5B.3 INTERACTIVE QUALITY CONTROL AND OPERATIONAL PRODUCT GENERATION OF HOURLY MULTI-SENSOR PRECIPITATION ESTIMATES IN THE NWS

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1. INTRODUCTION

NOAA National Weather Service (NWS) field offices generate near-real-time estimates of gridded hourly precipitation by combining rain gage data with gridded radar and satellite data. These grids are subject to extensive interactive quality control operations which ultimately produce the "best estimate" grid for a given hour. An example grid is shown in Figure 1. Quantitative precipitation estimate (QPE) grids are used by the NWS for creating official river forecasts for over 2800 locations nationwide. They also provide critical data for water resource services beyond flood forecasting, including water supply and drought management.

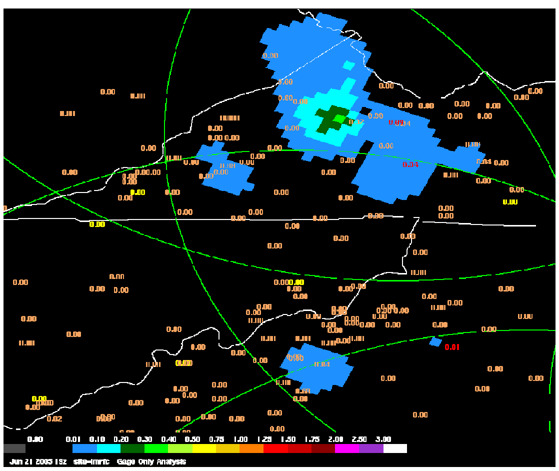

Figure 1. Precipitation grid sample with gage values and green radar rings.

This paper begins with a brief overview of the Multi-sensor Precipitation Estimator (MPE) software suite developed by the NWS Office of Hydrologic Development (OHD) and installed at the (13) NWS River Forecast Centers (RFCs) and (122) NWS Weather Forecast Offices (WFOs). Most RFCs use the MPE software although a few use locally developed software. Many WFOs create and view MPE products, but they perform minimal data quality control because of the time it requires.

Operational use of early versions of MPE began in 1992. OHD continues to adapt MPE to expanded requirements and new data sets. This paper describes the new products and interactive features recently added to MPE, with emphasis on quality control tools used on the input rain gage, radar, and satellite data. Hourly precipitation is the focus of overall MPE processing. However, the MPE system has evolved to process data at multi-hour durations and to process other data elements such as station temperature and freezing level. Later discussion covers this evolution and new methods for sharing locally generated data, including the RFC estimates and radar bias information.

This paper also describes the end-to-end process for generating precipitation data sets, which differs by office because of varying climatology, varying data availability and quality, and individual office preferences. The paper concludes with discussion of future plans for the creation and use of meteorological model forcings such as precipitation and temperature data elements.

2. MPE OVERVIEW

The traditional role of the MPE software has been the creation and quality control (QC) of gridded 4-km hourly-duration precipitation (Lawrence, 2003). Recently, the "DailyQC" functionality developed in the NWS Western Region was added to MPE. It provides quality control of multi-hour values for station precipitation and temperature reports, and for freezing level estimates. As such, the MPE system now operates in two distinct modes, defined by the data being processed. Each mode has two stages: a pre-processing stage and an editing stage. The two modes and their primary applications, as shown in Figure 2, are:

1) <u>Hourly Grid Editing</u> – Processes hourly precipitation. The MPE_FieldGenerator is the pre-processor for generating gridded hourly estimates. The MPE_Editor hourly mode provides the interactive QC review and edit tools

2) <u>Multi-Hour Station Editing</u> – Processes multi-hourly station precipitation, temperature, and freezing level data. The DailyQC pre-processors collect the data and performs basic QC. The MPE_Editor DailyQC mode provides a separate set of tools for interactive QC review and edit.

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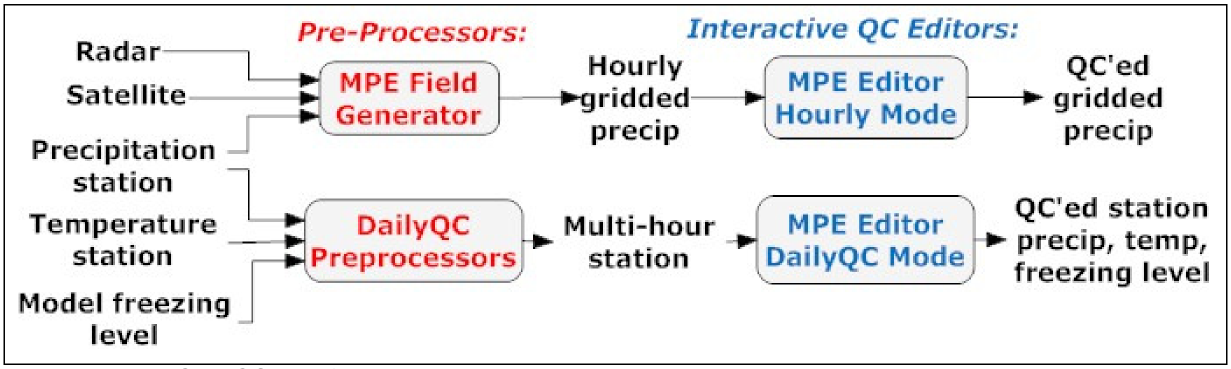


Figure 2. Basic QPE QC data flow. Hourly and multi-hourly modes, and two-stage processing in pre-processor and interactive editor are shown.

Listed below are the 17 precipitation grid types generated by MPE. Most are created in the MPE_FieldGenerator by combining gage, radar, and satellite estimates in different permutations, and by applying bias correction algorithms which adjust gridded radar and satellite estimates based on comparisons with "ground truth" gage values. Some are used as is, including the satellite-only grid and the NOAA's NSSL (National Severe Storms Laboratory) radar mosaic. The forecaster specifies one of the grids as the initial best estimate and then edits it as necessary to produce the final best estimate grid.

Precipitation Grid Types:

- Gage-Only
- Radar-Only (3):
  - Mosaicked per radar elevation
  - Mosaicked by average value
  - Mosaicked by maximum value
- Radar Bias Corrected (3):
  - Using field bias
  - Using local bias
  - Using triangulated local bias
- Radar-Gage Multi-Sensor (2):
  - Using field bias radar corrected grid
  - Using local bias radar corrected grid
- Satellite-Only
- Satellite Bias Corrected: using local bias
- Satellite Multi-Sensor (3):
  - Satellite-radar
  - Satellite-gage
  - Satellite-radar-gage
- NSSL Radar Mosaic (3):
  - Raw
  - Local bias corrected
  - Radar-gage multi-sensor

The algorithms also use monthly climatologically-modeled grids of precipitation and temperature from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) model (Daly, 2008). Figure 3 displays a sample PRISM "normal" grid. The historical normal values provide key weighting factors used in generating estimates for locations where no measurements are available. It relates an actual measurement and normal value at a nearby location to the station with no data but with a known normal value.

Most areas of the country have multiple radars which cover the same grid area. Different methods exist to determine which radar value(s) to use. The default method uses the radar with the lowest sampling elevation. Alternative methods make use of the average value or the maximum value of the overlapping values. All methods use the pre-derived radar "climatology" grid, which defines the area effectively covered by each radar, to determine whether the radar provides acceptable coverage for a given overlap area.

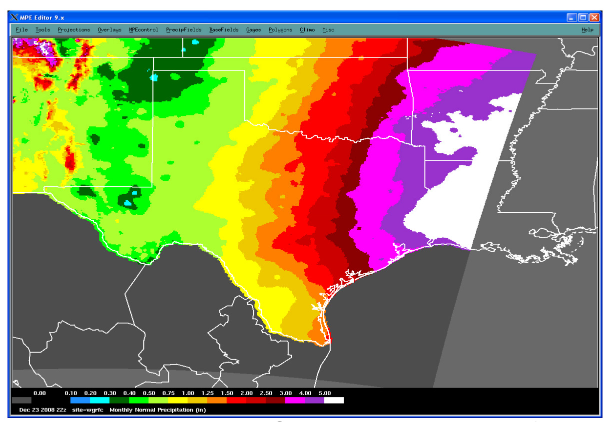


Figure 3. December PRISM normal precipitation for West Gulf RFC area.

3. NEW HOURLY PRODUCTS

Precipitation estimates are based on measurements from radars, gages, or satellite sensors. Each type has strengths and weaknesses. Gages typically provide the most accurate readings, but can have quality problems and their value may not accurately represent the spatial coverage of the rainfall. Radars provide excellent spatial coverage but as shown in Figure 4 have major gaps in mountainous areas, suffer from beam overshooting of cold-air precipitation, and can have other quality problems. Satellite data provide complete coverage but because of the indirect measurement of rainfall, they can have serious quality issues.

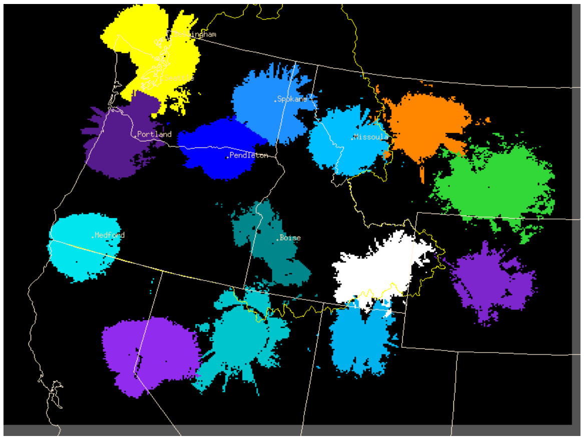


Figure 4. Effective winter radar coverage climatology over western United States.

The MPE software uses these data sources to produce initial estimates of precipitation. Improvements in data communication capabilities, sensor and model data availability, and model algorithms have led to new products in MPE. These new products are described below.

3.1 SATELLITE PRODUCTS

A set of new MPE products is based on satellite derived estimates provided from the Hydro-Estimator (HE) algorithm developed by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) (Kuligowski, 2006). The HE algorithm uses infrared window channel brightness temperatures to discriminate raining from non-raining areas, with adjustments based on numerical weather prediction model data. The resulting Satellite Precipitation Estimate (SPE) product has been available in MPE for many years, both as a raw product and as a product with a gage bias correction applied to it. Recently, three new satellite based estimates have been added to combine the satellite, gage and radar estimates to produce a satellite-radar, satellite-gage, and satellite-gage-radar multi-sensor estimate. The basic process for producing these grids is shown in Figure 5.

3.2 Q2 PRODUCTS

The NSSL has developed a prototype system for generating real-time gridded precipitation estimates as part of the National Mosaic and QPE (NMQ) project (Vasiloff, 2007). The NMQ generates "Q2" QPE products using radar and satellite data combined with gage data and input from numerical weather models. The estimates are based heavily on radar data, using the full 3-dimensional set of available scan data. Specialized algorithms automatically QC the estimates, including use of localized reflectivity-radar (Z-R) relationships. The resulting product is generated at NSSL and transmitted to many RFC offices on an experimental basis.

The Q2 grids do not use rain gage data that has been interactively quality-controlled. To provide value-added estimates, MPE has been modified to combine the locally reviewed gage data with the Q2 product to derive two additional products: the local bias-corrected Q2 grid and the multi-sensor Q2-gage grid. All three new products provide the forecaster with alternative grids which can be used as the initial best estimate or can be combined with other grids using the polygon substitution tool.

3.3 TRIANGULATED PRODUCTS

For many years, MPE has produced two bias-corrected products by mathematically comparing radar and rain gage estimates. First, the mean field bias product "raises" or "lowers" each radar grid value by a computed multiplicative factor. However, by incorporating the radar area out to a 230-km radius, the field bias may not capture local bias effects which can be prevalent. The second product uses a moving local analysis, typically for a 40-km radius area, to compute a bias for each grid cell and thereby better account for local effects.

A third method has been incorporated into MPE. The "Process3" method was originally developed by the Tulsa District of the U.S. Army Corps of Engineers and implemented by the Arkansas-Red River Basin RFC (Schmidt, 2000). This method places more emphasis

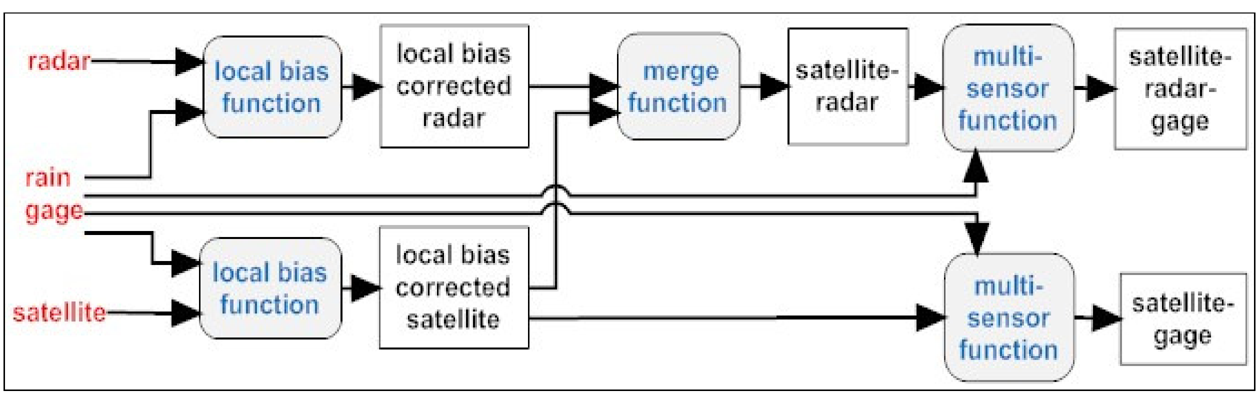


Figure 5. Generation of multi-sensor satellite-based grids showing how raw estimates are bias corrected and merged.

on the rain gage values and makes use of a triangulated irregular network (TIN) fitted to the local rain gage network. First, a radar mosaic is created using the maximum or average value where values from multiple radars overlap. Second, the radar mosaic values are compared with the triangulated network of gage values to produce a bias adjustment grid. This method uses interpolation techniques to define the bias at grid cells which do not have gage values. The resulting bias adjustment is used to create the final precipitation grid.

3.4 RFC ESTIMATED PRODUCTS

Both the RFC and WFO can generate QPE using MPE. Because of their different mission focus and staff resources, the RFC staff perform more quality control on the QPE product. Therefore the RFC product is generally more accurate. Recent changes to MPE operations allow an RFC to transmit their best estimate product using the communications network in the NWS Advanced Weather Interactive Processing System (AWIPS). The product is part of the ZETA98 World Meteorological Organization (WMO) product suite, and is available to users outside the RFC, including the WFO offices.

Options were added to MPE_Editor to enable WFO forecasters to ingest and use the RFC product. It can be used as the initial estimate in lieu of the WFO-generated MPE product or a portion of the RFC grid can be used via the polygon substitution tool.

4. NEW INTERACTIVE FEATURES

Precipitation measurements are notorious for their complex and frequent errors. Although automated QC helps considerably, forecaster interaction is necessary to produce acceptable precipitation estimates. This QC is implemented via the MPE_Editor application, which is essentially an extensive quality control tool.

The basic operational approach is for the forecaster to review the different initial estimated grids, and compare them with the raw radar, satellite, and gage values to look for consistency and accuracy. Grid fields can be edited using polygon-edit map techniques and gage values can be edited using custom interfaces. After any edits are made, the original grid “field generation” process is repeated. The forecaster reviews the updated estimates, makes any additional QC adjustments, and repeats this process as necessary until a final grid is accepted.

The following sections briefly describe the significant additions and enhancements made to the MPE_Editor QC tools.

4.1 POLYGON GRID EDITING

Meaningful grid editing tools are essential to the QC of the gridded estimate. Using the polygon edit tool, the forecaster delineates a polygon on the selected/displayed grid using mouse controls and performs operations on the grid values within the polygon. Beyond the previously available “set” action for setting all delineated values to a fixed forecaster-specified value, the following new operations are available:

- Scale - scales values by the specified ratio
- Raise/Lower - adjusts values as needed to be equal or greater than, or equal or less than, respectively, the specified value
- Snow - sets all values to the specified value, and gages within the polygon whose values are less than the specified value are removed
- Substitute – replace values with values from one designated grid among the other grids

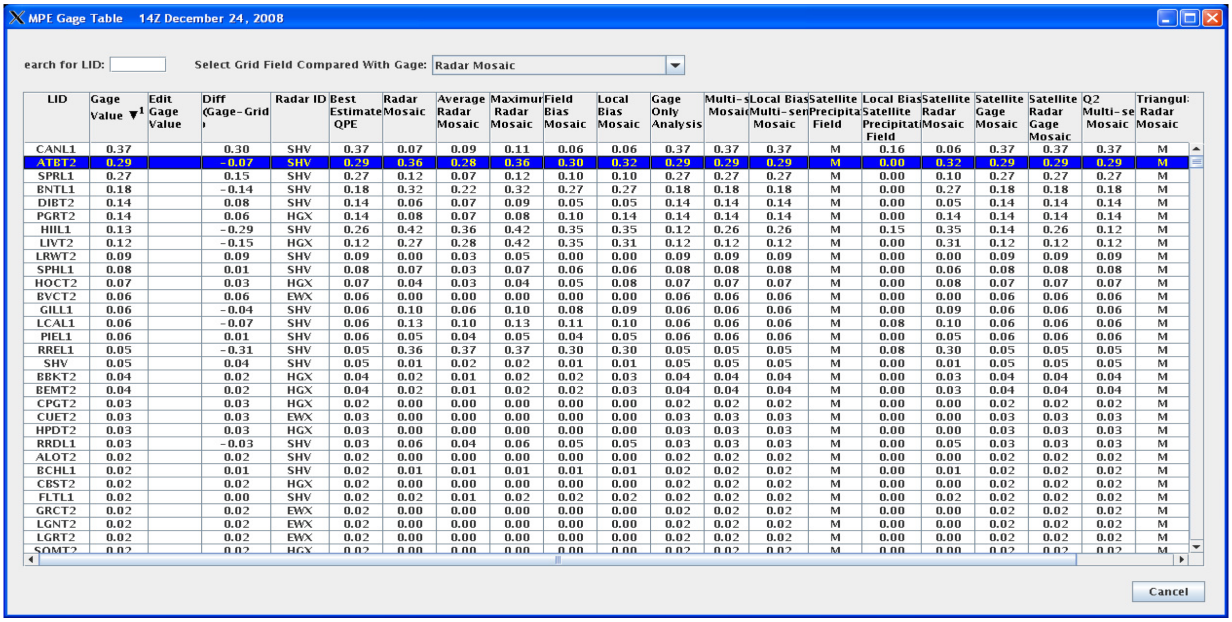
Polygon edit operations are often performed to remove anomalous propagation (AP) and ground clutter artifacts from the radar precipitation mosaics, preventing them from contaminating the radar bias corrected grids. Multiple polygon operations can be applied to the same hourly grid. Even after applying the edits, these operations can be reviewed and “undone”.

Furthermore, the polygon edit actions can be made persistent so that they automatically apply not just to the current hour’s grid but also to all subsequent grids. This latter feature is especially helpful for perpetual cases where estimates from a given grid type are preferred for one portion of the forecast area while for other portions, other grid types are preferred. For example, persistent polygons allow the satellite-only estimates to be automatically applied to one data-sparse sub-area while the radar-gage bias-corrected multi-sensor estimates are used for the remainder of the forecast area.

4.2 GAGE DATA EDITING

In order to ensure numeric and spatial consistency, gage values are compared against the values for the grid cell containing the gage. The forecaster can overlay annotated gage values onto the colored grid display. Significant differences between the gage and grid value can be detected by inspection.

Furthermore, different grid types often yield different values for the same grid cell. These result primarily from the errors in the contributing radar, gage, and satellite measurements which the forecaster QC process must resolve. Two custom interfaces provide the forecaster the ability to compare gage and grid values and to edit the gage value. The “Gage Table” window and the “7x7 Display” window are shown in Figure 6 and 7, respectively. Both been enhanced recently.



MPE Gage Table 14Z December 24, 2008

earch for LID: Select Grid Field Compared With Gage: Radar Mosaic

LID	Gage Value ▼1	Edit Gage Value	Diff (Gage-Grid)	Radar ID	Best Estimate QPE	Radar Mosaic	Average Radar Mosaic	Maximur Radar Mosaic	Field Bias Mosaic	Local Bias Mosaic	Gage Only Analysis	Multi-s Mosaic	Local Bias Multi-sen Mosaic	Satellite Precipita Field	Local Bias Satellite Precipitat Field	Satellite Radar Mosaic	Satellite Gage Mosaic	Satellite Radar Gage Mosaic	Q2 Multi-se Mosaic	Triangul: Radar Mosaic
CANL1	0.37		0.30	SHV	0.37	0.07	0.09	0.11	0.06	0.06	0.37	0.37	0.37	M	0.16	0.06	0.37	0.37	0.37	M
ATBT2	0.29		-0.07	SHV	0.29	0.36	0.28	0.36	0.30	0.32	0.29	0.29	0.29	M	0.00	0.32	0.29	0.29	0.29	M
SPRL1	0.27		0.15	SHV	0.27	0.12	0.07	0.12	0.10	0.10	0.27	0.27	0.27	M	0.00	0.10	0.27	0.27	0.27	M
BNTL1	0.18		-0.14	SHV	0.18	0.32	0.22	0.32	0.27	0.27	0.18	0.18	0.18	M	0.00	0.27	0.18	0.18	0.18	M
DIBT2	0.14		0.08	SHV	0.14	0.06	0.07	0.09	0.05	0.05	0.14	0.14	0.14	M	0.00	0.05	0.14	0.14	0.14	M
PGRT2	0.14		0.06	HGX	0.14	0.08	0.07	0.08	0.10	0.14	0.14	0.14	0.14	M	0.00	0.14	0.14	0.14	0.14	M
HIIL1	0.13		-0.29	SHV	0.26	0.42	0.36	0.42	0.35	0.35	0.12	0.26	0.26	M	0.15	0.35	0.14	0.26	0.12	M
LIVT2	0.12		-0.15	HGX	0.12	0.27	0.28	0.42	0.35	0.31	0.12	0.12	0.12	M	0.00	0.31	0.12	0.12	0.12	M
LRWT2	0.09		0.09	SHV	0.09	0.00	0.03	0.05	0.00	0.00	0.09	0.09	0.09	M	0.00	0.00	0.09	0.09	0.09	M
SPHL1	0.08		0.01	SHV	0.08	0.07	0.03	0.07	0.06	0.06	0.08	0.08	0.08	M	0.00	0.06	0.08	0.08	0.08	M
HOCT2	0.07		0.03	HGX	0.07	0.04	0.03	0.04	0.05	0.08	0.07	0.07	0.07	M	0.00	0.08	0.07	0.07	0.07	M
BVCT2	0.06		0.06	EWX	0.06	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.06	M	0.00	0.00	0.06	0.06	0.06	M
GILL1	0.06		-0.04	SHV	0.06	0.10	0.06	0.10	0.08	0.09	0.06	0.06	0.06	M	0.00	0.09	0.06	0.06	0.06	M
LCAL1	0.06		-0.07	SHV	0.06	0.13	0.10	0.13	0.11	0.10	0.06	0.06	0.06	M	0.08	0.10	0.06	0.06	0.06	M
PIEL1	0.06		0.01	SHV	0.06	0.05	0.04	0.05	0.04	0.05	0.06	0.06	0.06	M	0.00	0.05	0.06	0.06	0.06	M
RREL1	0.05		-0.31	SHV	0.05	0.36	0.37	0.37	0.30	0.30	0.05	0.05	0.05	M	0.08	0.30	0.05	0.05	0.05	M
SHV	0.05		0.04	SHV	0.05	0.01	0.02	0.02	0.01	0.01	0.05	0.05	0.05	M	0.00	0.01	0.05	0.05	0.05	M
BBKT2	0.04		0.02	HGX	0.04	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.04	M	0.00	0.03	0.04	0.04	0.04	M
BEMT2	0.04		0.02	HGX	0.04	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.04	M	0.00	0.03	0.04	0.04	0.04	M
CPGT2	0.03		0.03	HGX	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M
CUET2	0.03		0.03	EWX	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	M	0.00	0.00	0.03	0.03	0.03	M
HPDT2	0.03		0.03	HGX	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	M	0.00	0.00	0.03	0.03	0.03	M
RRDL1	0.03		-0.03	SHV	0.03	0.06	0.04	0.06	0.05	0.05	0.03	0.03	0.03	M	0.00	0.05	0.03	0.03	0.03	M
ALOT2	0.02		0.02	SHV	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M
BCHL1	0.02		0.01	SHV	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	M	0.00	0.01	0.02	0.02	0.02	M
CBST2	0.02		0.02	HGX	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M
FLTL1	0.02		0.00	SHV	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	M	0.00	0.02	0.02	0.02	0.02	M
GRCT2	0.02		0.02	EWX	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M
LGNT2	0.02		0.02	EWX	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M
LGRT2	0.02		0.02	EWX	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M
SOMT2	0.02		0.02	HGX	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	M	0.00	0.00	0.02	0.02	0.02	M

Cancel

Figure 6. Gage Table listing all gages and estimates from different grid types at the gage location. Differences between gage and selected grid type/field are listed. The table can be sorted by any column value and the gage value can be edited.

The Gage Table lists each gage location on a row of the table, with the table columns containing the following:

- Gage identifier – gage location id (LID)
- Gage value – original gage value
- Edited gage value – column for editing the value for the gage; this blank cell can be set to indicate a missing value or an edited value
- Difference value – difference between the gage value and the estimate at the grid cell containing the gage for a selected grid type
- Radar identifier – indicates the radar which was used for the radar estimate
- Best value – indicates the value from the best estimate grid
- Grid values – value for each of the generated grid types for the cell containing the gage

The table can be sorted by any of the column values which can be especially helpful. For example, sorting on the difference value column can highlight inconsistent values, or sorting on the gage value column can focus on the higher value gages.

Each row of the Gage Table presents the values from multiple grid types for the single grid cell containing the gage. In a complementary fashion, the 7x7 Display presents the values for a single grid type but for multiple surrounding grid cells. Value-colored numbers are shown for a 7x7 grid cell area encompassing the gage. The grid field type being compared against can be specified by the forecaster. The forecaster can edit the gage value numerically or set it to missing or "bad" so the location will not be used in later analyses.

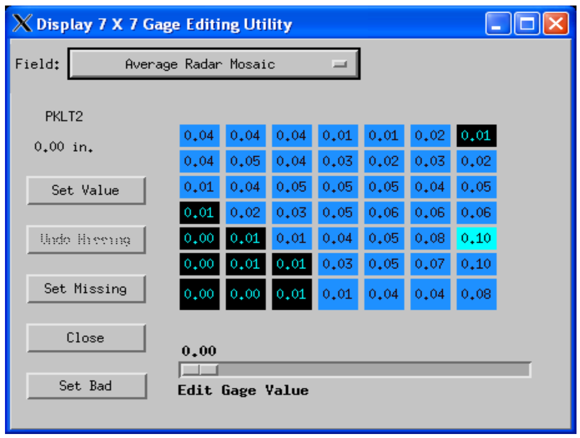


Figure 7. 7x7 Gage Table for selected gage. The gage value is noted in the top left corner and the 7x7 grid contains value-colored values from the selected grid type/field. The forecaster edits the gage value as necessary.

4.3 RFC DISTRIBUTION OF RADAR BIAS

As mentioned above, a mean field bias value is computed for each hour and for each radar. It indicates whether the radar is over or under-estimating the precipitation, based on a mathematical trend analysis of the gage and radar values. The bias value is transmitted to the Radar Product Generator (RPG) for use as supplemental information for radar precipitation products distributed to external customers and for other NWS purposes. Historically, the bias was computed at the WFO as it is networked to the RPG. However, many WFOs do not perform the proper gage quality control, which often leads to inaccurate bias values.

In order to provide the best bias information to all users, the MPE software was modified to allow the RFC to transmit its bias values to the WFO. From there, the WFO system can use the RFC-computed bias instead of its own computed bias and transmits the RFC bias to the RPG. In addition to improving the quality of the bias information in the RPG supplemental radar products, this also improves the quality of the WFO MPE estimates. The RFC invokes this transfer of bias information using newly provided interactive controls. This transfer can be configured to be performed automatically.

4.4 RFC DISTRIBUTION OF QPE GRID

MPE precipitation grids can be displayed and edited in the MPE_Editor, and displayed in the AWIPS hydrologic viewing tool, HydroView. Recent changes allow the forecaster to also display locally-generated and RFC-generated MPE products in the predominant AWIPS data viewing tool, Display-2-Dimensions (D2D). Viewing MPE products within the widely used D2D is desirable as the data can be overlaid with other hydrometeorological products. Viewing RFC MPE products at the WFO is desirable because RFC products are of higher quality than the WFO. Using interactive and automated options, each RFC can configure the transfer of their products. Together, the gridded best estimate and bias information sent from the RFC provide the WFO with the highest quality QPE information.

4.5 OTHER INTERACTIVE ENHANCEMENTS

Miscellaneous interactive features added to MPE include the following:

- Ability to add forecaster-specified multi-hour periods of selected grid types
- Ability to intelligently manage displayed color of annotated gages and gridded field values
- Improved ability to zoom into selected areas, and display grids using split screen for comparison

5. NEW MULTI-HOUR QUALITY CONTROL OF STATION DATA

The previous sections described gridded data generated using objective analysis and bias adjustment techniques. The station-based methods of the "DailyQC" mode produce quality-controlled station data, or grids computed using distance and PRISM-weighted station data for use by the river forecast models.

This section discusses the DailyQC mode. Besides using different algorithms, it differs from the hourly mode in that it focuses on station gage measurements rather than radar or satellite data. Also, it operates in multi-hour mode, though it has an option to generate hourly estimates. The primary functions of the DailyQC mode are:

- QC of 6-hour and 24-hour station precipitation data
- QC of instantaneous and daily maximum/minimum station temperature data
- QC of 6-hour freezing level data, using Rapid Update Cycle (RUC) model data mapped to virtual stations
- Time distribute 24-hour precipitation gage values to 6-hour values

The DailyQC preprocessor retrieves station data and performs automated quality control checks on the data. The data are then displayed in the MPE_Editor on a map. Values are color-coded by their assessed quality "level", as shown in Figure 8. The forecaster can filter the displayed stations based on value, elevation, station type, and quality code. Individual values are reviewed and pop-up edit windows allow further analysis and data edits. Monthly PRISM data for total precipitation and maximum and minimum temperature are used in estimating missing station values and in the QC checks. Using objective analysis, grids can be rendered from the station data and mean areal values for precipitation, temperature, and freezing level (i.e. MAP, MAT and MAZ, respectively) can be derived.

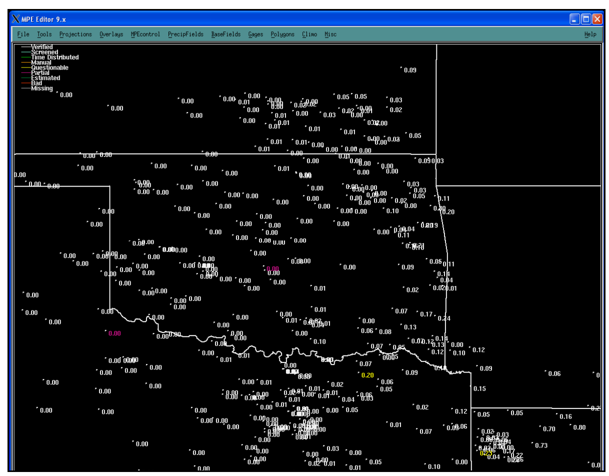


Figure 8. Main MPE/DQC display with color coded gage values.

5.1 QUALITY CONTROL INTERACTION

Gross range checks are applied against all data to ensure general data validity. More specific automated checks are then performed, with different tests applied to different data elements. The results are presented to the forecaster for consideration during the review process. For precipitation data, the following checks are applied:

- Spatial Consistency Check – If the difference between the reported value and a distance-weighted estimated value based on the 30 closest stations exceeds a threshold, the value is marked as "questionable"
- Temporal Consistency Check – If the difference between the 24-hour value and the sum of the four 6-hour values exceeds a threshold, the station is marked as "temporally inconsistent"
- Sensor Consistency Check – If the difference between two values from multiple sensors at the same location exceeds a threshold, then the values are marked as "spatially inconsistent"

For temperature data, only a spatial consistency check is applied. No automatic QC checks are done on the freezing level data.

Once the forecaster selects the data element to display, the data are displayed on a map with values color-coded by the quality code. The forecaster selects a station and opens the editor window. The precipitation edit window is shown in Figure 9. For precipitation and temperature data, an estimated value based on neighboring stations is computed and shown, along with climatological normal values. The user can also display a time series graph to review the temporal trend of a single station. Freezing level data can also be edited, although no associated estimated or climatological values are provided.

The forecaster judges the spatial and temporal consistency of the data, considering the estimated and normal values, and accepts or resets the value or its quality control level. This process is repeated for all stations and represents the core activity within the DailyQC mode.

5.2 DATA VALUE ESTIMATION

For each precipitation and temperature station, an estimated value is determined and shown to the forecaster for reference when evaluating station data quality. Also, this estimated value is used if a value is missing. For precipitation data, the neighboring station data are used along with the PRISM normal values. For temperature data, the neighboring station data are used and a lapse rate is applied.

For gridded data, similar operations take place when rendering a grid from the station values. For each cell in the grid, an inverse-distance weighting method is used for all three weather elements. Additionally, when rendering precipitation and temperature grids, the method considers PRISM normal values, and the temperature grid rendering also applies a simple lapse rate factor.

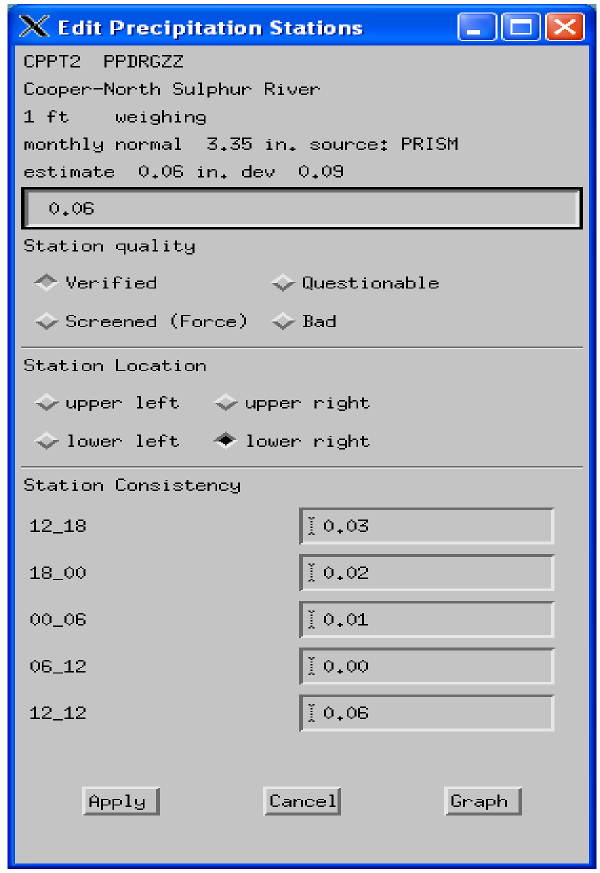


Figure 9. Edit Precipitation window. The actual value is shown in upper text box, with station characteristics, estimated and normal values, station quality code, and adjacent time period values also shown.

5.3 DAILYQC PRODUCTS

After the data for all three elements are reviewed, the application can generate the data in different forms for subsequent use in river modeling or other operations. Data forms include station gage data, mean areal data, and gridded data as follows:

- Station gage
  - precipitation (6-hour and 24-hour)
  - temperature (6-hour and daily maximum/minimum)
  - freezing level (6-hour)
- Mean areal
  - precipitation (6-hour)
  - temperature (6-hour)
  - freezing level (6-hour)
- Gridded
  - precipitation (6-hour, 24-hour)
  - temperature (6-hour, daily maximum/ minimum)
  - freezing level (6-hour)

5.4 DISAGGREGATION POST-PROCESSING

A new disaggregation option within the DailyQC processing disaggregates 6-hour precipitation gage values to 1-hour values. This disaggregation processing is done in an automated fashion using one of two algorithms. Both methods use neighboring values to define the hour-by-hour time distribution of the 6-hour value.

The gridded method uses the average of the values from (9) surrounding grid cells to define the hourly distribution of the 6-hour gage value. All surrounding grid cells are assigned an equal weight. The neighboring-station method uses neighboring hourly station values which are weighted by distance and by monthly normal PRISM precipitation.

The chosen algorithm is applied against a pre-defined list of 6-hour stations. Their 6-hour values are then time-distributed to generate the 1-hour gage values. These values are saved and made available for use in subsequent runs of the MPE gridded hourly analysis. This represents a rare direct connection between the hourly and DailyQC modes.

6. END-TO-END PRODUCT PROCESSING

The full end-to-end approach for creating and using the data sets varies by RFC. The MPE_Editor process is scheduled per local policy, but is commonly sequenced to precede the river forecast model runs, which execute at least 2-3x/day. The order and steps followed within an MPE_Editor session can vary by region, office, forecaster, and event.

The precipitation, temperature, and freezing level data sets ultimately generated can take different forms. The Gridded Hourly mode generates hourly grids, while the DailyQC mode generates multi-hour data in either station, mean areal, or gridded form. The choice of which mode and which form to use depends on the configuration of the forecast models which use the data. River model pre-processors are available for using either gridded or station quality-controlled estimates. The RFCs local policy also determines how they will distribute the grids and the radar bias values for external use.

6.1 SUPPLEMENTAL QPE USES

In addition to supporting river forecast models, the precipitation data sets have additional, external uses. As part of the NWS Verification Program, QPE grids are sent to the National Precipitation Verification Unit (NPVU; http://www.hpc.ncep.noaa.gov/npvu/), where they are used to verify coincident Quantitative Precipitation Forecast (QPF) data. Grids are also made available to NCEP where they are used for atmospheric model data assimilation and for generating a national mosaic. QPE grids are also retained at other agencies, including the NOAA National Climatic Data Center (NCDC) and the National Aeronautics and Space Administration (NASA).

The QPE grids are also accessible through a public web interface, as part of the web presence for the Advanced Hydrologic Prediction Service (AHPS). By accessing the "precipitation" tab at http://www.weather.gov/ahps/, one can view images like the one shown in Figure 10. Downloads of current or archived precipitation data for the entire CONUS and Puerto Rico are supported. Comparisons of multiple-day estimates with PRISM normal estimates can be generated. This web page is referenced by other web services, allowing a large audience to use the data.

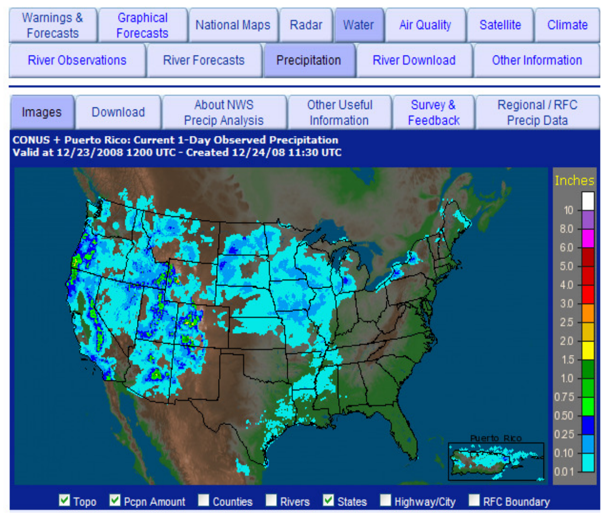


Figure 10. Web graphic of national 1-day observed precipitation mosaic. (from weather.gov, water-precipitation tab)

7. FUTURE PLANS

This paper described the many changes to the MPE application suite completed over the last few years. More changes to the functionality, along with expanded use of the products, are envisioned for the future.

Functional changes will be needed as part of the NWS Community Hydrologic Prediction System (CHPS) being deployed in late 2009. CHPS will provide a new extensible framework for executing hydrologic models and operations. The existing method for using quality-controlled station data within the modeling system will be retired. Instead, the precipitation, temperature, and freezing level data will be expected solely in gridded form. MPE_Editor is one of the core tools that will provide this gridded data and extensions to its current functionality will likely be required. Other functional changes will be required to adapt to the new radar product suite provided by the introduction of dual polarization radar capabilities, planned for late 2010.

Expanded use of the products is expected with the use of distributed hydrologic modeling in CHPS. By its nature, distributed modeling depends on gridded forcings of the kind that MPE produces. Planned water resources activities such as river-estuary-ocean (REO) modeling will also benefit from use of gridded precipitation. Increased usage from external customers, whether through linked web pages or through direct use of publicly available products, is expected as awareness of the availability of high-quality precipitation data increases.

8. SUMMARY

The MPE suite of applications provides an extensive set of quality control operations for precipitation, temperature, and freezing level data. Over the last few years, major changes to the system have been implemented, including new products, new interactive features, new data transfer mechanisms, and support for new durations and weather elements. Together these changes provide a more comprehensive and useful system for NWS field office generation of critical data sets used within the NWS water resources program and by external customers.

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