Investigation of 2007 Summer Extreme Precipitation Events Using an Integration of Observations and WRF Simulations

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Objectives

- To evaluate WRF and NAM performance on three precipitation cases in Oklahoma (OK) during summer 2007 using the NARR and OK Mesonet precipitation data.
- To validate the WRF classified convective and stratiform precipitation using the NEXRAD and OK Mesonet observations.

Data

The Mesonet rain gauge data are integrated into 3 hourly precipitation which is used as ground truth to validate WRF and NAM simulated 3 hourly precipitation. NARR data are used as WRF forcing and are also included in the comparison.

Model Configurations

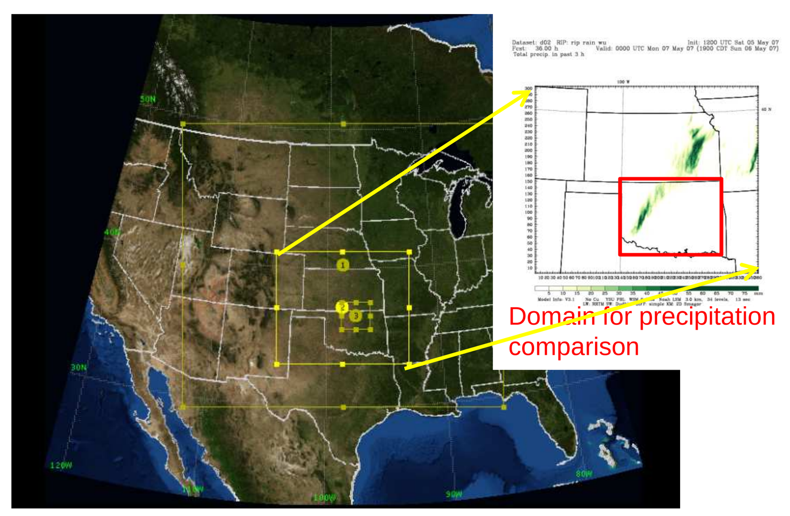

Figure 1. Model integration domain for WRF.

	WRF	NAM
Dynamic core	wrf-arw	wrf-nmm
Domain	3 nested domains from outermost US to innermost OK state	North American
Horizontal resolution (km)	9 km, 3 km, 1 km	12 km
Vertical levels	35	60
PBL parameterization	YSU	MYJ
Microphysics parameterization	WSM6	Ferrier
Cumulus parameterization	KF for the outermost domain, none for the rest	BMJ

Table 1. Model configurations.

Results:

1) May 06-07 (case 1)

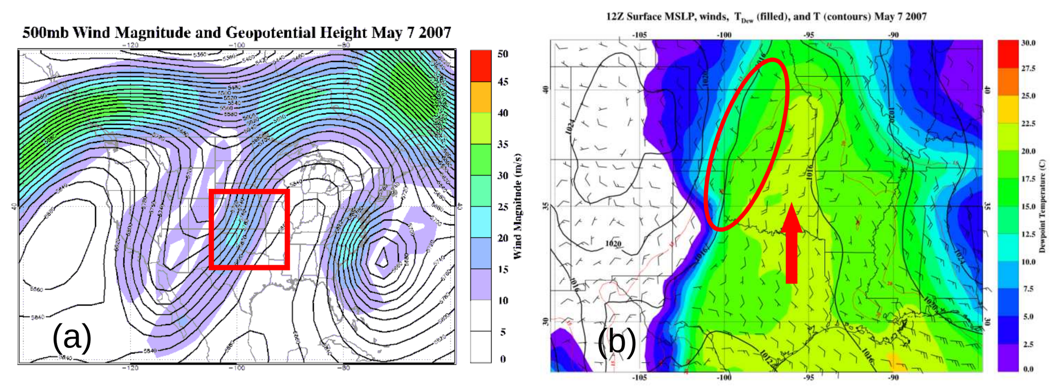

Figure 2. Synoptic Pattern during May 06-07 precipitation event from NARR.

Fig. 2 (a) shows daily averaged geopotential height at 500 mb. A short wave trough was above OK state during May 6-7.
(b) Surface map with temp., dew point temp., MSLP and wind field. A moisture flux is from south to north through OK state. Cold front also affected that area.

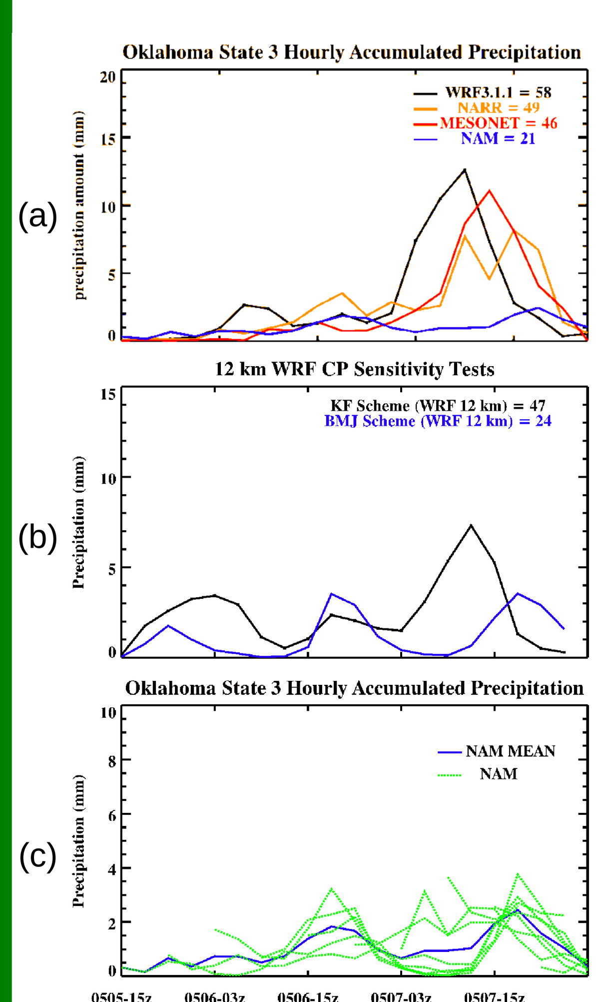

Figure. 3 State mean 3 hourly accumulated precipitation using various data sources.
(a) State mean 3 hourly accumulated precipitation from Mesonet, NARR, WRF (3 km resolution), and NAM (averaged value from different runs).
(b) WRF (12 km) simulations by adopting different cumulus schemes (KF and BMJ). (c) Original NAM with different forecast cycles and the ensemble average.

In fig. 3 (a), Precipitation simulated by WRF started 3 hours earlier than obs. The total precipitation was 12 mm more than obs. NAM is under predicting precipitation by more than 50%.

In the two simulation runs as shown in fig.3b, WRF reduced resolution to 12 km (the same as NAM resolution), and also uses KF and BMJ cumulus parameterization schemes to compare with each other.

The result shows there is similarity between 3 km and 12 km WRF runs with KF scheme, peaked at about the same time even though the value is smaller in the 12 km resolution run.

Also it is quite comparable in 12 km WRF run using BMJ scheme and NAMs, even the two with a lot differences in model configurations.

The results indicate horizontal resolution is not the major factor that causing underpredicting problem. Simulation is more sensitive to cumulus schemes.

Summary of May 06-07 (case 1)

1. Based on observations, the major precipitation event started around 03z on May 7, and lasted until 00z on May 8 and is affected by short wave trough and cold front.
2. From WRF, precipitation reached the peak about 3 hour earlier than the observation and is overpredicting about 26% through the event.
3. Precipitation forecast from NAM missed the peak and significantly underprediting about 50% of the precipitation.
4. Sensitivity study carried out by reducing WRF resolution from 3 km to 12 km with different CP schemes shows horizontal resolution is not the major factor that causing underpredicting problem. Simulation is more sensitive to cumulus schemes.

2) May 24 (case 2)

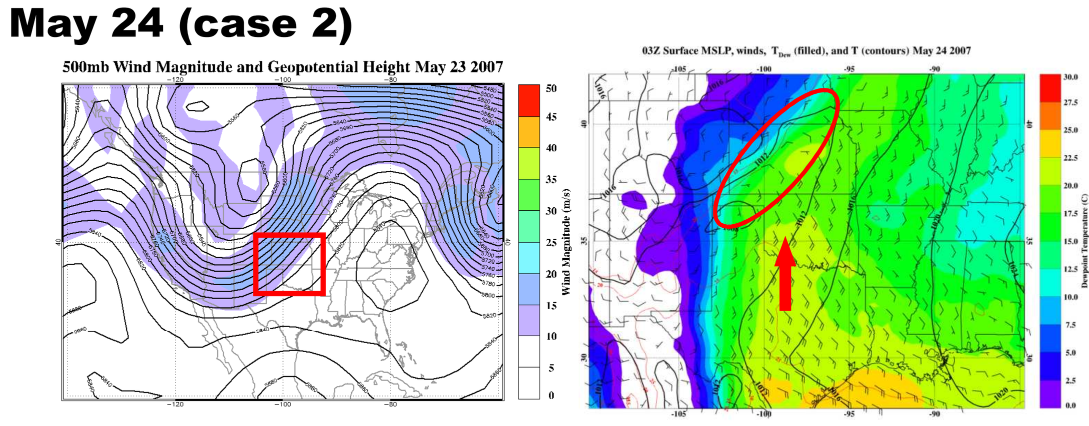

Fig. 4 Synoptic Pattern during May 24-25 precipitation event.
It shows short wave trough, cold Front and moist low level air mass can be contributed to this squall line event.

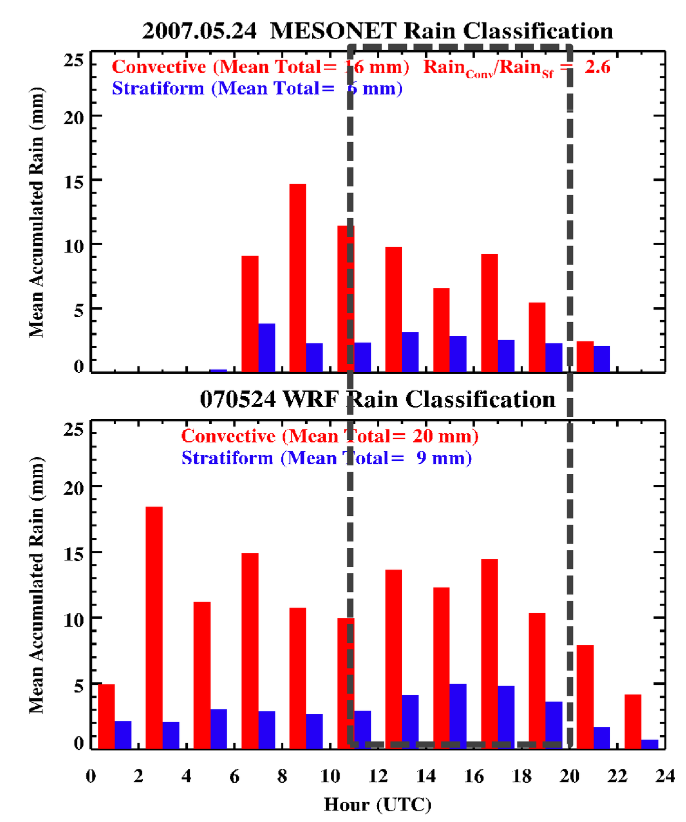

Fig. 5 Precipitation Classification in Mesonet and WRF.

1. The box indicates the same spatial domain covered by both NEXRAD and WRF over OK state.
2. Both obs. and WRF have shown that convective precip. is dominant although their total precip. and trend are slightly different.

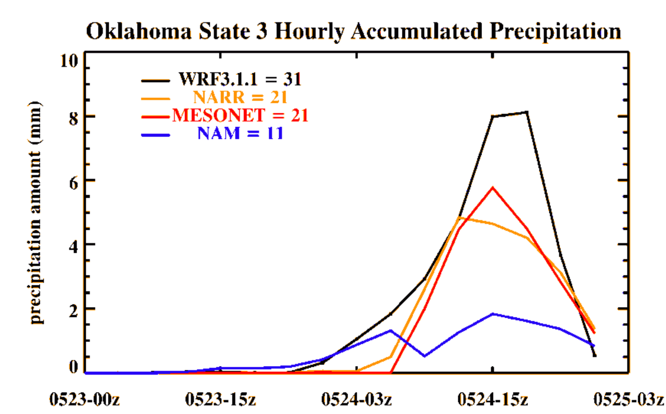

Fig. 6 3 hourly state mean precipitation from May 23 to 25.
WRF is over predicted the total precipitation in this case. On the other hand, NAM is under predicting the precipitation amount.

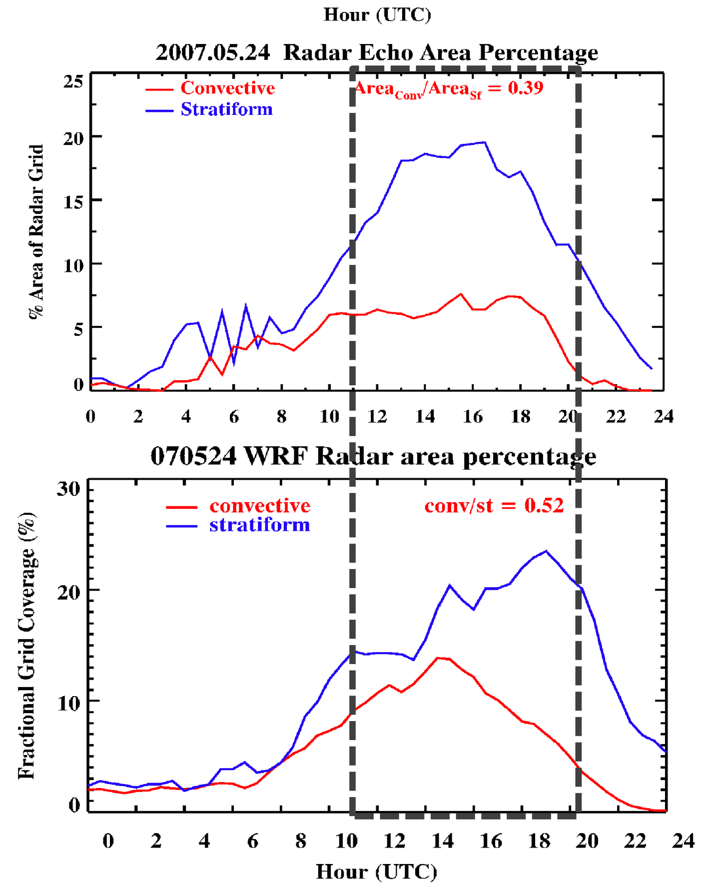

Fig. 7 Classified radar reflectivity for convective and stratiform area coverage.
1. Stratiform region is greater than convective region in both model and observation.
2. In WRF simulation, the peak for convective area coverage appears earlier than stratiform area.
3. The stratiform peak in WRF occurs later than observation, however, the amount is almost the same between the two.
4. In WRF, convective coverage is slightly larger than observation. Accordingly, the ratio of convective and stratiform area coverage in WRF is higher than radar.

Summary of May 24 (case 2)

1. Compared to the Observations, WRF over predicted the total precipitation by 50%, and NAM under predicted the total precipitation by 50%
2. Both NEXRAD and WRF simulations have shown that convective precipitation is dominant, while the Stratiform precipitation covers much larger area than convective precipitation.
3. WRF did a good job in capturing the squall line in both Cases 1 and 2.

3) June 14 (case 3)

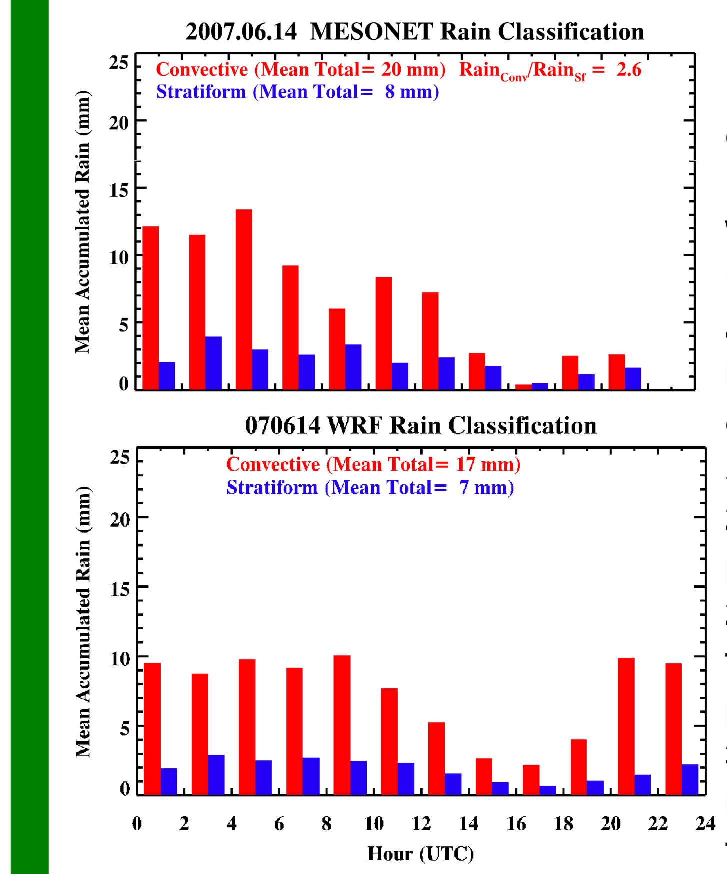

Fig. 8 Precipitation Classification in Mesonet and WRF.
1. Good agreement between observation and simulations.
2. Convective precipitation is 2.5 times more than stratiform precipitation.
3. WRF produced more convection from 20z to 24z.

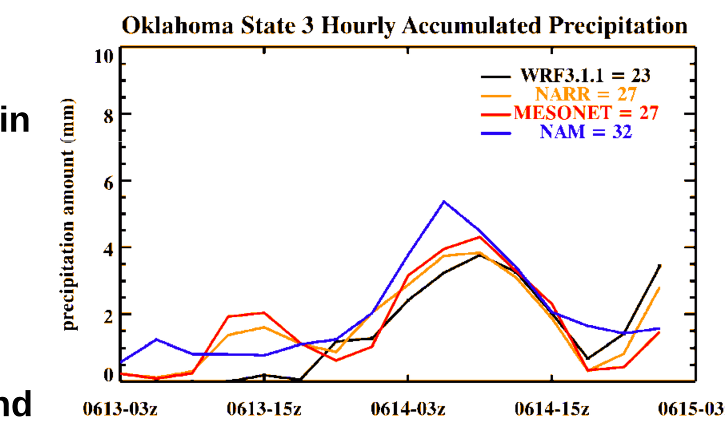

Fig. 9 3 hourly state mean precipitation. Both NAM and WRF did a good job in producing the right amount of precipitation and capturing the peak.

1. Same as the Case 2, stratiform precipitation covers much larger area than convective precipitation.
2. Close ratio of area coverage between WRF and obs.
3. Stratiform precipitation peaks did not occur at the same time, i.e., WRF has 3 hours delay.

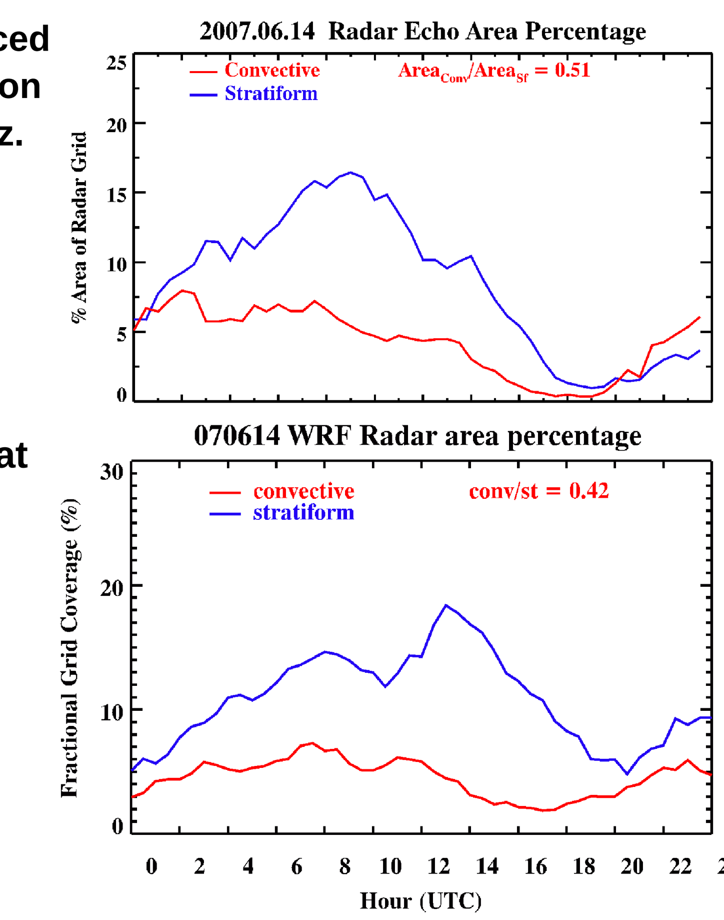

Fig. 10 Classified radar reflectivity for convective and stratiform area fractional coverage.

Summary of June 14 (case 3)

1. The precipitation event is affected by Quasi-linear Mesoscale System.
2. Precipitation forecasts from both WRF and NAM are correlated well with observations.
3. After applying classification scheme, WRF shows very similar result in both rain classification and Radar reflectivity area coverage with observation.

Conclusion

1. Compared to NARR and OK Mesonet observed precipitation, WRF overestimates and NAM underestimates precipitation in the Cases 1 and 2, but agree well in the Case 3.
2. Both observation and WRF have shown that Convective precipitation dominates, but Stratiform precipitation covers much larger area than convective precipitation.
3. As showed in case 1 sensitivity study, horizontal resolution is not the major factor that causing underpredicting problem. Simulation is more sensitive to different cumulus schemes.

Future Work

1. Develop schemes that make comparison between model simulation and observation more objective.
2. Expand the sensitivity study to more cases to investigate how 12 km WRF respond to different CP schemes.
3. More sensitivity studies should be conducted to see whether classified precipitation and area coverage are sensitive to different CP or MP schemes.

Acknowledgements

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