P2.19 AN INVESTIGATION OF IHOP CONVECTIVE SYSTEM PREDICTABILITY USING A MATRIX OF 19 WRF MEMBERS

Isidora Jankov*, William A. Gallus, Jr.*, Brent Shaw#, and Steven E. Koch#
*Iowa State University, Ames, Iowa
#NOAA Research – Forecast Systems Laboratory, Boulder, Colorado

1. INTRODUCTION

A matrix of 19 WRF (Weather Research and Forecasting model) members was created using different combinations of physical schemes and run for eight IHOP (International H_2O Project) convective cases. Cases were purposely selected to have significant rainfall observed and/or forecasted in the IHOP domain over the central United States. For each case, three different treatments of convection were used: the Kain-Fritsch (KF) scheme (Kain and Fritsch 1992), the Betts-Miller-Janjic (BMJ) scheme (Betts 1986, Betts and Miller, 1986, Janjic 1994), and the use of no convective parameterization. For each of these three choices, three different microphysical schemes were used, Lin et al. (1983), NCEP-5 class, and Ferrier (Ferrier et al., 2002). Within these nine configurations, two different planetary boundary layer schemes were used, MRF (Troen and Mahrt, 1986) and Eta (Janjic 1994). This 18-member matrix was supplemented with one additional member using the thermal diffusion surface physics scheme instead of the OSU scheme used for the full 18-member matrix. The 'control' run used the KF convective scheme, MRF PBL and NCEP class-5 microphysics.

2. RESULTS

Subjective analysis of rainfall forecasts indicates that the greatest variability in the forecasts comes from changes in the choice of convective scheme, although noticeable impacts also occur from changes in the microphysics or PBL scheme. The Eta PBL scheme seems to be moister and slightly cooler than the MRF scheme, which impacts convective system development. The Lin et al. microphysics typically results in the most rainfall, and the NCEP-5 class produces the least. The surface physics scheme has limited impacts on the forecast.

Calculated Equitable Threat Scores (ETS) for all model versions and for the first six hours (Table 1) indicate relatively well-predicted light precipitation; while for heavier thresholds there is almost no skill. Three out of eight cases exhibit relatively high predictability for all thresholds, and two cases exhibit very low predictability.

Threshold (in.)	**.01**	**.25**	**.50**	**1.0**
June 19, 12Z	.353	.212	.150	.068
June 13, 00Z	.251	.275	.236	.157
June 15, 06Z	.090	.023	.004	.000
June 04, 00Z	.332	.210	.134	.078
May 23, 12Z	.176	.026	.000	.000
May 24, 18Z	.209	.074	.039	.003
June 02, 12Z	.407	.145	.000	.000
May 16, 06Z	.355	.024	-.003	.000

Table 1. ETS values for all cases for the 00-06 h forecast period, with relatively good forecasts in red and relatively bad forecasts in green.

The same analysis but for the 12-18 hour forecast period indicates generally lower scores, as might be expected, and once again, higher scores for the lighter amounts (Table 2).

Threshold (in.)	**.01**	**.25**	**.50**	**1.0**
June19, 12Z	.171	.171	.147	.074
June 13, 00Z	.188	.068	.031	.000
June 15, 06Z	.184	.274	.259	.060
June 04, 00Z	.203	.143	.152	.056
May 23, 12Z	.328	.105	-.001	-.002
May 24, 18Z	.273	.151	.040	.000
June 02, 12Z	.007	-.002	-.001	.000
May 16, 06Z	.028	.009	-.001	.000

Table 2. As in Table 1 except for the 12-18 h forecast period.

Bias analyses (not shown) indicate that for light amounts, both convective schemes have substantially high biases during the early hours of the forecast. The worst overestimate occurs in the 06-12 h period. For heavier thresholds, it is hard to find a trend in Bias.

In addition, an analysis of ETS and Bias (not shown) indicates that there is no model configuration that stands out as best. The best configuration varies both with time and thresholds. For example, for the first six-hour period (00-06 h), the non-convective run with the ETA PBL and Lin et al. microphysics earns the highest ETSs for amounts lower than 0.5 inches, while for the heavier thresholds, the run with the KF scheme, ETA PBL and Ferrier microphysics (MP5) has the highest ETS (Table 3).

Corresponding author address: Isidora Jankov, ISU, Agronomy Hall 3010, Ames, IA. Email: ijankov@iastate.edu.

Threshold (in.)	.01	.10	.50	1.0
BMJETAMP2	.246	.167	.100	.053
BMJETAMP4	.249	.182	.070	.026
BMJETAMP5	.249	.177	.079	.029
BMJMRFMP2	.249	.179	.099	.054
BMJMRFMP4	.249	.178	.100	.046
BMJMRFMP5	.252	.180	.074	.038
KFETAMP2	.235	.187	.077	.055
KFETAMP4	.242	.201	.066	.033
KFETAMP5	.272	.205	.090	.063
KFMRFMP2	.255	.196	.073	.059
KFMRFMP4	.265	.211	.067	.041
KFMRFMP5	.276	.206	.075	.038
NCETAMP2	.349	.247	.086	.044
NCETAMP4	.327	.215	.048	.022
NCETAMP5	.298	.203	.055	.041
NCMRFMP2	.308	.201	.066	.039
NCMRFMP4	.304	.191	.057	.029
NCMRFMP5	.311	.208	.057	.032

Table 3. Average ETSs for all cases and different physics combinations for the 00-06 forecast period and different precipitation thresholds. MP2 represents Lin et al. scheme, MP4 NCEP-5 class, and MP5 Ferrier microphysics. Red text indicates best single value.

Later, during the 06-12 h period there is no clear winner (not shown). For the 12-18 h period the non-convective run with the MRF PBL and Lin microphysics has the highest skill for amounts lower than .5 inches (Table 4), but in the 18-24 h period the KF run with the MRF PBL and Lin et al. microphysics has the best score for amounts lower than 1 inch (not shown). In summary, over the four time periods, and for six different rainfall thresholds, the best ETSs by schemes are: Lin (11), NCEP5 (7), Ferrier (5), ETA PBL (13), MRF PBL (10), KF scheme (12), NC (8), and BMJ (4). It should be noted that differences in ETSs are usually small.

Threshold (in.)	.01	.10	.50	1.0
BMJETAMP2	.167	.141	.064	.020
BMJETAMP4	.162	.148	.065	.014
BMJETAMP5	.160	.145	.053	.020
BMJMRFMP2	.176	.148	.065	.022
BMJMRFMP4	.168	.145	.043	.009
BMJMRFMP5	.160	.126	.061	.015
KFETAMP2	.160	.145	.102	.029
KFETAMP4	.168	.157	.089	.018
KFETAMP5	.133	.122	.105	.027
KFMRFMP2	.177	.146	.103	.047
KFMRFMP4	.169	.155	.091	.027
KFMRFMP5	.172	.141	.085	.023
NCETAMP2	.156	.152	.079	.016
NCETAMP4	.156	.152	.079	.016
NCETAMP5	.164	.151	.057	.014
NCMRFMP2	.239	.213	.113	.043
NCMRFMP4	.211	.195	.118	.040
NCMRFMP5	.181	.159	.077	.034

Table 4. As in Table 3 except for 12-18h period.

In order to test the sensitivity to physics changes, standard deviations of ETSs are calculated when two of three model physics schemes are held fixed and the third varied (i.e PBL scheme and CP scheme are constant while microphysics varies). Table 5 shows values of standard deviations for changes in microphysics, PBL schemes, and convective parameterizations at both .01 and .5 inch precipitation thresholds.

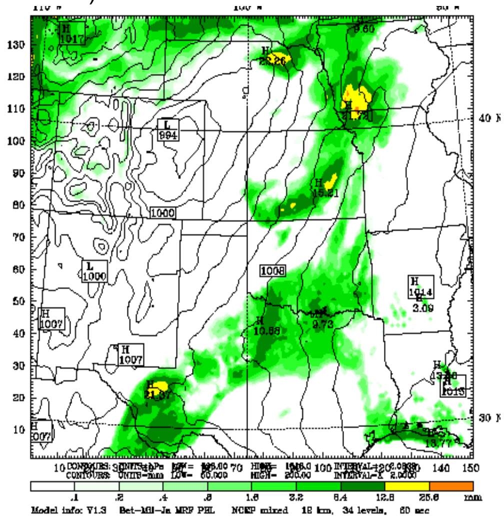
Thr. (in.)	Phys	00-06	06-12	12-18	18-24
.01	**MP**	.008	.008	.009	.008
	PBL	.007	.008	.013	.009
	CP	.031	.024	.014	.008
.50	**MP**	.010	.010	.009	.016
	PBL	.005	.004	.008	.009
	CP	.012	.013	.019	.015

Table 5. Standard deviations in ETS in time for different physics schemes at .01 and .5 inch precipitation thresholds.

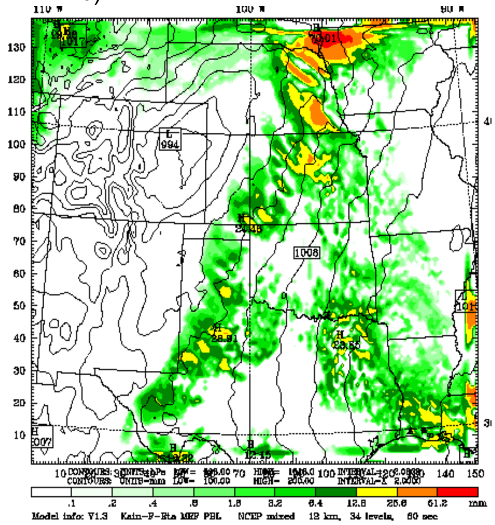
Results presented in Table 5 indicate that the highest sensitivity is to the convective parameterization for forecasts of 18 h or less, and especially for lighter amounts. For light precipitation the sensitivity decreases with time, while the opposite is the case for heavier precipitation. For lighter precipitation thresholds, sensitivities to the PBL and microphysics scheme are comparable, while for the heavier thresholds, sensitivity to microphysics is higher than that of PBL schemes. These results agree well with subjective impressions about the sensitivity to the physics changes.

In addition to the eight IHOP cases, two events from summer 2003 were simulated. Precipitation plots from one of these two runs (June 24, 2003) are used below to illustrate the sensitivity in some cases to the physics changes. Sensitivity to the different convective treatments during the 06-12 h forecast period of the June 24, 2003 case initialized at 18 UTC is illustrated in Figure 1. The high sensitivity to the convective treatment is obvious. Generally, both convective schemes have similar precipitation areas, except in the case of the BMJ run, the amounts are much lighter and less cellular in structure than in the case of KF. All three runs have a problem simulating the correct location of the convective line over central Nebraska. The KF run is slightly better than the BMJ run in simulation of precipitation over northwestern Texas, while the non-convective run completely misses it.

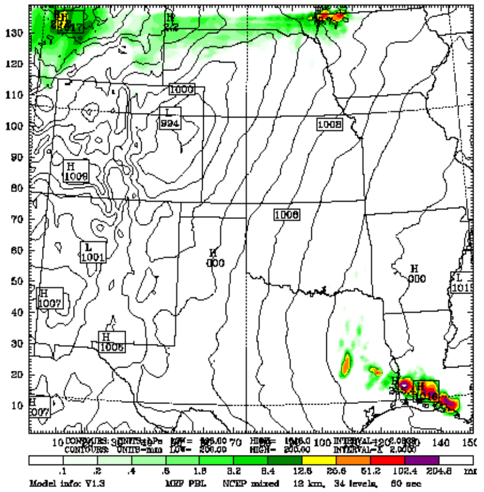
a)



b)



c)



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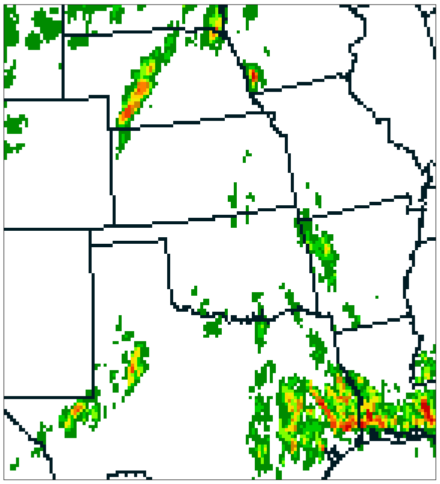

Figure 1. Precipitation for the 06-12 h forecast period for June 24, 1999 initialized at 18 UTC simulated by using a) BMJ convective scheme, b) KF convective scheme, c) no convective scheme and d) Stage IV 6h observation (18-00 UTC).

All runs are relatively good at simulating precipitation over the southeastern corner of the domain, with the non-convective run doing the best job in simulating the amounts.

For this particular case, runs with no convective scheme showed a high sensitivity to the choice of the PBL scheme. For the same forecast period, the run with no convective scheme, MRF PBL and NCEP-5 microphysics is presented in Figure 1c, and the run with the same configuration except the ETA PBL is presented in Figure 2. This comparison confirms a subjective impression that the ETA PBL is moister than the MRF. Similar analyses for non-convective runs with different combinations of PBL schemes and microphysics were performed. Runs with the ETA PBL generally produced wider precipitation areas and also resulted in prediction of the system over southeastern Nebraska, which in the case of the MRF PBL runs, existed only in the configuration using the Ferrier microphysics (not shown). The Ferrier scheme allows grid condensation at a relative humidity less than 100%, unlike the other two schemes, and this difference likely played a role in this case. Also, both MRF and ETA PBL runs produce the heaviest amounts with the Lin et al. microphysics.

In the future, factor separation will be used to examine in more detail the impact of different model physics on the precipitation forecast as well as interaction among those different physics. In order to obtain both qualitative and quantitative impressions about these interactions, the factor separation method will be performed using the skill

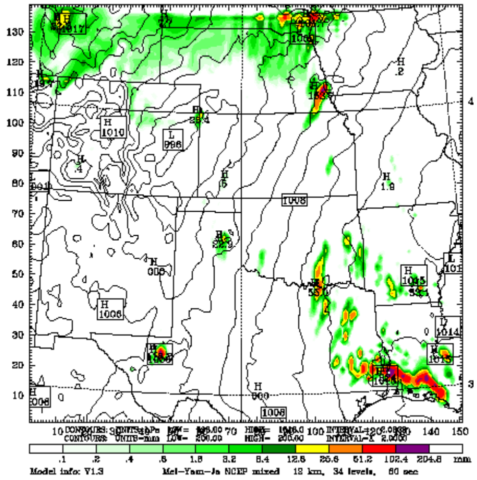

Figure 2. As in Figure 1c except for the ETA PBL scheme.

score (i.e. ETS) and the precipitation amount, respectively.

Finally, to see how well the 19-member matrix works as an ensemble forecast an additional test was performed. Values of areas under discrete ROC (relative operating characteristic) curves (calculated using the trapezoidal method) at different thresholds are presented in Figure 3. A value of 0.5 or less for a probabilistic forecast indicates a forecast without skill. Figure 3 indicates relatively high values but just for lighter amounts and earlier forecast times.

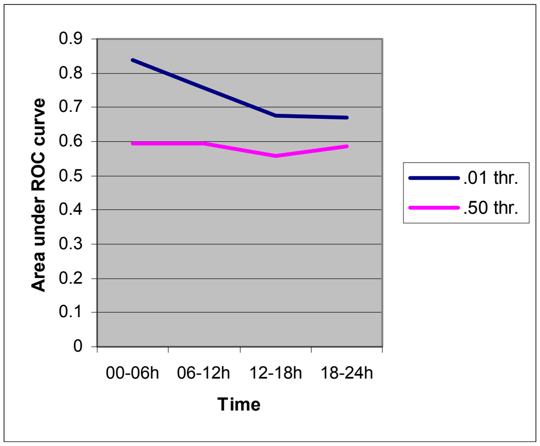

Figure 3. Areas under ROC curves for an ensemble consisting of 18 different physics runs at .01 and .5 inch thresholds for four 6h forecast periods.

Based on the fact that there is no particular combination of WRF model physics schemes that dominates in skill over time, this matrix of WRF model runs may hold potential to be a good ensemble if the ensemble spread is sufficient. Investigation of this hypothesis is the subject of future work.

3. SUMMARY

A matrix of 19 WRF members was created using different physical scheme combinations and run for eight IHOP and two summer 2003 cases. For the matrix, three different convective treatments (BMJ, KF and no convective scheme), two different PBL schemes (MRF and ETA) and three different sets of microphysics (NCEP-5, Lin et al., and Ferrier), were used, with one additional member using the thermal diffusion surface physics instead of the OSU scheme.

In order to test the sensitivity to physics changes, standard deviations of ETSs are calculated when two of three model physics are held fixed (i.e. PBL scheme and CP scheme are constant while microphysics varies). The results indicate the highest sensitivity is to the choice of the convective treatment, which is in good agreement with subjective impressions from the precipitation plots. Regarding sensitivity to the PBL and microphysical schemes, for lighter precipitation thresholds the sensitivities are comparable, while for heavier thresholds sensitivity to microphysics is higher. As one task for future work, factor separation will be used to examine in more detail the impact of different model physics on the precipitation forecast as well as on interaction among the different physical schemes. By performing the factor separation method using a skill score (i.e. ETS) and the precipitation amount together, both qualitative and quantitative impressions about the interactions will be obtained.

Finally, because this research shows that there is no particular combination of WRF model physics schemes that dominates in skill over time for these warm season convective events, this matrix of WRF model runs may form a good ensemble if the ensemble spread is sufficiently large. The use of this mixed physics ensemble will be investigated in more detail in the future.

4. ACKNOWLEDGEMENTS

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