The Role Of Physical Scheme Interactions In Design Of a Mixed-Physics Ensemble For Warm Season MCS Rainfall Forecasting

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INTRODUCTION

• Mesoscale Convective Systems (MCSs) are the major source of warm season precipitation for the mainly agricultural central US.

• Despite numerous efforts that have been undertaken to improve the warm season MCS rainfall forecasts it remains the most poorly forecasted meteorological variable.

• The errors in simulated precipitations arise as a result of errors in both initial conditions and numerical models itself (in particular due to use of multiple parameterizations-physical schemes for sub-grid processes).

OBJECTIVES

- To investigate the impact that different physical schemes as well as their interactions have on simulated rainfall.

- To investigate if and how these impacts change when different initial conditions are used.

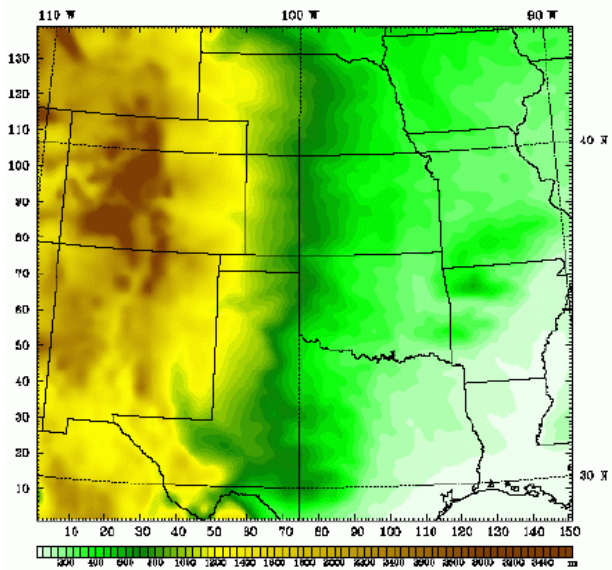
- To apply the obtained knowledge in a design of a mixed-physics ensemble for rainfall forecasts.

DATA AND METHODOLOGY

• Simulations of 8 International H_2O Project (IHOP) MCS events were performed by using 12 km Weather Research and Forecasting (WRF) model with ARW dynamic core.

• Both diabatic Local Analysis and Prediction System (LAPS) 'hot' start and 40km Eta analyses were used as initial conditions, while the boundary conditions were always from 40 km Eta output.

• The integrations were performed over the 24 hour period and over a limited domain of approximately 1500x1500 km.



3 DIFFERENT CONVECTION TREATMENTS :

- Betts-Miller-Janjic (**BMJ**)
- Kain-Fritsch (KF)
- and the use of no convective scheme (**NC**)

3 DIFFERENT MICROPHYSICS :

- Lin et al. (**MPL**)
- NCEP 5-class (MPN)
- Ferrier (**MPF**)

2 DIFFERENT PBL SCHEMES :

- MRF
- **ETA** (Mellor-Yamada-Janjic)

2 DIFFERENT INITIAL CONDITIONS:

- LAPS
- 40 km NCEP Eta model GRIB data

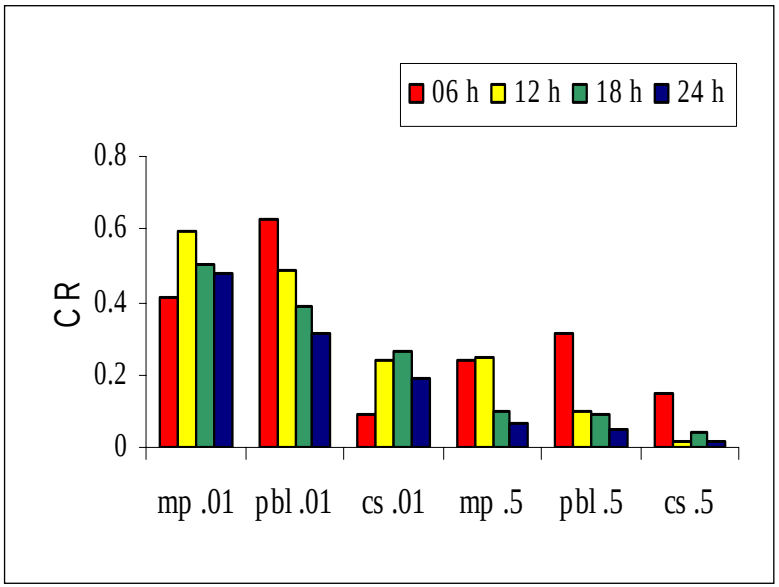
CONTROL RUN: KF-MRF-MPN

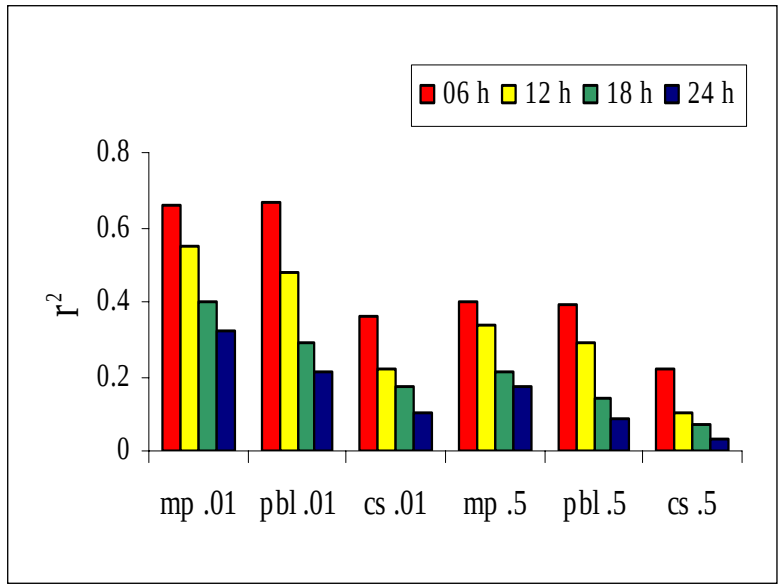
• As a measure of the sensitivity (mainly related to the precipitations spatial distributions) to the physics changes

• Correspondence Ratio (CR=I/U) and
• Squared Correlation Coefficient (r^2)

were calculated (smaller ratios indicate larger sensitivity).

The same trends were present for model runs initialized with different analyses





FACTOR SEPARATION METHOD (FSM)

• In order to quantify the impact of varying two different model physical schemes and their interaction on the simulated rainfall field, the factor separation methodology was used.

$$f_{12}-f_0=(f_1-f_0)+(f_2-f_0)+f_{12}^*$$

Factor separation methodology (FSM) was applied on both:

- System average rain rate
- Domain total rain volume

FSM individual change results
(all results tested for statistical significance)

RAIN RATE

- *For both 0.01 in. and 0.5 in. thresholds, the largest impact on system average rain rate for both initializations was due to changes in convective treatment* (KF to NC +).

RAIN VOLUME

- *The largest impact on domain total rain volume for runs initialized with LAPS analyses was due to changes in microphysics* (MPN to both MPL and MPF +), *while for runs initialized with Eta analyses it was due to changes in convective treatment* (KF to BMJ -).

Synergistic effects

- For runs initialized with LAPS analyses synergistic terms were often large but not statistically significant.

- The only statistically significant synergistic terms were negative and related to the interactions between **ETA** and **MPL** and **MPF**.

- Similarly interactions between **BMJ-MPL** and **MPF** resulted in large and negative syn. terms.

The same trends in synergistic interactions were present for runs initialized with Eta, except the syn. terms for runs initialized with Eta were more pronounced (statistically significant).

ENSEMBLES

Obtained information about the impacts of different schemes on simulated rainfall were used in design of 4 different ensembles for rainfall predictions.

1. 18-member ensemble (all physical configurations included)
2. 9-member ensemble (3 CS, **ETA** PBL, and 3 MP)
3. 6-member ensemble (3 CS, 2 PBL, and **MPF**)
4. 6-member ensemble (**BMJ**, 2 PBL, and 3 MP)

Threshold (in.)	Ensemble type	Area under ROC curve			
		00-06h	06-12h	12-18h	18-24 h
	Runs initialized with Eta analysis				
0.01	18_full	0.802	0.721	0.691	0.720
	9_cu_**ETA**_mp	0.805	0.752	0.708	0.712
	6_cu_pbl_**MPF**	0.791	0.731	0.682	0.684
	6_**BMJ**_pbl_mp	0.775	0.685	0.700	0.662
0.25	18_full	0.662	0.596	0.600	0.706
	9_cu_**ETA**_mp	0.674	0.643	0.641	0.704
	6_cu_pbl_**MPF**	0.652	0.606	0.607	0.661
	6_**BMJ**_pbl_mp	0.640	0.546	0.590	0.624
	Runs initialized with LAPS analysis				
0.01	18_full	0.871	0.743	0.649	0.634
	9_cu_**ETA**_mp	0.882	0.835	0.743	0.719
	6_cu_pbl_**MPF**	0.851	0.797	0.711	0.703
	6_**BMJ**_pbl_mp	0.862	0.802	0.703	0.701
0.25	18_full	0.664	0.635	0.582	0.582
	9_cu_**ETA**_mp	0.674	0.694	0.619	0.602
	6_cu_pbl_**MPF**	0.644	0.638	0.591	0.600
	6_**BMJ**_pbl_mp	0.637	0.605	0.552	0.558

Values > 0.5 potential for skillful forecast
Values around 0.7 useful forecast.

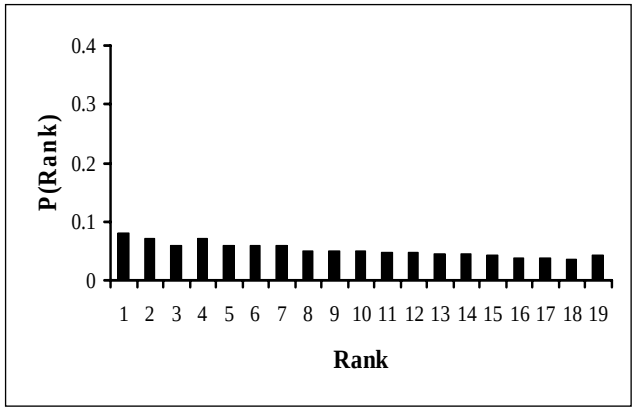
In addition…….

Areas under ROC curves were computed for runs combining various physical schemes and different initial conditions.

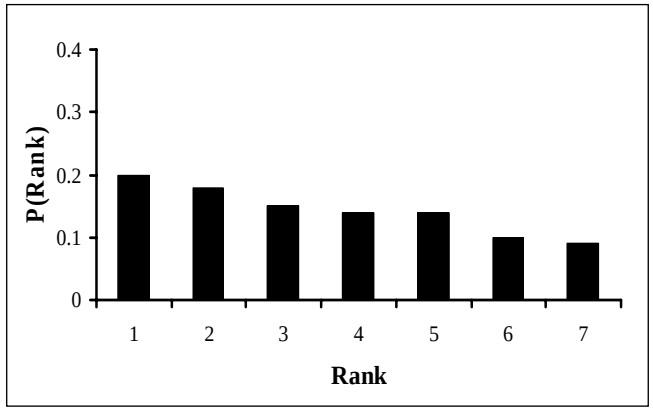
** The largest values were detected for ensembles which combined runs initialized with Eta analyses using different convective treatments and runs initialized with LAPS analyses using different microphysics.

** These scores were still lower than those presented for 9-member ensemble.

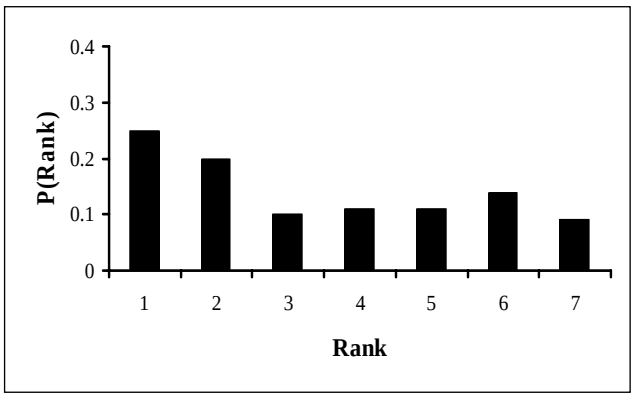
00-06h



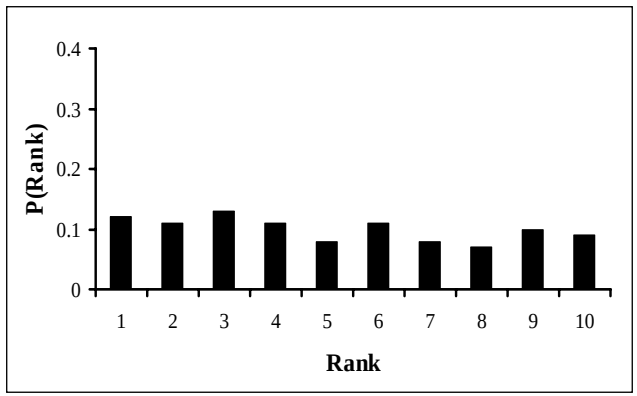
18-member



6-member-MPF

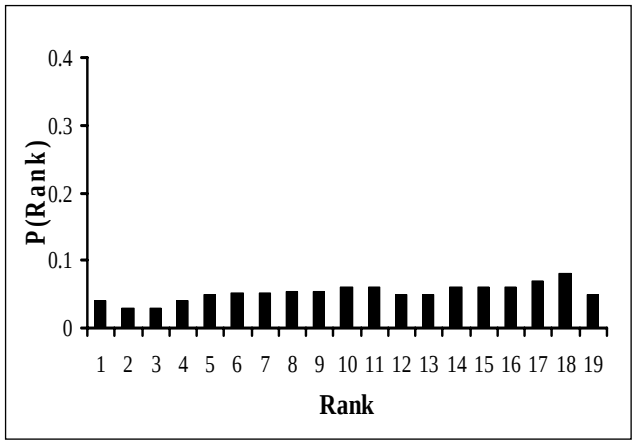


6-member-BMJ

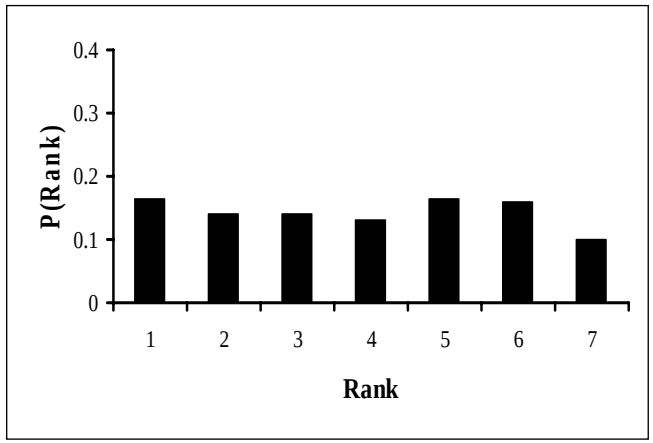


9-member

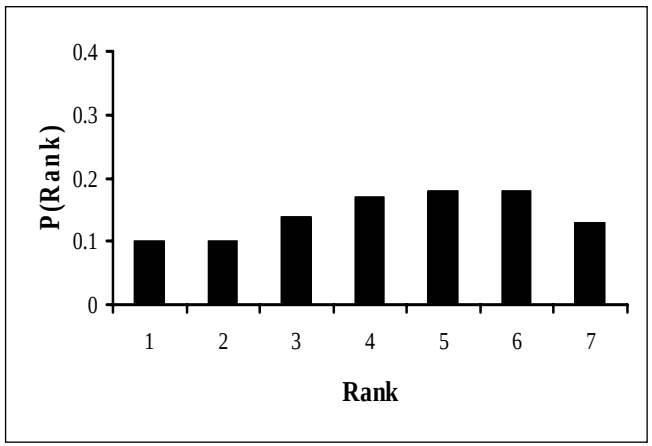
12-18h



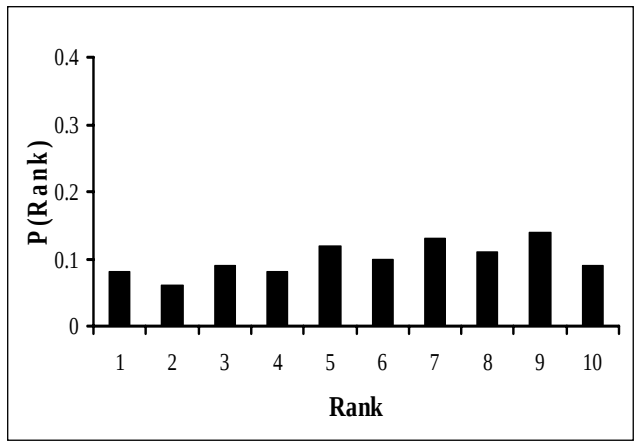
18-member



6-member-MPF



6-member-BMJ



9-member

SUMMARY

- Changes in physical schemes impact simulated rain rate and rain volume differently for runs initialized with different analyses.

- Synergistic terms analyses reveal that interactions between specific physical schemes are important no matter what initial conditions are used.

- Knowledge about impact that different physical schemes have on simulated rain can be successfully used in design of mixed-physics ensembles for warm season QPF forecasts.

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