THE NWS QPF VERIFICATION PROGRAM

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1. INTRODUCTION

The United States Weather Research Program (USWRP) and the National Weather Service (NWS) have recently identified quantitative precipitation estimates (QPEs) and forecasts (QPFs) as a priority for improvement in the research and operational communities (Fritsch et al. 1998; Office of Meteorology 1999). Objective assessment and quantification of the skill of QPFs in the NWS end-to-end (ETE) forecast process are necessary to: (1) identify the value added at each step of the ETE forecast process; (2) assist in improving the forecasts; and (3) insure that the ETE forecast process represents the most efficient use of resources to produce quality QPF information for hydrologic services. The NWS recently outlined a uniform national QPF verification program and plans to establish the National Precipitation Verification Unit (NPVU) to fulfill these requirements. The NPVU will become operational by October 2000. Verification statistics from the NPVU will serve to support NWS programmatic decisions and numerical weather predication (NWP) model changes, provide feedback to individual forecasters and forecast offices, and ultimately improve QPFs and associated products for outside users. The success of the program is dependent upon the timely availability of all QPEs and QPFs.

The basic components of the NWS national QPF verification program are described in Office of Meteorology (1999) with adjustments being made according to recommendations from the NWS QPF Process Assessment Team (NWS 1999). A conceptual outline has been given in McDonald et al. (2000). The NPVU will be established at the NOAA Science Center in Camp Springs, MD, where it will be administered by the NWS Office of Meteorology (OM) and co-managed by the Hydrometeorlogical Prediction Center (HPC).

The (prototype) NPVU participated in the NWS QPF Process Assessment by providing objective QPF verification of NWS QPFs over three River Forecast Center (RFC) areas. A Western Region Follow-on Assessment (WRFA) continues during the 1999-2000 winter season for the Northwest RFC and the California-Nevada RFC. QPF verification methods used for the NWS QPF Process Assessment will be discussed, and some results will be presented. Other preliminary efforts within the (prototype) NPVU have been in assisting the HPC in updating their QPF verification activities. QPF verification methods and results for HPC's 06-h, 24-h, and 5-day QPFs will be described to illustrate the current quasi-real-time HPC QPF verification process. Finally, future plans for the national QPF verification program will be presented.

2. NWS QPF PROCESS ASSESSMENT METHODS & RESULTS

Details concerning the charge given to and the efforts of the QPF Process Assessment Team are found in NWS (1999). This section will describe the objective comparative QPF verification study that was key to the findings and recommendations of the team. The study included QPF products from the Environmental Modeling Center (EMC), Techniques Development Laboratory (TDL), HPC, Weather Forecast Offices (WFOs), and River Forecast Centers (RFCs) for a 6-month cool-season period (Oct. 1998 to Mar. 1999). QPF verification was conducted for three geographically and climatologically diverse RFC areas: ABRFC; OHRFC; and CNRFC. The study was limited due to the nature of data archival at each of the various centers and offices and the time allowed for the team to complete its assessment.

NWP 12-36-h QPFs were obtained for the 0000 UTC model runs of the Nested Grid Model (80 km), Eta model (32 km), and the Aviation (AVN) run of the MRF (1° x 1°). Model grids were remapped to a 30-km grid using an area-preservation technique (Mesinger 1996). The TDL QPF product comes from the Local AWIPS MOS Program (LAMP) QPF model (20 km). HPC 06- and 24-h graphic QPFs were translated to the verification grid in a semi-continuous manner since the HPC did not include a zeroline. WFO QPFs on the HRAP grid (4 km) were mosaicked together over each RFC domain and grid-averaged to the verification grid. RFC QPFs were also grid-averaged from the HRAP grid to the verification grid.

For the ABRFC and OHRFC, observed data were obtained from the RFC Stage III analyses in

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[#] This research was supported in part by an appointment to the COMET Postdoctoral Fellowship Program and UCAR Visiting Scientist Program sponsored by the National Weather Service and administered by the University Corporation for Atmospheric Research pursuant to the National Oceanic and Atmospheric Administration Award No. NA97WD0082.

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NetCDF or xmrg format (both on the HRAP grid). The observed data was also grid-averaged to the 30-km verification grid so that all of the observed and forecast data were on the same resolution grid. Observed data for the CNRFC were obtained from Mountain Mapper (MM, Henkel and Peterson 1996), which is a program that renders observed point data to the HRAP grid via climatology (PRISM).

A modest suite of 6- and 24-h verification measures were computed for a variety of temporal domains (1, 3, & 6 mo and single days). Forecast projections were limited to the 1200 to 1200 UTC period, which corresponded with HPC's day 1 QPF and the WFO and RFC 1200 UTC QPFs, and included 06-h forecast increments at standard synoptic times.

Evaluation of the results by the QPF Process Assessment Team indicated that, for both the ABRFC and the OHRFC over the 6-mo period, 24-h mean absolute errors were better for the HPC than for the WFOs and the RFCs (Fig. 1). Results also indicated that the AVN performed the best of the NWP and statistical model QPFs for this cool season. The team thus recommended to the NWS Corporate Board that the WFOs be relieved of the responsibility of producing QPF as input into the NWS River Forecast System (NWSRFS).

Results of the QPF process assessment over the CNRFC (Fig. 2) were found to be inconclusive. The WFO scores were better than all other QPFs for higher amounts, but several factors may have biased the results. These factors include common grid rendering of the observed and forecast point data via Mountain Mapper and inclusion of updated forecasts during wet events up to 18 h into the forecast period. The team recommended that the verification study be continued during the 1999-2000 wet season to better ascertain the relative performance of QPF process components in the western U.S.

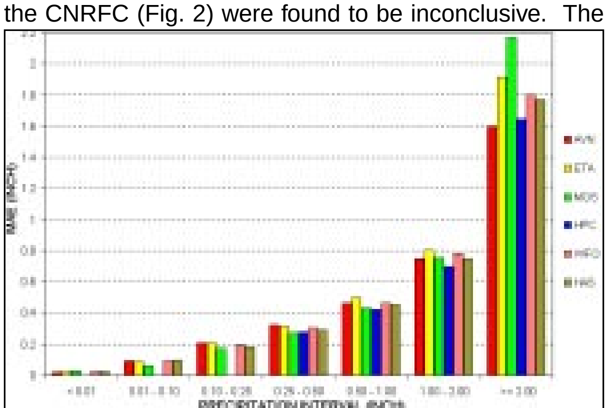

Figure 1. Mean absolute errors for 24-h QPFs over both the ABRFC and OHRFC for the 6-mo period Oct. 1998 - Mar. 1999.

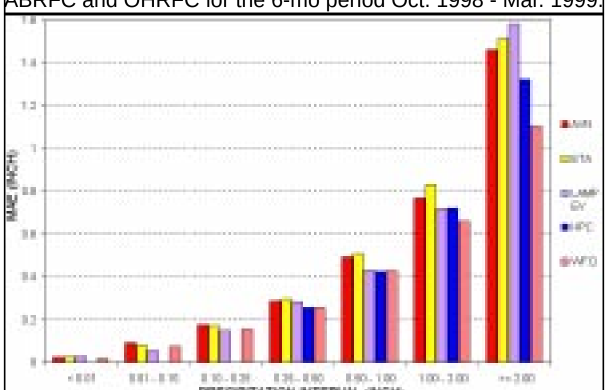

Figure 2. Mean absolute errors for 24-h QPFs over the CNRFC for the 5-mo period Nov. 1998 to Mar. 1999.

3. WESTERN REGION FOLLOW-ON ASSESSMENT METHODS & RESULTS

The QPF verification methods used for the WRFA were approved by the NWS Corporate Board in October 1999. The methods are to be the same as those used by the NWS QPF Process Assessment Team with adjustments made accordingly to eliminate apparent discrepancies, as noted earlier. The primary correction made in this assessment is the elimination of updated QPFs from the WFOs. Both point and gridded verification methods are employed even though initial QPFs are made in different forms (point QPFs from the WFOs and gridded QPFs from HPC). The grid used for this assessment is an AWIPS 32-km grid rather than the previously used 30-km grid. Also, point QPFs from the NWRFC are included to supplement those from the CNRFC.

Both 6- and 24-h verification statistics are computed for each month as well as the entire 5-mo assessment period. Statistics are computed for the full range of precipitation amounts and for discrete precipitation intervals (e.g., 0.25"<=ppt<0.50", 0.50"<=ppt<1.00", etc., where ppt can be the observed amount, the forecast amount, or both the observed and forecast amount). RFC quality-controlled point observations and MM derived gridded fields are used as the observed verification data.

Figure 3 shows the NWRFC MAEs for the 6-h day 1 period (F00-F24) from Nov. 1999 - Jan. 2000. These statistics have been computed via the point methodology, and the precipitation intervals are based upon observed amounts only. Overall, the slight edge appears to be with the WFOs; however, given the sample size (not shown) the differences may be statistically insignificant.

4. HPC QPF VERIFICATION

In January 1999, the HPC transferred QPF verification from the Intergraph system to a Unix-based HP workstation at the (prototype) NPVU. Several errors in the prior QPF verification system were corrected, but the basic characteristics were continued so that results could be compared with the 30+ years of QPF verification data (Olsen et al. 1995). Additionally, an

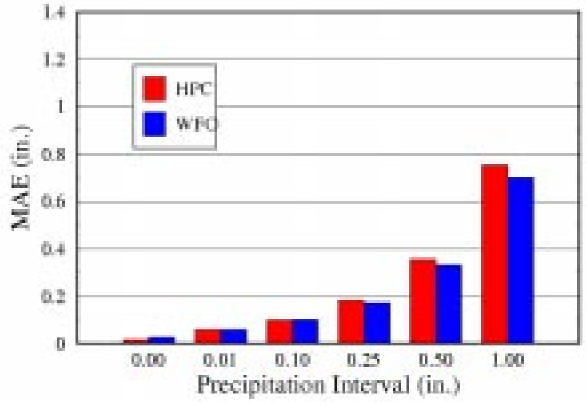

Figure 3. HPC and WFO 6-h day1 (F00-F24) mean absolute errors over the NWRFC from Nov. 1999 - Jan. 2000. MAEs are computed from points and grouped according to observed amount.

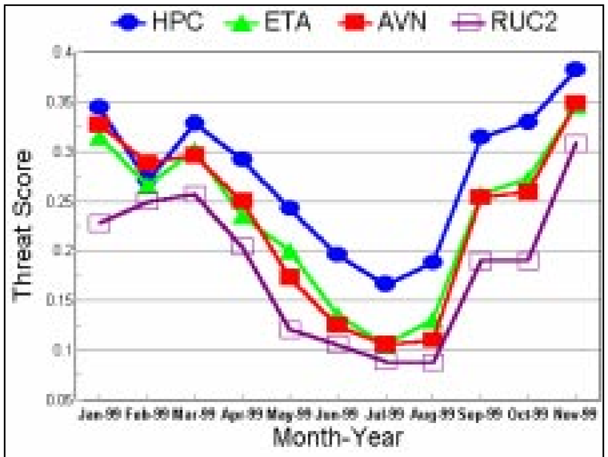

Figure 4. National 0.25" threat scores at 600+ sites for 06-h QPFs from Jan. to Nov. 1999. HPC QPFs are for F00-F06. Eta, AVN, and RUC2 QPFs are for F06-F12.

automated 5-day QPF verification system has been established to replace the manual system.

4.1 *06-h QPF Verification*

At the present time, 06-h QPF verification is performed at 600+ METAR locations throughout the conterminous U.S. Each of these stations has been evaluated for reliability and consistency. However, HPC forecasters still quality control the precipitation reports before verification is performed. Both EMC model and HPC forecasts are bilinearly interpolated to the station locations. Only thresholds statistics (threat score, bias score) are currently computed because HPC forecasts have traditionally been issued in a threshold format starting at 0.25".

As of 06 December 1999, HPC began issuing fully continuous QPF grids (Hoke et al. 2000). More informative and hydrologically meaningful verification measures will soon be computed and intercomparisons with other QPFs will be made. Also, over the course of the following year, the aforementioned RFC Stage III (soon to be RFC-wide) and MM analyses will be utilized as observational grids such that the 06-h QPF verification system methodology will change from a point to a gridded structure.

Monthly 0.25" threat scores from Jan.-Nov. 1999 are shown in Figure 4. The HPC 91E QPF (F00-F06) is compared with the Eta, AVN, and RUC2 F06-F12 QPFs. Threat scores indicate that HPC forecasters are adding value to the NWP guidance for this forecast period. The QPF performance is much better during the cool season than during the convective warm season.

4.2 *24-h QPF Verification*

The HPC has been issuing 24-h QPFs since September 1960 and has always utilized a verification system to measure progress and monitor forecast quality (Olsen et al. 1995). A gridded verification scheme has been consistently maintained resulting in nearly 40 years of threat and bias scores. Much of the effort has involved manual intervention; however, more and more individual components are becoming automated to maximize resources without degrading the quality of the QPF verification.

At present, the 24-h QPF verification system is characterized by manual gridded analyses of 24-h gauge data from the RFCs, translation of the HPC graphical product to a grid, and remapping of NWP model output to a common grid. The QPF verification grid used prior to 1999 has a spacing of 1/6 of the LFM grid (~30 km). Since January 1999, the AWIPS #221 grid (~32 km) has been used. Only those grid points over the contermi-nous U.S. are verified, and threat and bias scores for the day 1, update, and day 2 QPFs are produced.

Figure 5 shows the yearly 1" threat scores from 1965 to 1999 for each HPC 24-h QPF product. Trends indicate that improvements in 24-h QPF have been made. As expected, the day 1 QPF is better than the update and day 2 QPF.

Figure 6 shows the 0.50" 24-h threat scores for Jan. 1999 to Feb. 2000. HPC is consistently better than

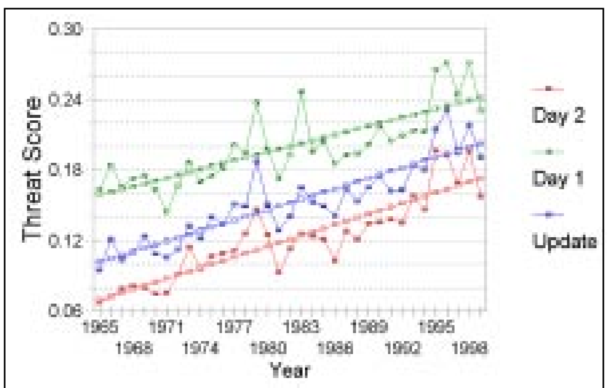

Figure 5. HPC 24-h day 1, day 2, and updated day 2 annual 1" threat scores. A least squares linear fit to each forecast is shown. (Image courtesy D. Reynolds/HPC)

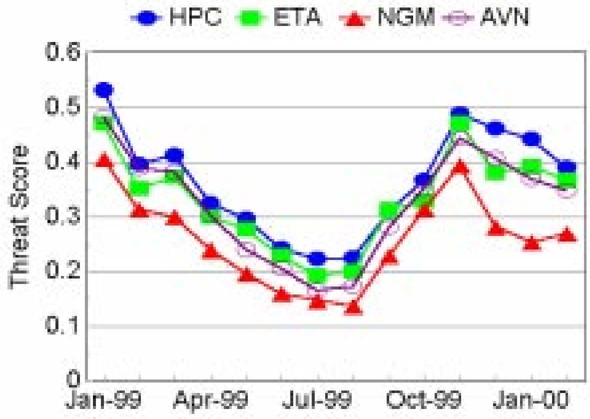

Figure 6. National 0.50" threat scores for Jan. 1999 to Feb. 2000 via grid methodology. HPC QPF is from F00-F24 and NWP QPFs are from F12-F36.

the best NWP QPF with extremely high scores during Jan. 1999. The AVN and Eta trade places being the best NWP QPF with the NGM consistently having the lowest threat scores.

4.3 *5-day QPF Verification*

Part of the medium range (3-7 day) forecast product suite at the HPC includes a day 1 to day 5 cumulative QPF for the conterminous U.S. This QPF is also produced as a graphic and translated to the verification grid. Its valid time prior to December 1999 corresponded with the F24-F144 5-day QPF from the 0000 UTC run of the Medium Range Forecast (MRF) model. As of 06 December 1999, HPC adjusted its 5-day QPF to correspond to the same valid period as the F12-F132 QPF from the MRF. The best observed data available for this forecast period incorporates 1200 UTC to 1200 UTC 24-h accumulations. Thus, the verification and forecast data used to be time lagged by 12 h with the observed data ending time occurring prior to the forecast data ending time. This time lag was not deemed critical given the length of the period, although there may be some unknown implications/errors.

5. FUTURE PLANS

The NPVU plans to become fully operational in fall of 2000 to include verification of QPFs from the EMC, TDL, HPC, and RFCs over the conterminous U.S., as well as any WFOs that issue QPFs for local purposes. Initial development will concentrate with selected RFCs. A 2-mo Operational Test and Evaluation period will take place from 15 June - 15 August 2000. Most likely, the NWS QPF verification program will include a display and feedback method using the World Wide Web.

Eventually, if possible, the software for the national QPF verification program will be incorporated into AWIPS for greater accessibility in the NWS. Since the NWS is tending toward probabilistic QPF in the next few years (Office of Meteorology 1999), the verification program will be modified to reflect these changes.

The conference presentation accompanying this paper will be available at the following URL address: http://www.hpc.ncep.noaa.gov/npvu/probstat15.

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