SIMPLE- AND MODIFIED-POOR MAN'S QPF ENSEMBLES, AND A NEURAL NETWORK APPROACH

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1. INTRODUCTION

As part of the World Climate Research Programme's International Working Group on Numerical Experimentation (WGNE) effort, NCEP/EMC has been receiving precipitation forecasts from a number of international operational centers to be verified over the Contiguous United States, and we provide precipitation forecast files from our global model (GFS) to our international partners to be verified over their respective domains. The availability of these QPF data from different operational models in near real time gave us a chance to experiment with multi-model (or "poor man's") QPF ensembling. In 2005, as a by-product of the precipitation verification, we began verifying the simple arithmetic averaging of the QPF from the international models and NCEP's NAM and GFS models. Later we experimented with several approaches to improve on the simple averaging.

2. AVAILABLE MODEL QPF AND ANALYSIS

The 8 models used in the ensemble are:

No. 1 and 2: NAM and GFS: NCEP's mesoscale and global models

No. 3 and 4: CMC and CMCGLB: regional and global models from Canadian Meteorological Centre

No. 5-8: DWD, ECMWF, JMA and UKMO: global models from Deutscher Wetterdienst, European Centre for Medium-Range Weather Forecasts, Japan Meteorological Agency and UK Met Office, respectively.

This study focuses on the 00-24h and 24-48h forecasts from the 12Z model cycles, which are the forecast hours in common among the data from all 8 models available to us. Verifying analysis used in this study is the NCEP/CPC 0.125° daily (12Z-12Z) gauge analysis.

The resolution of the international models' QPF files are between 0.234° and 0.9°. The NAM QPF, with a resolution of 12km, is the highest-resolution QPF available among the eight models. For this study, all model QPF files are mapped to a 40-km Lambert Conformal grid (AWIPS Grid 212) before the computation of ensemble means. The verifying analysis is also mapped to Grid 212.

In case of missing QPF files from one or more international model(s), ensemble means in this study are computed from the remaining available models.

3. THE ARITHMETIC AVERAGES

We started out with a simple arithmetic average of all available models, dubbed "MEDLEY". A typical MEDLEY forecast is shown in Fig. 1. Equitable threat (ETS) and bias scores for the most recent one-year period are shown in Fig. 2. As can be seen from these figures, MEDLEY seems to do well in capturing the general features of the actual precipitation field, but details in the individual models' QPF tend to be smoothed out, and there is widespread light precipitation that is not present in the verifying analysis.

Our first attempt at refining "MEDLEY" was to exclude two "worst-performing" models (defined

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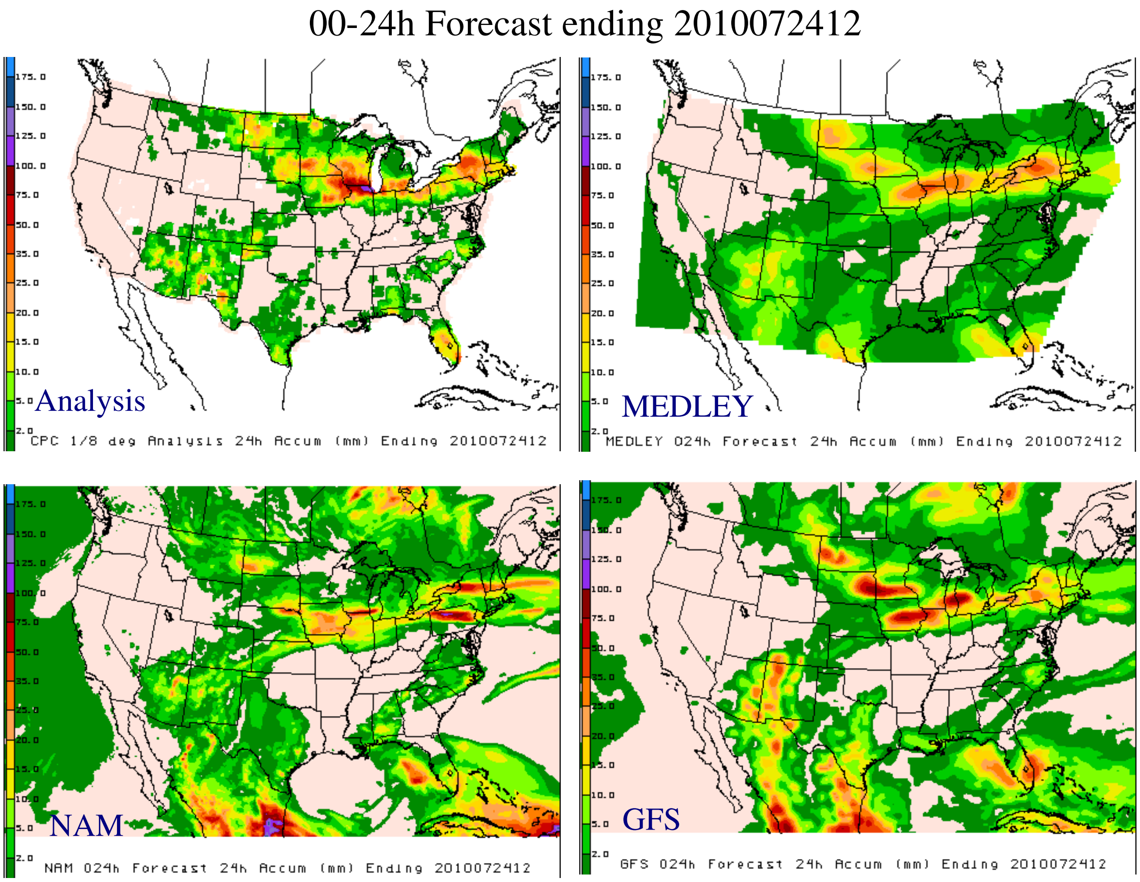
00-24h Forecast ending 2010072412

Fig. 1. 00-24 precipitation forecast from MEDLEY, NAM, GFS, and 24h verifying analysis. Valid time is 12Z 24 Jan 2011.

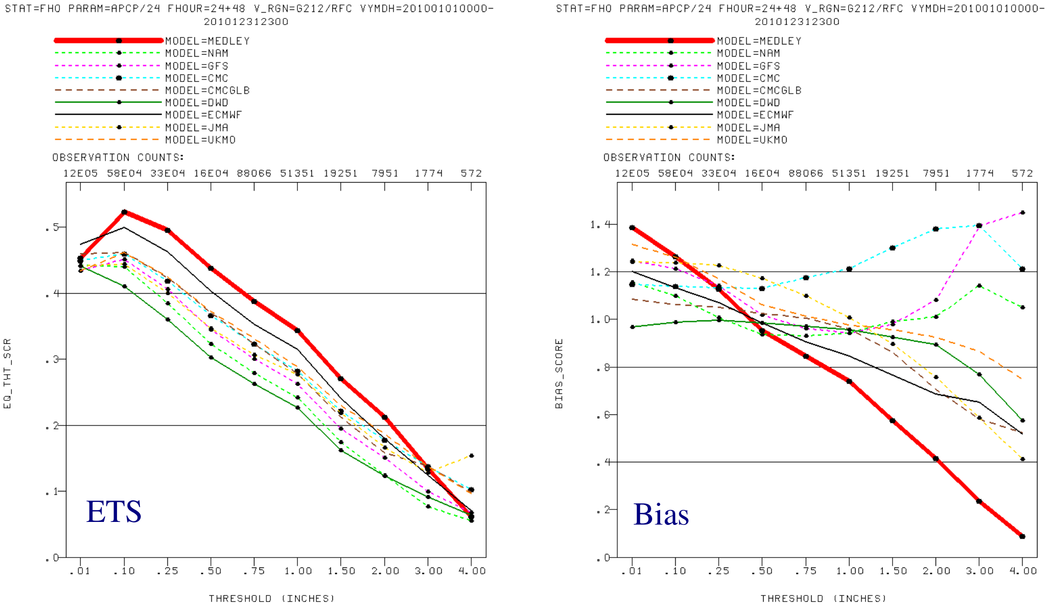

Fig. 2. Equitable threat and bias scores for MEDLEY (heavy red lines) and the 8 member models, for 00-24 and 24-48h forecasts, Jan-Dec 2010.

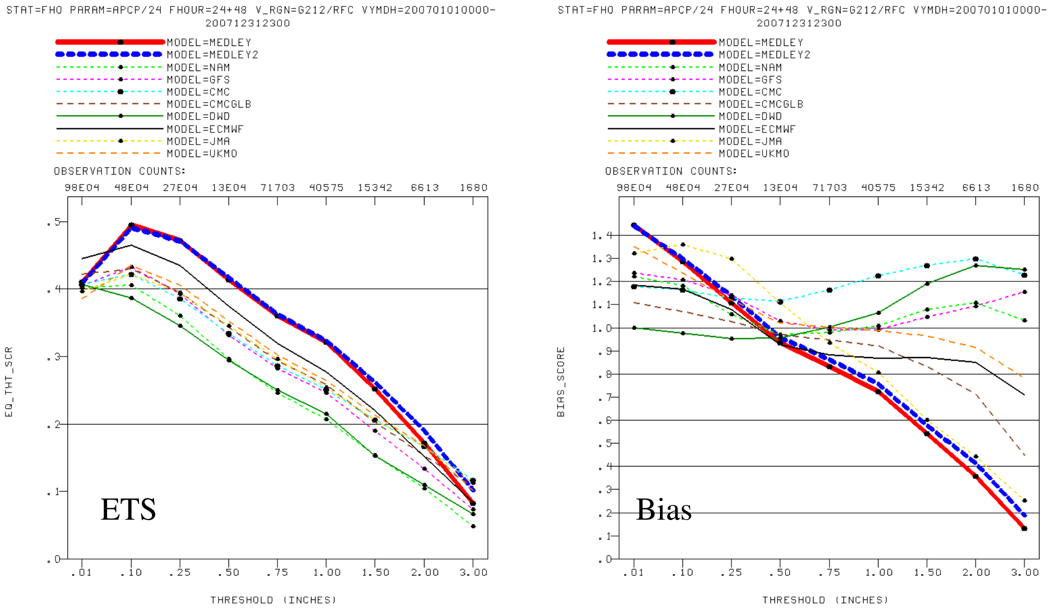

Fig. 3. Equitable threat and bias scores for MEDLEY (heavy red lines) and MEDLEY2 (heavy blue line) and the 8 member models, for 00-24 and 24-48h forecasts, Jan-Dec 2007.

as having the lowest average equitable threat scores at precipitation thresholds of 0.1”, 0.25”, 0.5”, 0.75” and 1” per day in the preceding 30 days) from the ensemble mean. Most days, this modified average, dubbed “MEDLEY2”, did not appear to be significantly different from the original MEDLEY. Over a long time period, the exclusion did seem to improve the ensemble average slightly, as shown in Fig. 3.

4. PROBABILITY MATCHING

Both the simple and modified arithmetic averages (MEDLEY and MEDLEY2) exhibited excessively large areas of low level precipitation and reduced maximum precipitation amounts. To address this issue, we applied the probability matching (PM) method outlined in Ebert (2001) to compute a deterministic QPF field from an ensemble of QPFs. Ebert hypothesized that the most likely spatial representation of the precipitation field is given by the ensemble mean, while the best frequency distribution of precipitation amounts is given by the ensemble of model QPFs as a whole. For a given forecast period (00-24h or 24-48h of a forecast cycle), we take all precipitation values of MEDLEY, ranking them from high to low (call this the QPF distribution *A*). Then we pool the precipitation values from all “member models” together, ranking them from high to low, and keeping every n^{th} value (call this the QPF distribution *B*. Usually *n*=8, unless one or more international QPF files are missing. The pool of precipitation values are from the area covered by all *n* models, *i.e.,* the MEDLEY domain). The grid point with the highest MEDLEY value are given the highest value in distribution *B,* the grid point with the second highest MEDLEY value are given the second highest value in distribution *B,* and so on. Thus we arrive at a probability matched QPF product (dubbed MEDLEY3).

The annual precipitation scores for the year 2010 (Fig. 4) show how PM improved the MEDLEY forecast. MEDLEY3's ETS is as good as MEDLEY in the middle threshold ranges, and much better than MEDLEY in lower and higher thresholds. The improvement over bias values is striking – MEDLEY's bias is too high in the low thresholds and too low in the high thresholds; MEDLEY3 has largely corrected this problem.

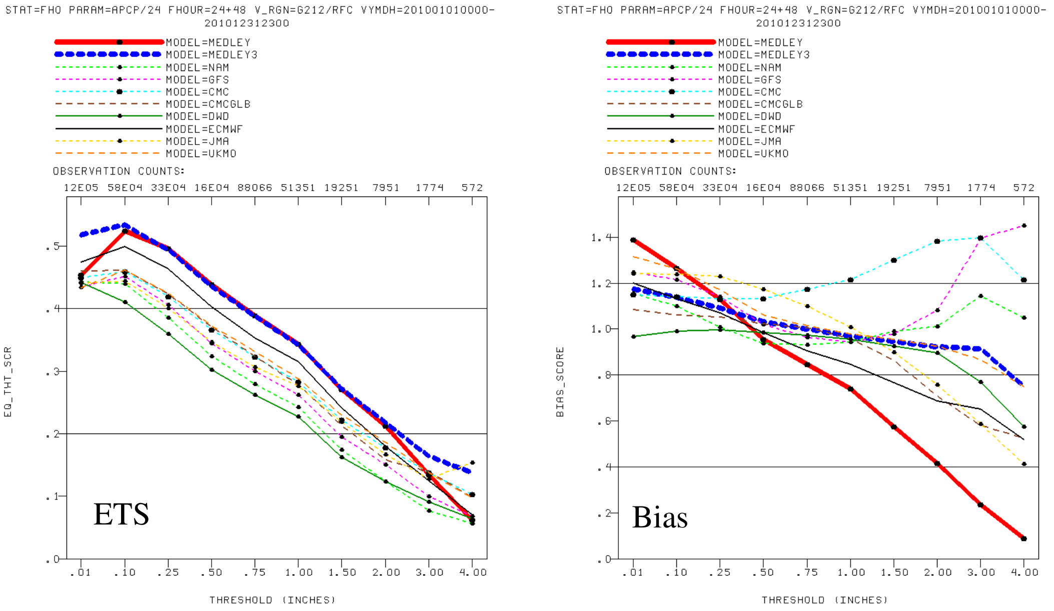

Fig. 4. Equitable threat and bias scores for MEDLEY (heavy red lines) and MEDLEY3 (heavy blue line) and the 8 member models, for 00-24 and 24-48h forecasts, Jan-Dec 2010.

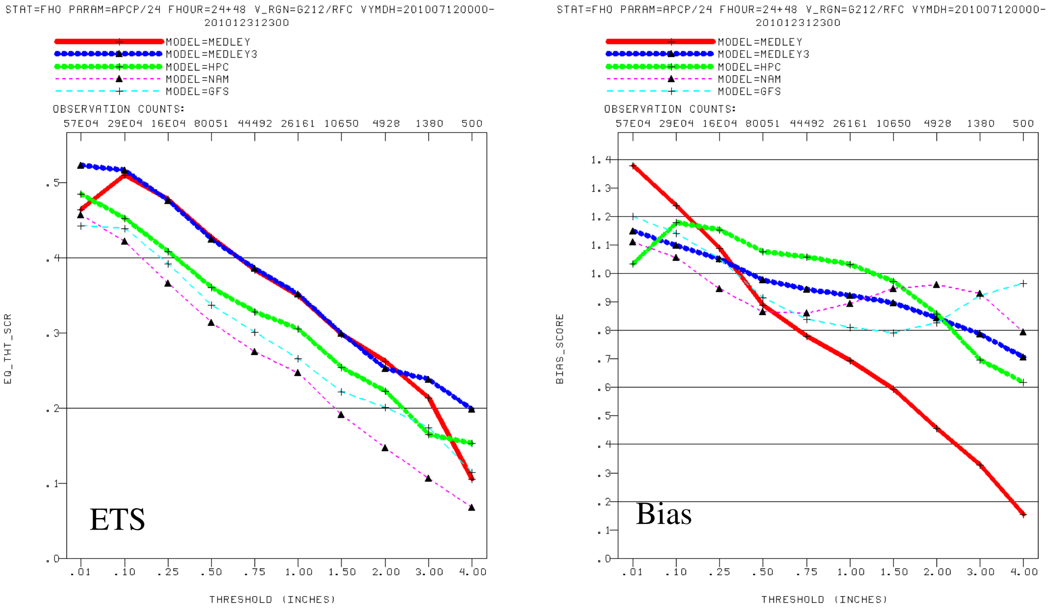

Fig. 5. Equitable threat and bias scores for MEDLEY (heavy red lines), MEDLEY2 (heavy blue line) , HPC QPF (heavy green line), NAM (thin red dashed line) and GFS (thin blue dashed line), for 00-24 and 24-48h forecasts, 12 Jul – 31 Dec 2010.

NCEP's Hydrometeorological Prediction Center (HPC) produces a QPF that is a product of “human intelligence”, made by HPC forecasters by subjectively blending a large number of operational and experimental model QPFs and ensemble solutions based on the forecasters' past experience and current observations (Novak *et al.,* 2011). The HPC QPF usually outperforms individual forecast models and ensembles. Figure 5 compares MEDLEY, MEDLEY3, HPC QPF, NAM and GFS, from mid Jul (when we first began verifying the HPC QPF in EMC's QPF verification

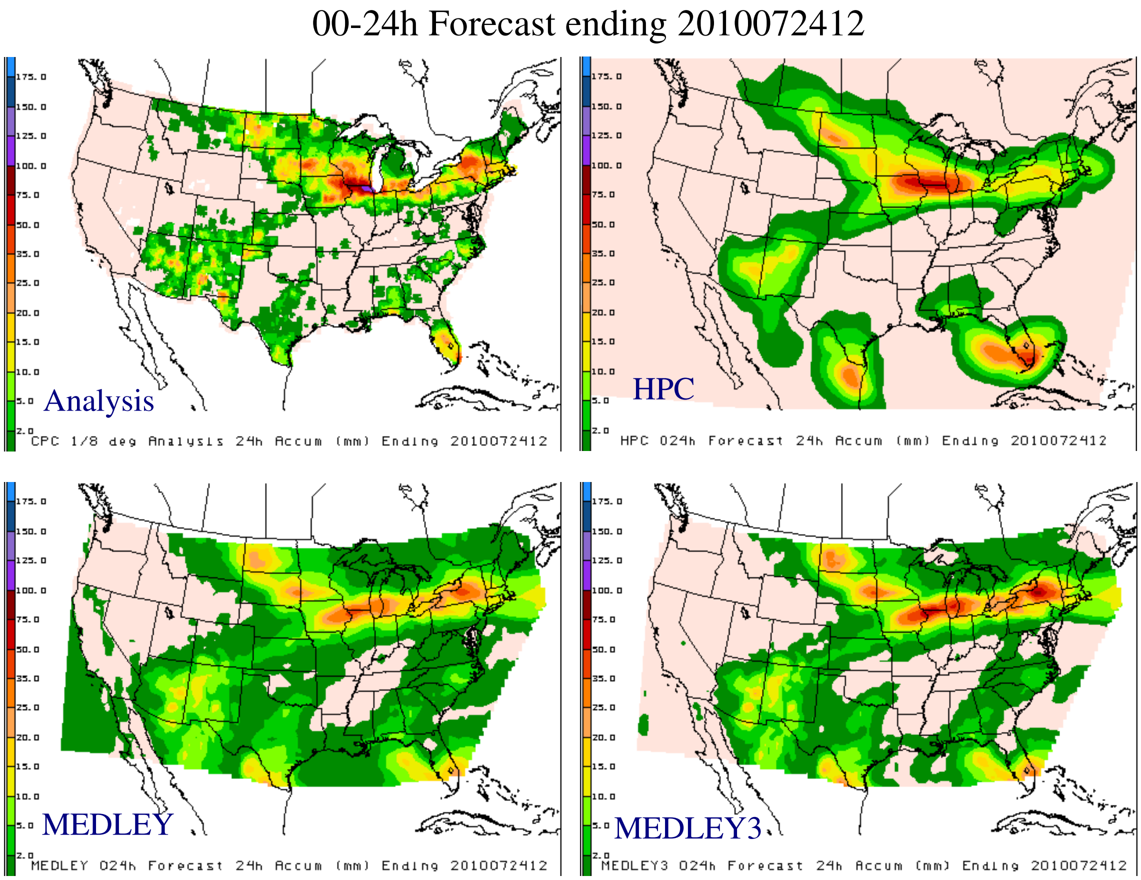

Fig. 6. 00-24h forecasts from HPC, MEDLEY and MEDLEY3, compared to the verifying 24h CPC gauge analysis. Valid time is 12Z 24 Jul 2010.

package) to the end of Dec 2011. The HPC QPF easily outperformed both NAM and GFS and has enviable bias scores; still, MEDLEY3 outperformed HPC QPF in all threshold categories, and the bias scores are comparable.

An example of MEDLEY3 forecast, compared to MEDLEY and HPC QPF, is shown in Figure 6. Here both MEDLEY and MEDLEY3 have very good placement of precipitation features, and produced a bit more details in the southwest, compared to the HPC forecast. Compared to the original MEDLEY, the probability-matched MEDLEY3 has larger values in high precipitation areas, which better matches the observations. MEDLEY has large areas of unverified light precipitation, which has been corrected – though not completely – in MEDLEY3. We traced this back to large areas of light precipitation in some member models.

5. A NEURAL NETWORK APPROACH

We have begun experimenting with a neural network (NN) approach to the multi-model ensemble. Details of the NN approach is described in Krasnopolsky and Lin (2011). We used model and verifying analysis data (including the latitude/longitude information for each data point) in 2009 to train the neural network. A multiple linear ensemble is also created to serve as a baseline in evaluating the non-linear NN results.

A sample forecast of NN QPF is compared to several other QPFs in Fig. 7. MEDLEY and MEDLEY3 captured general precipitation features quite well, with the probability-matched

00-24h Forecast ending 2010102412

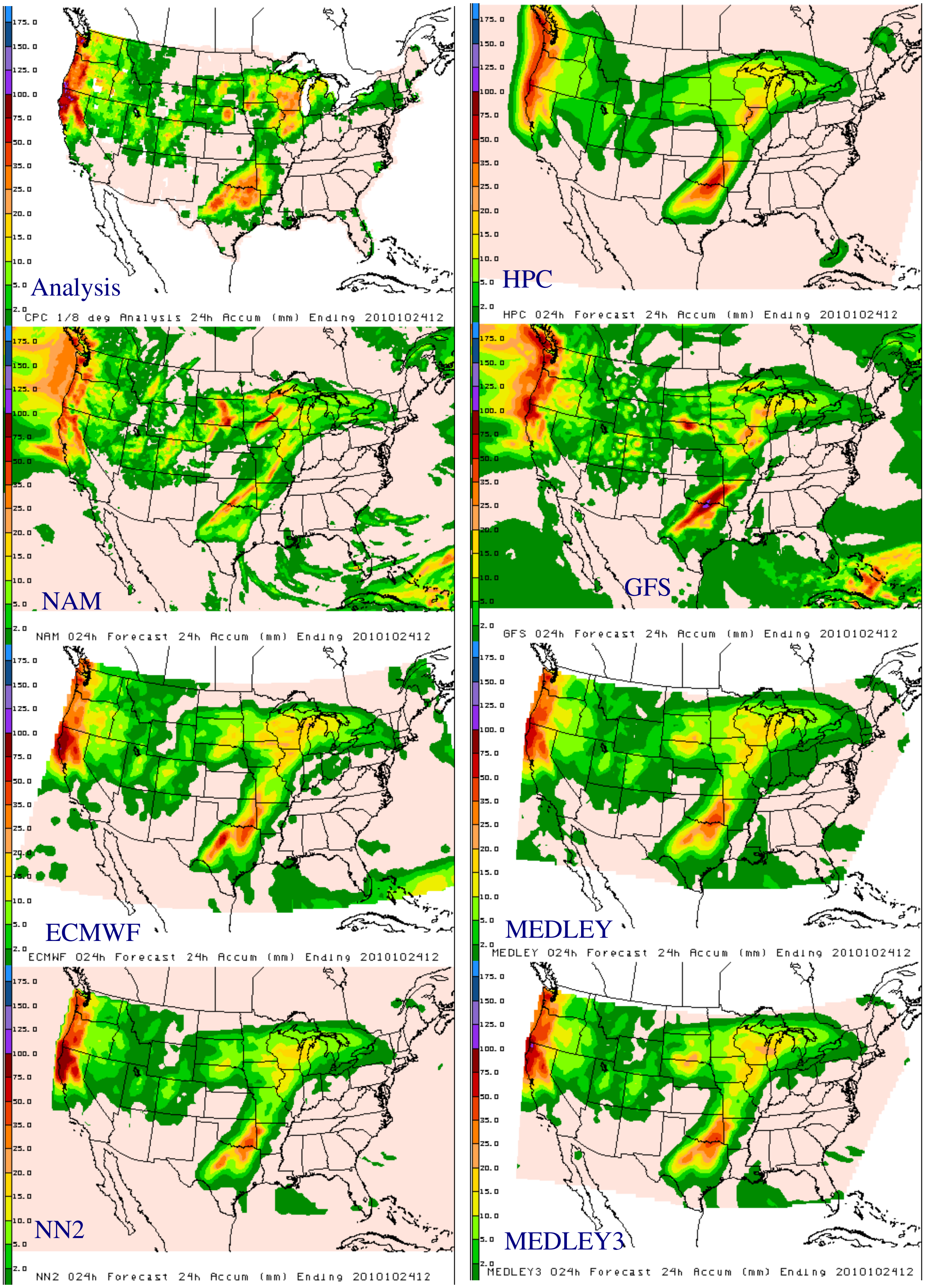

Fig. 7. Neural network (NN2) QPF compared to the MEDLEYs and other model QPFs and analysis.

MEDLEY3 doing slightly better in areas of high precipitation and eliminated some areas of false light precipitation in MEDLEY. The NN QPF stood out in capturing the sharp details in the Northwest region, and did not have the problem of widespread light precipitation.

6. CONCLUSIONS

A number of multi-model QPF ensemble approaches have been tested in this study. The simple arithmetic average produces a product that is too “smoothed out”. Withholding two worst-performing members from the ensemble improves the performance slightly.

The probability matching approach improves the ensemble greatly, though there are still some residue problems of false light precipitation, which has been traced to individual models with the similar problem; this might be corrected in the future by performing bias adjustment on individual member models.

The neural network approach has shown promise. An advantage of the NN approach is its flexibility - we plan to introduce additional information (other QPF fields, upper level fields and information from neighborhood grid points) as additional input for the neural network.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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