Activities and Plans to Improve WSR-88D Rainfall Estimation and Forecasting in the National Weather Service

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Office of Hydrologic Development
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Outline

- OHD staff and funding resources dedicated to Quantitative Precipitation Estimation (QPE) enhancement
- Near-term (0-2 yrs) Precipitation Processing System (PPS) and Multisensor Precipitation Estimator (MPE) enhancements
- Long-term (3+ yrs) QPE science frontiers
- 0-6 hour Quantitative Precipitation Forecasting for the flash flood program

Mission Statement

Hydrometeorology Group

To develop and apply cutting-edge scientific rainfall analysis and forecast techniques using WSR-88D radar and hydrometeorological data sources to improve hydrologic operations and products

Scientific Staff Resources

Hydrometeorology Group
Hydrologic Science and Modeling Branch

- Richard Fulton, meteorologist, team leader
- Chandra Kondragunta, meteorologist
- Dong-Jun Seo, hydrologist (UCAR) (60%)
- Feng Ding, meteorologist/computer specialist (RSIS...started in January)
- GS-13 vacancy (not yet advertised)
- Need for new full-time UCAR scientist

Software Engineering Staff Resources

AWIPS and NEXRAD Groups
Hydrologic Software Engineering Branch

- Paul Tilles (MPE)
- Bryon Lawrence (MPE)
- Moria Shebsovich (MPE) (contractor)
- Dennis Miller (PPS)
- Jihong Liu (PPS) (contractor)
- Cham Pham (PPS+MPE) (contractor)
- Scott Vandemark (PPS)

Scientific R&D Funding Support for QPE Enhancement

- Advanced Hydrologic Prediction Services (AHPS) FY02
  - Probabilistic/Ensemble QPE - $45k - external contractor
  - Statement of Work at http://www.nws.noaa.gov/oh/hrl/papers/wsr88d/031302.htm
- AHPS FY03
  - Probabilistic/Ensemble QPE - $45k - ext. contractor
  - Enhance MPE to Support Flash Flood Services -$100k - internal contractor
  - Multisensor Precipitation Nowcaster (MPN) -$40k -internal contractor
  - Polarimetric QPE - requested $60k, got $0k
- Other funding from NEXRAD Product Improvement (NPI) program, AWIPS, and WSR-88D Radar Operations Center

American Meteorological Society's Short Course on QPE and QPF

13 January 2002 Orlando, Florida

http://www.nws.noaa.gov/oh/hrl/presentations/amsshortcourse/index.html

- Overview of operational rainfall estimation procedures
- Scientific techniques for estimating precipitation
- Improving radar rainfall estimates using rain gauges and satellite data
- Review of operational satellite rainfall estimation algorithms
- Introduction to quantitative precipitation forecasting
- Factors determining efficiency and rainfall intensity
- Forecasting precipitation associated with mesoscale convective systems
- Calibration of forecasts

5-Year Science Infusion Plan for Improved Quantitative Precipitation Estimation in the National Weather Service

- Draft plan located at http://www.nws.noaa.gov/oh/hrl/papers/papers.htm#wsr88d
- Related paper for 2002 Federal Interagency Hydrologic Modeling Conference at http://www.nws.noaa.gov/oh/hrl/papers/wsr88d/qpe_hydromodelconf_web.pdf
- Comments on future directions are welcome
- Other WSR-88D rainfall estimation publications, training course materials, and presentations are available on-line at http://www.nws.noaa.gov/oh/hrl/papers/papers.htm#wsr88d

Recent Precipitation Processing System (PPS) Enhancements

Build 1, WSR-88D Open RPG
Field Deployment in Progress

- Fixed integer-truncation bug
  - Improves rainfall products for light, long-lasting stratiform rainfall events
  - Description of problem at http://www.nws.noaa.gov/oh/hrl/papers/2001mou/MOU01_PDF.html and .../papers/2000mou_pdf/MOU00_PDF.html
  - Quantitative evaluation of old vs new DPA products is in progress
  - Forecast office perceptions of performance improvement are welcome

Near-term PPS Enhancements

Build 2, WSR-88D Open RPG
Field Deployment beginning Fall 2002

- Gauge-radar mean field biases will be automatically passed from WFO's AWIPS MPE back to PPS within the local WSR-88D ORPG(s)
  - First time ever that PPS graphical rainfall products will be gauge-bias-adjusted (WFO forecasters can choose to apply bias or not)
  - Once per hour (H+25) or whenever forecaster manually reruns MPE
  - Biases will not be applied to rainfall amounts in Digital Precipitation Array (DPA) products (bias written in product header for ext. users)
  - Will require WFO forecasters to monitor radar and raingauge data quality if they hope to make quantitative use of rain gauge data to calibrate their radar rainfall products
  - Dependent on AWIPS 5.2.2 delivery of MPE to WFOs

Near-term PPS Enhancements (cont.)

Build 3, WSR-88D Open RPG
Field Deployment beginning Spring 2003

- New PPS product: Digital Storm-total Precipitation (DSP)
  - 256-data-level digital counterpart to the existing 16-level graphical Storm Total Precipitation (STP) product
    - The only other PPS digital rainfall product besides DPA suitable for follow-on quantitative applications
  - Polar 2-km x 1-deg grid (raw resolution of PPS algorithm)
  - Generated every volume scan
  - Differencing of consecutive products can produce accumulations of any arbitrary duration desired (e.g., 5-min, 30 min, 1.5-hr, 2-hr, 24-hr)
  - Will expand future follow-on QPE hydrologic processing potential beyond existing legacy algorithms dependent on the DPA
  - Available for use in hydrology applications outside of the WSR-88D to enhance flash flood services
    - Future versions of MPE at the WFOs
    - Distributed hydrologic models
    - Flash Flood Monitoring and Prediction
    - Other value-added flash flood applications outside of NWS

Longer-term PPS Enhancements

Build 4, WSR-88D Open RPG
Field Deployment in Fall 2004

- Implement new Range Correction Algorithm (RCA)
  - To correct rainfall products for nonuniform vertical reflectivity profiles
  - Biggest benefits for cool season, stratiform rain events with brightband
- Enhanced PPS Preprocessing sub-algorithm (EPRE)
  - To allow PPS to accomodate the proposed new, variable WSR-88D antenna scanning patterns (no new science here, but improved processing efficiency)
- Improved removal of anomalous propagation (AP) contamination
  - Use of new fuzzy-logic Radar Echo Classifier (REC) algorithm to define *local* regions of non-raining echoes
  - Will replace legacy PPS Tilt Test technique
- Improved automated Precipitation Detection Function for PPS
  - Use of REC's AP-corrected reflectivity hybrid scan (instead of base reflectivity) to determine when rainfall starts accumulating in PPS
  - Manual forecaster adjustment of WSR-88D's Nominal Clutter Area will no longer degrade PPS rainfall accumulations
  - No impacts on radar scanning since changes impact PPS only

Multisensor Precipitation Estimator (MPE) Enhancements

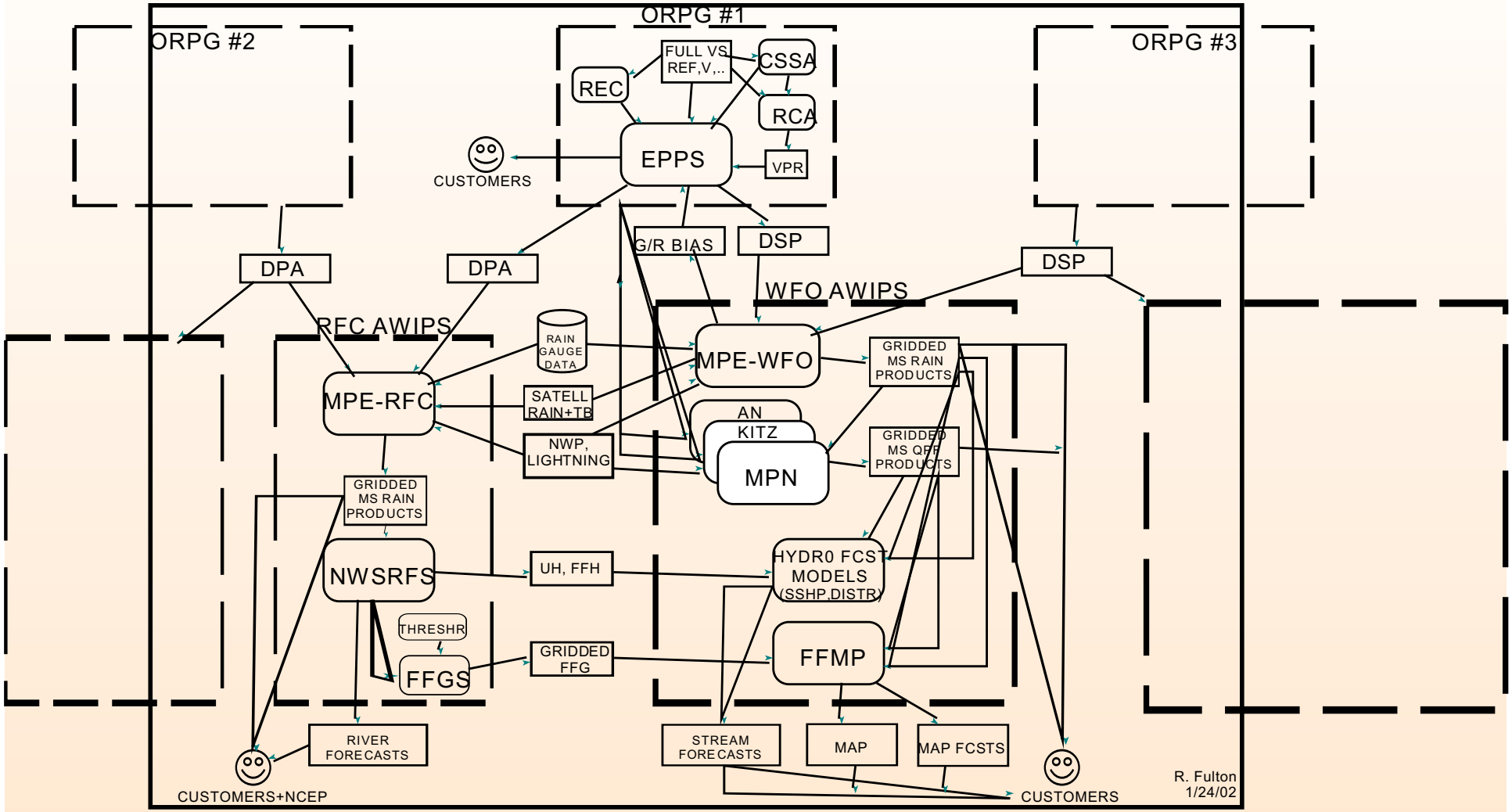
No longer referred to as “RFC-Wide”

- Incorporate satellite QPEs (SPEs) into MPE
  - Initial deployment in next build after AWIPS 5.2.2
    - HRAP-gridded NESDIS AutoEstimator SPEs will be D2D displayable in 5.2.2
  - Using optimal estimation, regression, or neural network multisensor merging techniques currently under evaluation
- Deliver MPE to WFOs and enhance it to serve flash flood monitoring needs of the WFOs
  - First version: Hourly 4-km regionally-mosaicked multisensor products (same as RFC capability)
  - Next version: Shorter accumulation periods and update times (minutes) and higher spatial resolution (1 km=1/4 HRAP)

Comparisons of future RFC and WFO implementations of the Multisensor Precipitation Estimator

	MPE-RFC	MPE-WFO
WSR-88D product input	DPA (range-corrected)	DSP (range-corrected)
Frequency of execution	Once/hour at H+00	Every 5-15 minutes
Rain accumulation durations	1 hour	15, 30 mins, 1, 3,6, 12, 24 hrs (user selectable)
Number of radars used	1 to many (to cover RFC)	1 to many (to cover CWA)
Spatial resolution	4 km (HRAP)	1 km (1/4 HRAP)
Rain gauge adjustment duration	Hourly to seasonal	Hourly to seasonal
Products	Hourly rainfall accumulation: 1) Multisensor (radar+gauge+satellite) 2) Radar-only 3) Gauge-only 4) Satellite-only 5) Mean-field-bias-adjusted radar 6) Local bias-adjusted radar 7) Local bias-adjusted satellite	15-minute through 24-hour rainfall accumulations: 1) Multisensor (radar+gauge+satellite) 2) Radar-only 3) Gauge-only 4) Satellite-only 5) Mean-field-bias-adjusted radar 6) Local bias-adjusted radar 7) Local bias-adjusted satellite
Purpose/Use	River monitoring and forecasting	Flash flood monitoring and forecasting

Future Vision for QPE in the NWS
Driven by Different RFC and WFO Requirements



Major NWS QPE-related Science Frontiers For Next 5-10 Years

- Higher spatial and temporal resolution QPE products to better support the WFO flash flood warning program (PPS: 1/4 km X 1/2 deg; MPE: 1/4 HRAP, 5-15 minute accumulations and updates)
- Automated tuning of QPE algorithm input parameters (e.g., Z-R parameters) based on meteorological data to optimize QPEs
- Use of other observed meteorological data (soundings, surface observations, lightning) and atmospheric model analysis fields to improve QPE analyses (e.g., rain vs snow, freezing level ident.)
- Polarimetric QPE algorithms (JPOLE and beyond)
- Real-time, on-the-fly validation and performance monitoring of multisensor QPE products and algorithms
- Probabilistic/Ensemble QPE algorithms
- Improved automated quality control algorithms for radar, rain gauge, and satellite rainfall data
- Snowfall estimation algorithms

State-of-the-Art Technology for Short-term QPF To Support Flash Flood Warning

QPN=Quantitative Precipitation Nowcasts (0-6 hours)

- Steady-state, deterministic **extrapolation** of current radar rainfall patterns has been the accepted standard in the 0 to 1-6 hour forecast periods (data driven)
  - Convective rainfall: ~1 hour predictability limit
  - Stratiform rainfall: ~6 hour predictability limit
- Existing NWS operational QPN algorithms are limited to single-radar-site:
  - WSR-88D Storm Cell Identification and Tracking (SCIT) algorithm (no QPF products)
  - MDL's AWIPS statistical-extrapolative 1-hr QPN algorithm
- Atmospheric model QPF performance in the 0-6 hour forecast period is poor but improving steadily
- Successfull operational rainfall nowcast algorithms in UK Met Office merge radar-extrapolated rainfall with atmospheric model-generated QPFs in the ~1-6 hour "no-man's land" of unpredictability
  - And they are linked to hydrologic models for flash flood warning guidance
- Current research focuses on accounting for storm initiation, growth, and decay
  - Algorithms are complicated and CPU expensive
  - Marginal benefit over steady-state techniques is dependent on ability to observe airmass boundaries using radar and/or satellite data
- Assimilation of observed radar reflectivity and velocity into storm-scale atmospheric models is another active research area to improve QPNs

Multisensor Precipitation Nowcaster (MPN)

Provides Short-term QPFs for Additional
Flash Flood Warning Lead Time

- Will generate gridded 1-km deterministic rainfall forecasts out to 30 minutes to 2 hours in the future, updated every 5-15 minutes
- Will use the observed DSP-based rainfall estimates from MPE-WFO as the main driving input
  - Leverages on MPE's advanced rainfall estimation technology (multiradar mosaicking, multisensor rainfall from radar, rain gauges, & satellite, range- and bias-corrected estimates)
- Based on *local* extrapolation of MPE multisensor radar rainfall echoes
  - Accounting for local motion is important since flash flood-producing storms often exhibit anomalous movement relative to their neighbors
- Accounts for storm growth and decay (but not initiation)

Where Should We Go with QPN in NWS to Increase Flash Flood Warning Lead Times?

- Implement simpler extrapolation algorithms to serve as baseline for QPN performance
  - MDL's statistical-extrapolative QPN algorithm
  - HL's extrapolative Multisensor Precipitation Nowcaster (MPN)
- Implement advanced fuzzy logic QPN algorithms as they become operationally viable
  - NCAR's Autonowcaster
- Measure & evaluate marginal benefit relative to extrapolative algorithms to learn strengths & weaknesses
- Implement probabilistic short-term QPN techniques
- Assimilate these short-term rainfall forecasts into distributed hydrologic models to provide additional warning lead time

Conclusions

- The Hydromet Group is involved in a wide variety of WSR-88D QPE and QPF science activities that will lead to improved RFC and WFO hydrologic operations
- Much more work remains to be done...