6 Difference in 12-hr accumulated precipitation with DA-CTRL.

Fig. 7 Time height cross section from (a) KWK radar site, (b)-(m) CTRL and DA of each microphysics scheme.





In the time-height cross sections within 100km radius of KWK radar site, precipitation lasted for entire forecast period with strong echoes beneath the melting layer at 5km AGL with moderate echoes above the melting layer. Smaller reflectivity was simulated in all of CTRL runs during the first 6 hours due to model spin-up. Afterwards, heavy convective cells (>35 dBZ) were simulated in the CTRL runs. In 3D-Var DA experiments, initial precipitation was generated and over-predicted precipitation after 6hours was alleviated. Strong reflectivity was simulated in Milbrandt-Yau and NSSL schemes below the melting level. Overall, the intensity and phase of convective precipitation was best captured by WDM6 scheme.

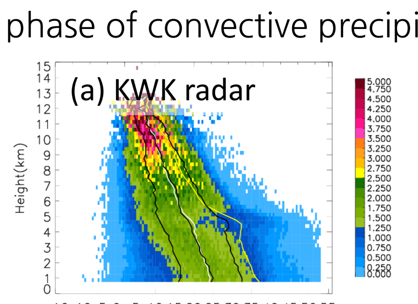
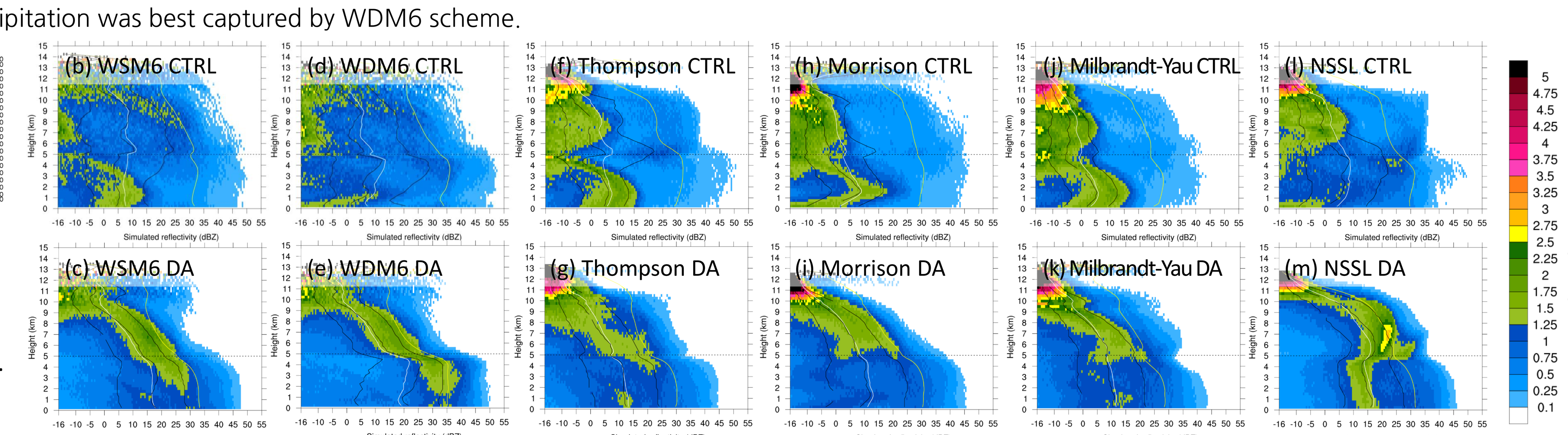


Fig. 8 CFAD from (a) KWK radar site, (b)-(m) CTRL, and DA simulations for each microphysics scheme.



From the CFAD of KWK radar site, hydrometeor grows over the entire depth. However, disorganized structures are shown in CTRL runs. Small drops prevail under the melting level in part by failing to produce initial convection. In DA experiments, growth of solid precipitation was captured in all schemes. However, growth below the melting level is not seen in Thompson, Morrison, and Milbrandt-Yau schemes. WSM6, WDM6, and NSSL continue to grow below the 0℃ level. NSSL scheme shows strong reflectivity core above 5km but rapid decrease in reflectivity through the melting level.

Difference in profile show an increase in ice & snow in WSM6 and WDM6 DA runs. For all the schemes, water vapor mixing ratio increased only above 3km after radar data assimilation. FSS is improved for all schemes in DA experiments indicating positive results with radar DA. However, FAR and BIAS reveals over-prediction of precipitation compared to AWS observation.

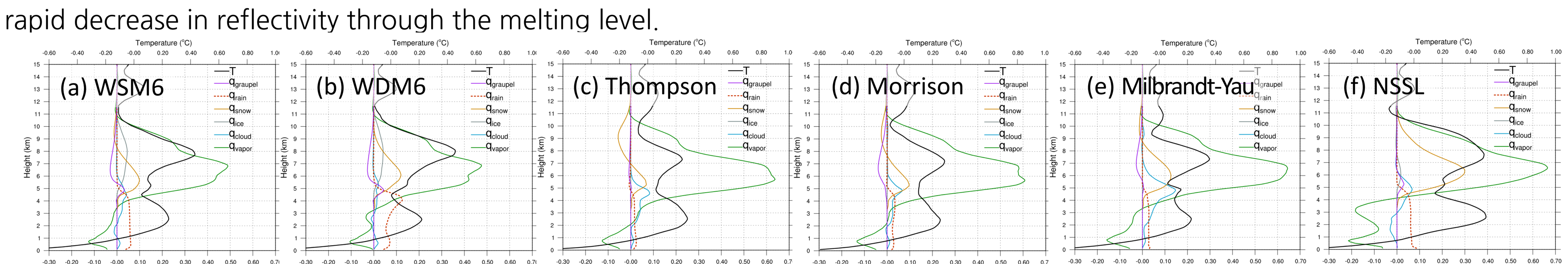


Fig. 9 Difference of mean profile (DA-CTRL) for KWK.

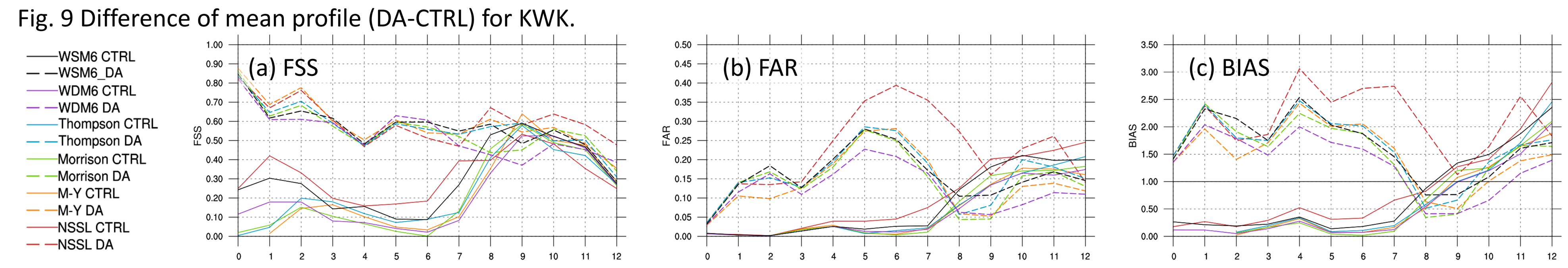


Fig. 10 (a) Fractional skill score (FSS), (b) false alarm rate (FAR), and (c) bias.

Summary & Conclusion

- Sensitivity experiments of assimilating KMA S-band Doppler radar (radial velocity, reflectivity) with 6 different microphysics schemes using WRFDA 3.7 (new hydrometeor classification and modified RH assimilation) have been evaluated.
- Radar DA improves precipitation forecasts during the model spin-up time and produce precipitation approaching the western coast of the Korean Peninsula.
- THCS shows higher reflectivity below the melting level improving the overall precipitation forecast. The enhancement is most noticeable in WDM6 scheme. All CMP schemes have negative biases in CTRL run - tendency to simulate reflectivity much smaller than radar below 5 km due to CMP schemes inability to simulate large raindrops (qrain) However, there is a positive bias when radar DA is utilized.
- Comparison of vertical profiles show increase in q_v at mid-levels but reduced q_v and increased temperature in lower-levels between DA-CTRL experiments. In particular, there exist greater bias at low levels where radar data do not exist.

	FSS	FAR	BIAS
WSM6	0.304/0.565	0.080/0.158	0.752/1.651
WDM6	0.222/0.534	0.061/0.124	0.560/1.329
Thompson	0.228/0.570	0.078/0.159	0.723/1.652
Morrison	0.216/0.555	0.077/0.144	0.683/1.546
Milbrandt-Yau	0.239/0.591	0.074/0.139	0.656/1.504
NSSL	0.317/0.604	0.095/0.221	0.848/2.116

Table. 2. Mean scores for 12hour forecast (CTRL/DA)

Acknowledgement

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