Multisensor Precipitation Estimator (MPE)

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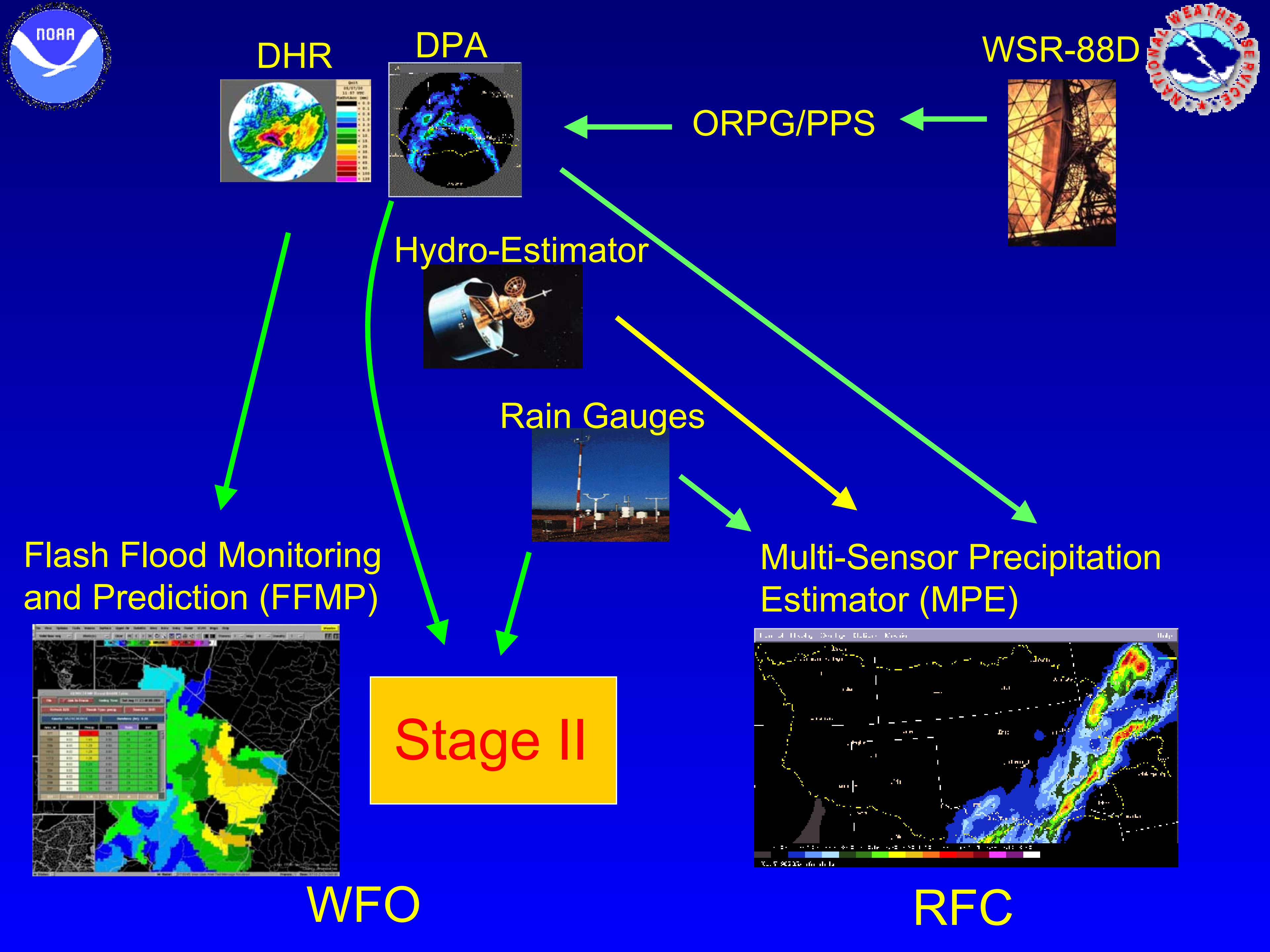
Silver Spring, MD

NWS Flash Flood Workshop, Aug 27-29, 2002

In this presentation

- What is MPE?
- How has MPE come about?
- What can MPE do now?
- What are the upcoming improvements?


DHR
DPA
WSR-88D
ORPG/PPS
Hydro-Estimator
Rain Gauges
Flash Flood Monitoring and Prediction (FFMP)
Stage II
Multi-Sensor Precipitation Estimator (MPE)
WFO
RFC

MPE

- Replaces Stage II/III
- Based on;
  - operational experience
  - new science
  - existing and planned data availability from NEXRAD to AWIPS and within AWIPS
  - ‘multi-scale’ accuracy requirements (WFO, RFC, NCEP, external)

More accurate QPE

More accurate flood forecast,

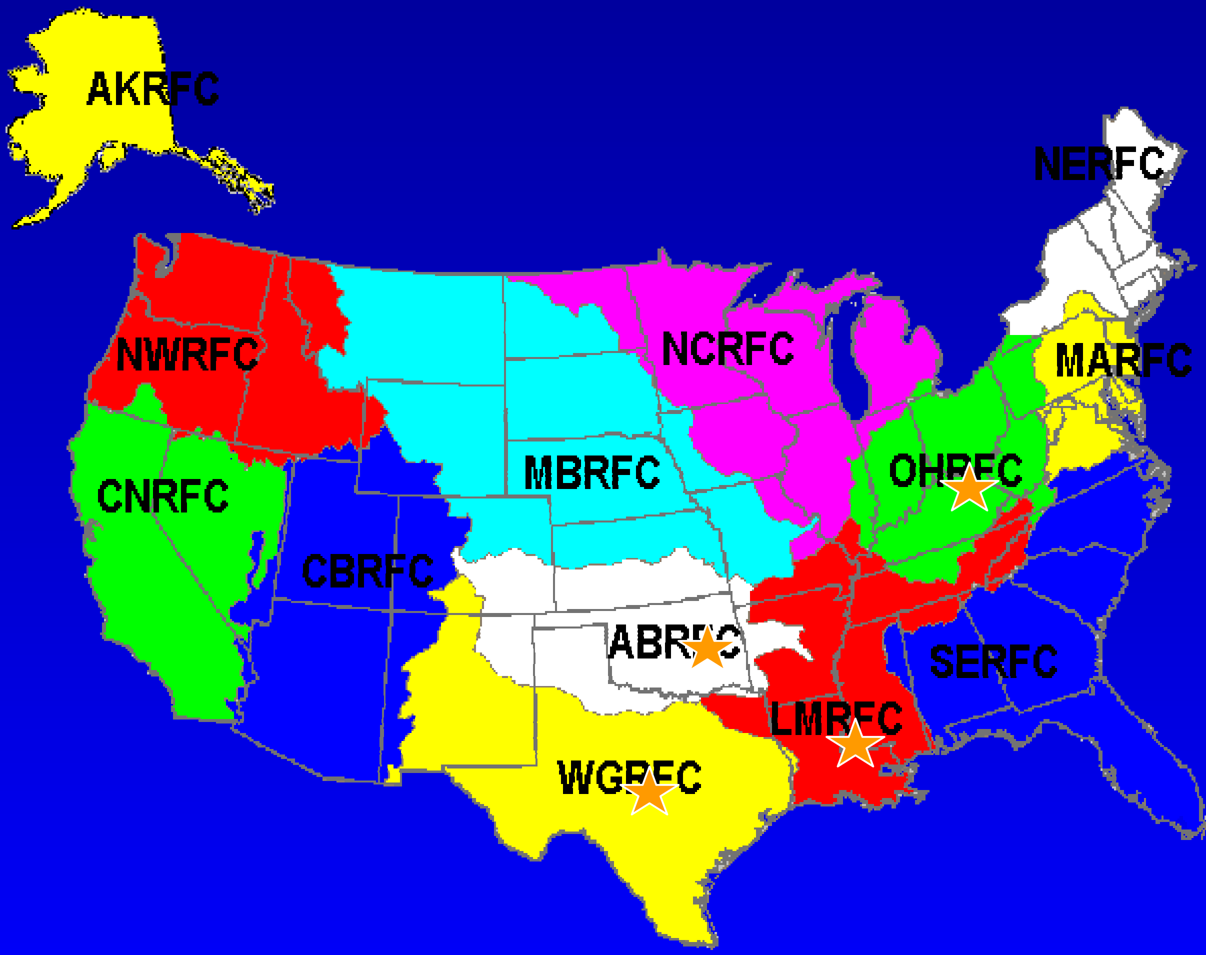
Longer flood forecast lead time

Improved QPF

Driving Issues

- Systematic errors in WSR-88D (i.e. radar-only) rainfall estimates;
  - in detection of precipitation
  - in estimation of (in particular, large) precipitation amount

Use of Radar-Based/Aided Precipitation Estimates In Quantitative Hydrologic Forecasting



WSR-88D Rainfall Estimates

Issue 1 - Systematic errors in rainfall detection

- Sources
  - beam overshooting
  - beam blockage
  - uncertainty in locating beam blockage
  - uncertainty in locating, quantifying, and correcting partial beam blockage

Issue 2 - Systematic errors in rainfall estimates over a large area

- Sources
  - lack of radar calibration
  - uncertainty in the Z-R relationship
  - vertical profile of reflectivity (VPR)

Issue 3 - Systematic errors in rainfall estimates over small areas

- Sources
  - space-time variability in the Z-R relationship
  - hail
  - vertical profile of reflectivity (VPR)
  - ground clutter and ground clutter suppression
  - truncation error

Stage II/III vs MPE

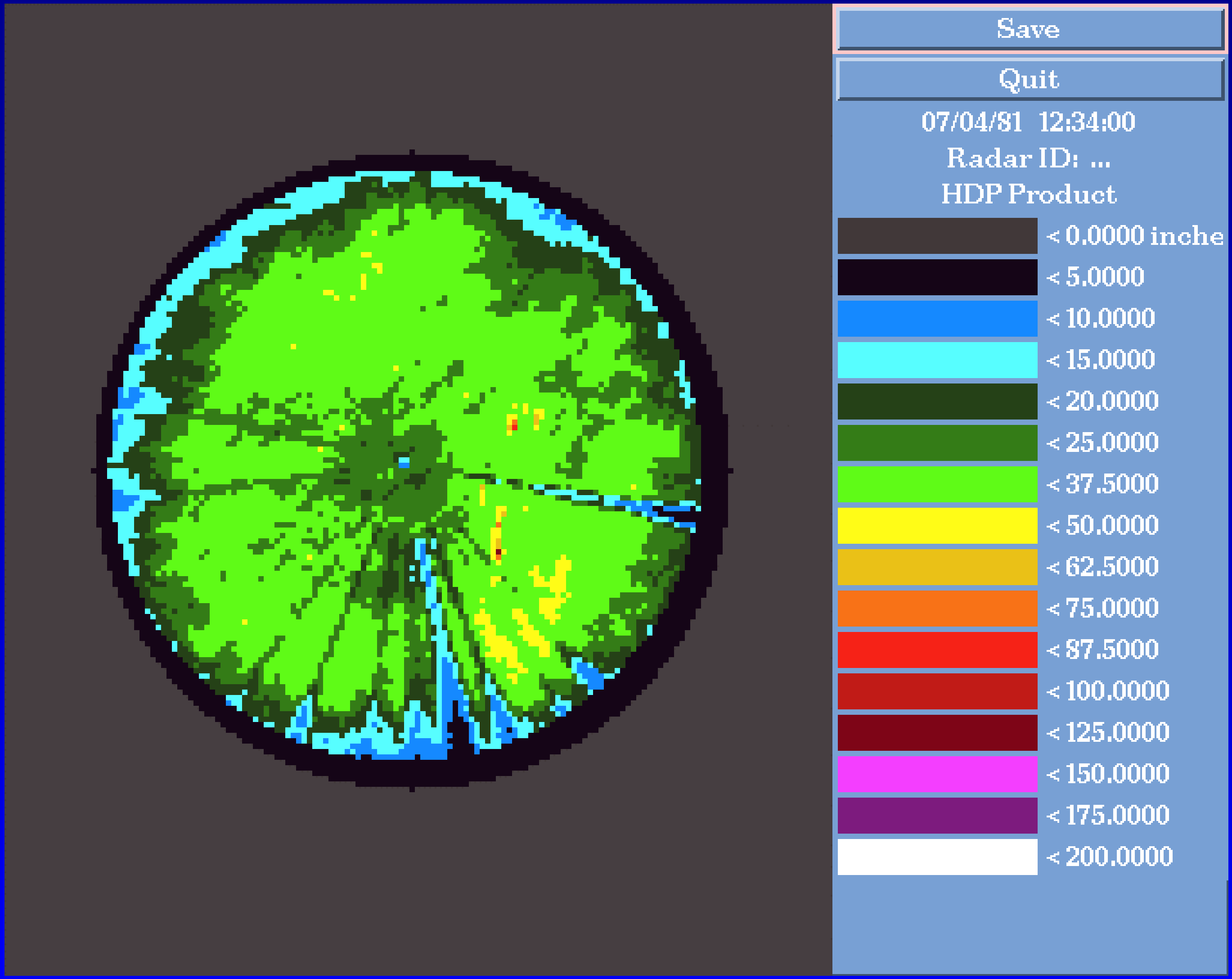
- No delineation of effective coverage of radar
- Radar-by-radar precipitation analysis
- Mosaicking without radar sampling geometry accounted for

- Delineation of effective coverage of radar
- Mosaicking based on radar sampling geometry
- Service area-wide precipitation analysis
- Improved mean-field bias correction
- Local bias correction (new)

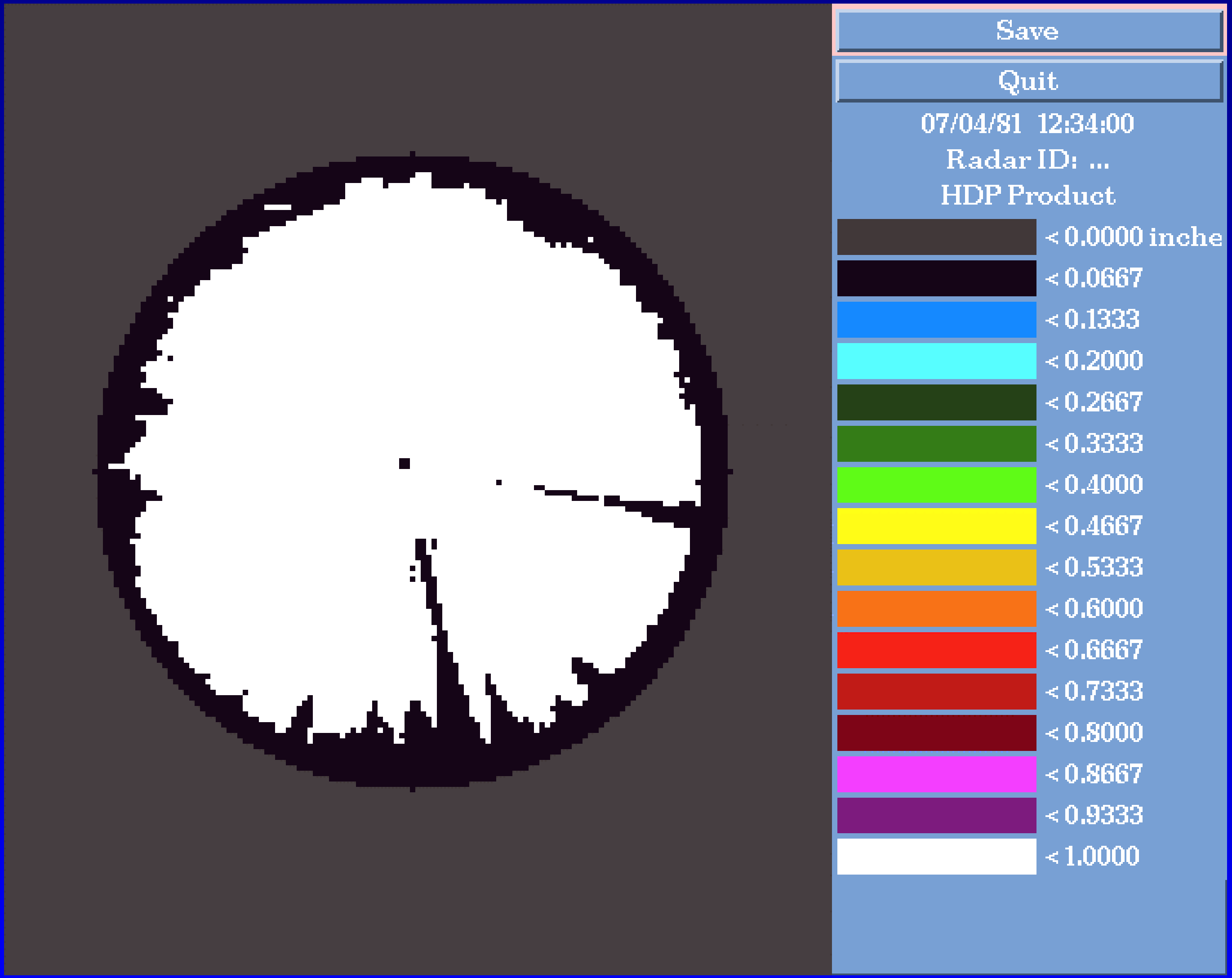
Delineation of Effective Coverage of Radar

- Addresses Issue 1
- To limit the quantitative use of radar data to those areas where radar can ‘see’ precipitation consistently
- Based on multi-year climatology of Digital Precipitation Array (DPA) product

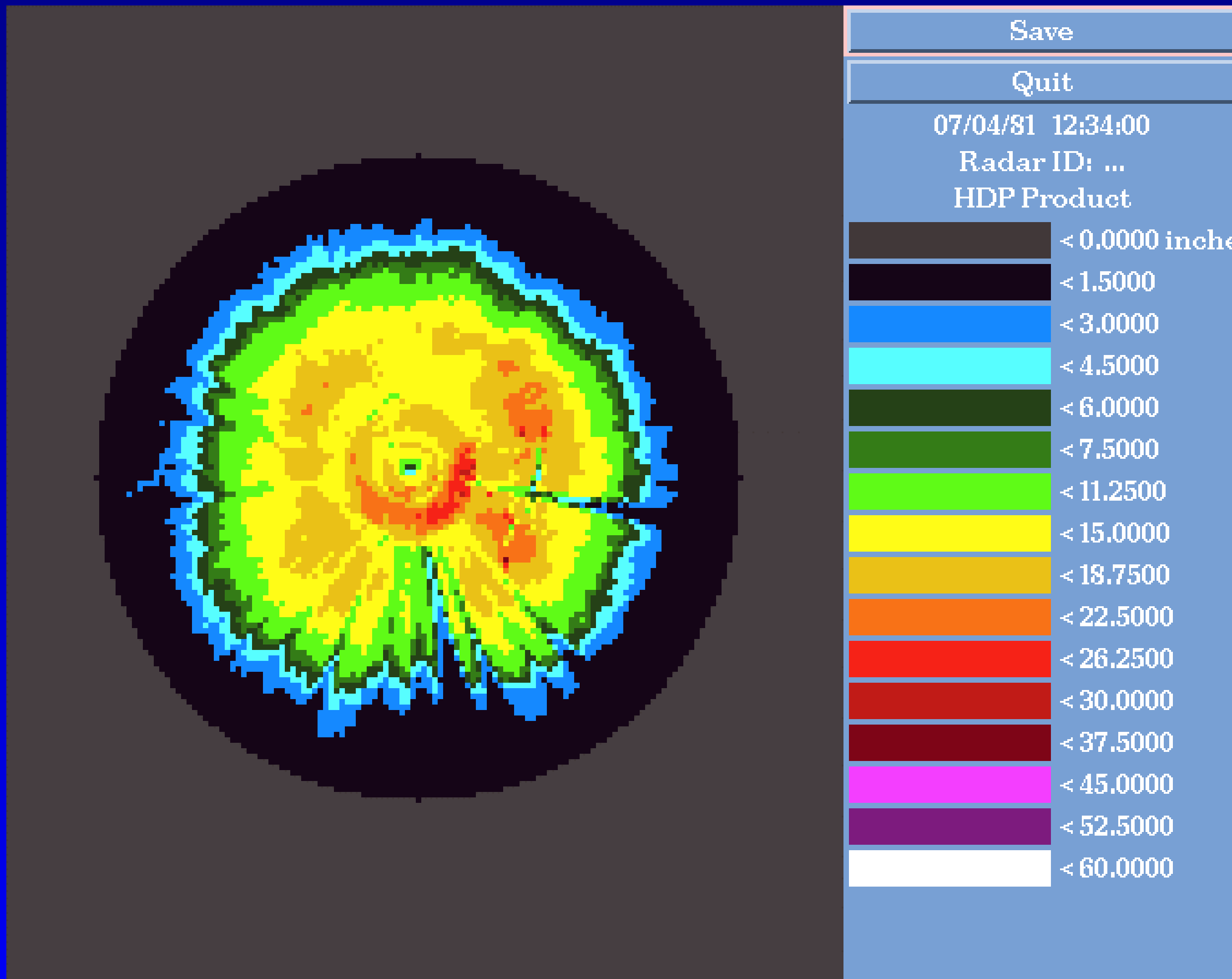
Radar Rainfall Climatology - KPBZ, Warm Season



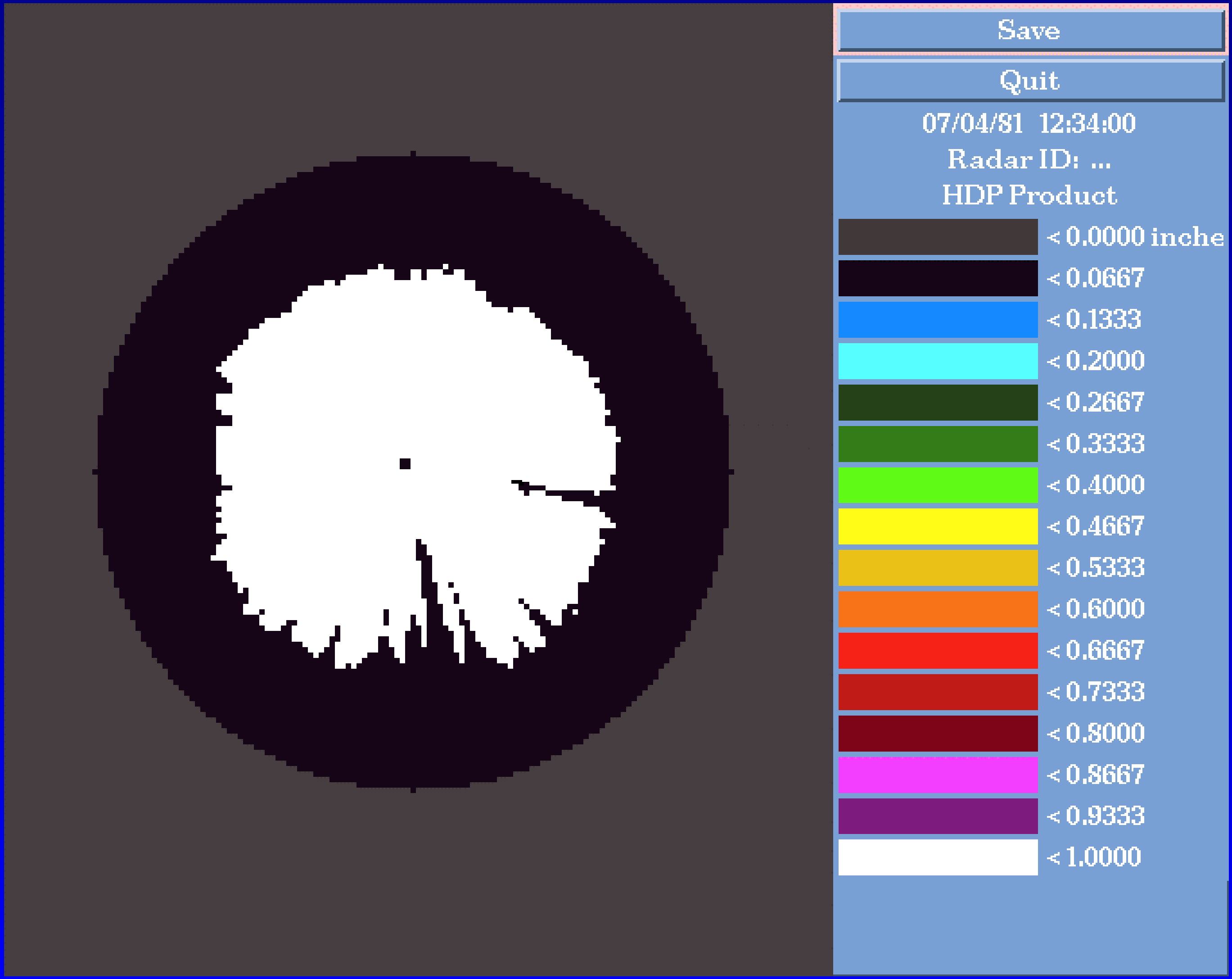
Effective Coverage - KPBZ, Warm Season



Radar Rainfall Climatology - KPBZ, Cool Season



Effective Coverage - KPBZ, Cool Season



RadClim

- A software package to;
  - process long-term DPA data
  - display various statistics
  - display hybrid scan sectors and occultation tables
  - display PRISM data
  - delineate effective coverage (if necessary, via manual-editing)

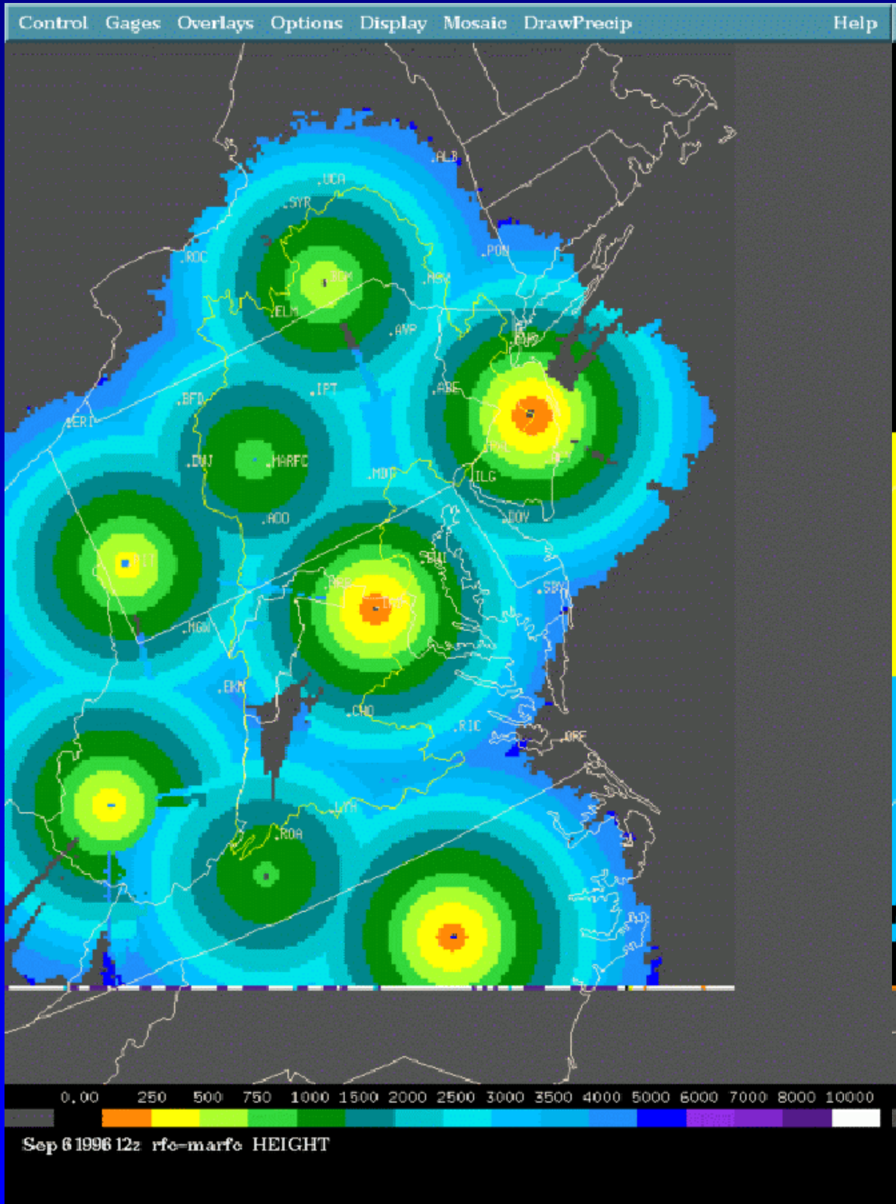
Mosaicking Based on Sampling Geometry of the Radars

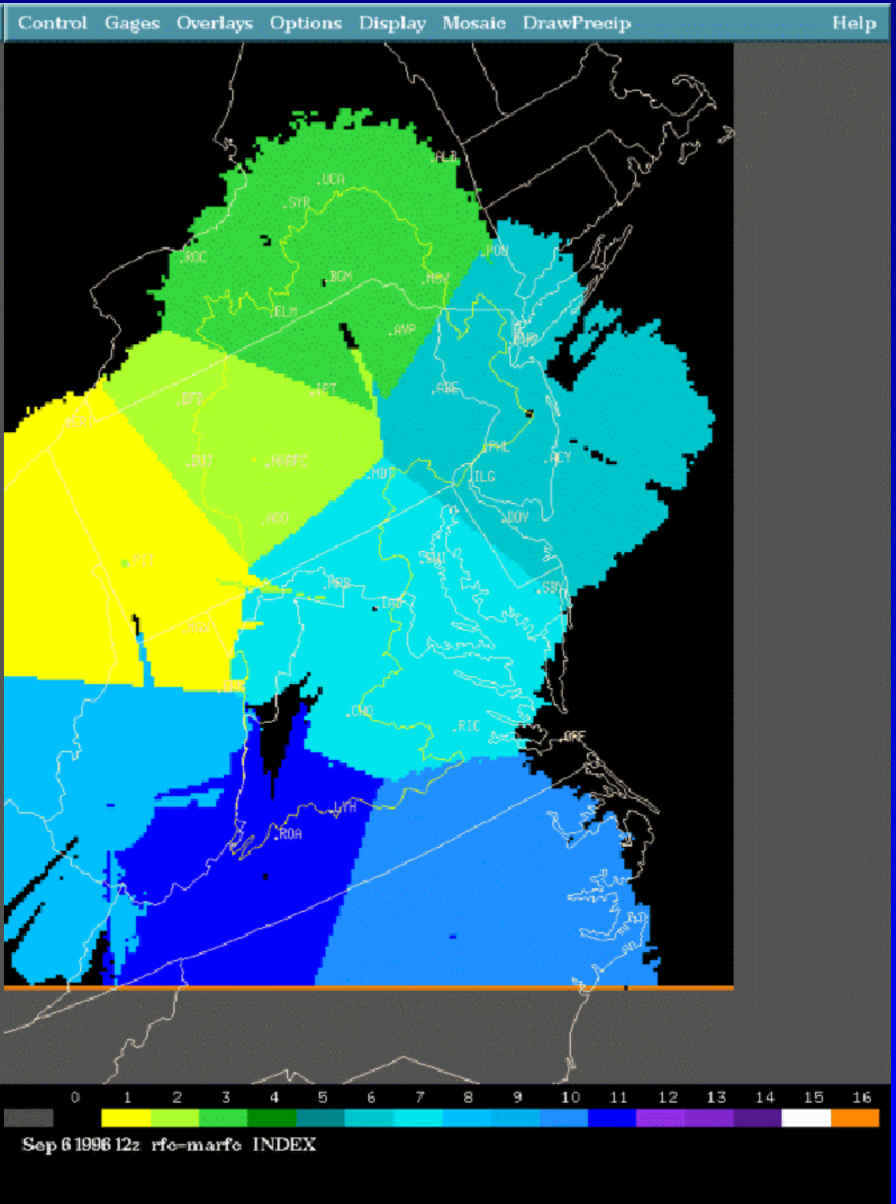
- In areas of coverage overlap, use the radar rainfall estimate from the lowest unobstructed sampling volume

Mid-Atlantic River Forecast Center (MARFC)

Height of Lowest Unobstructed Sampling Volume

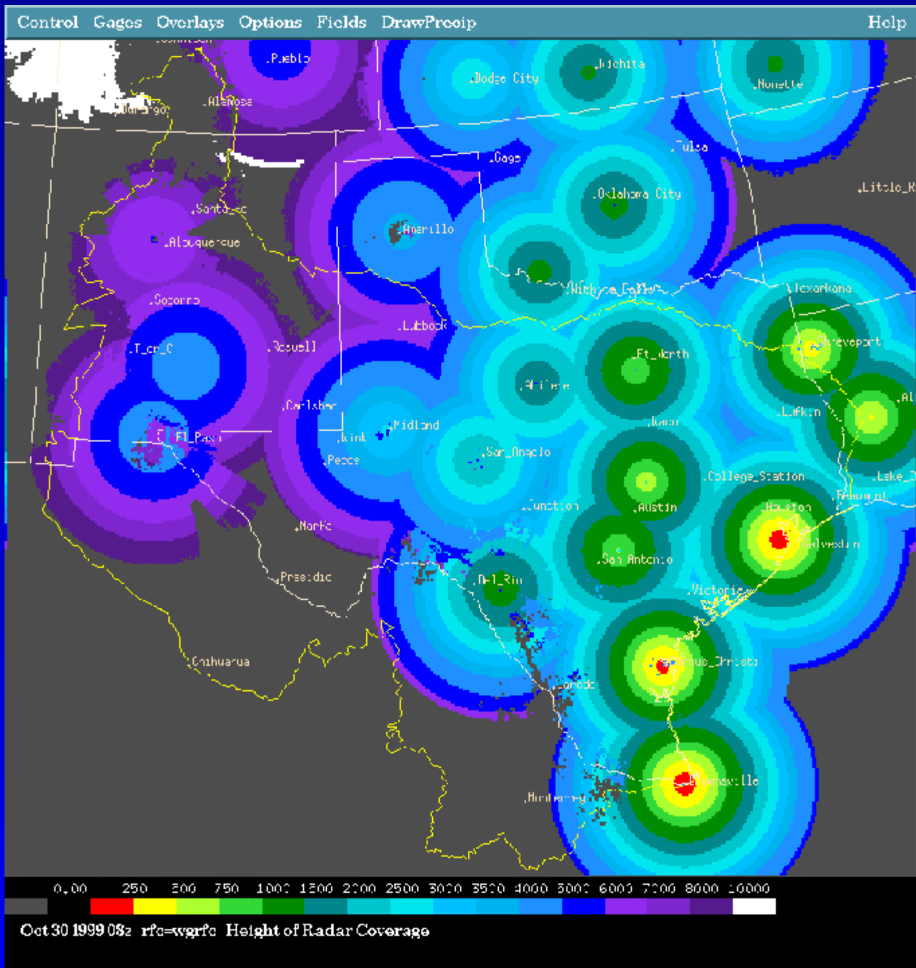
Radar Coverage Map



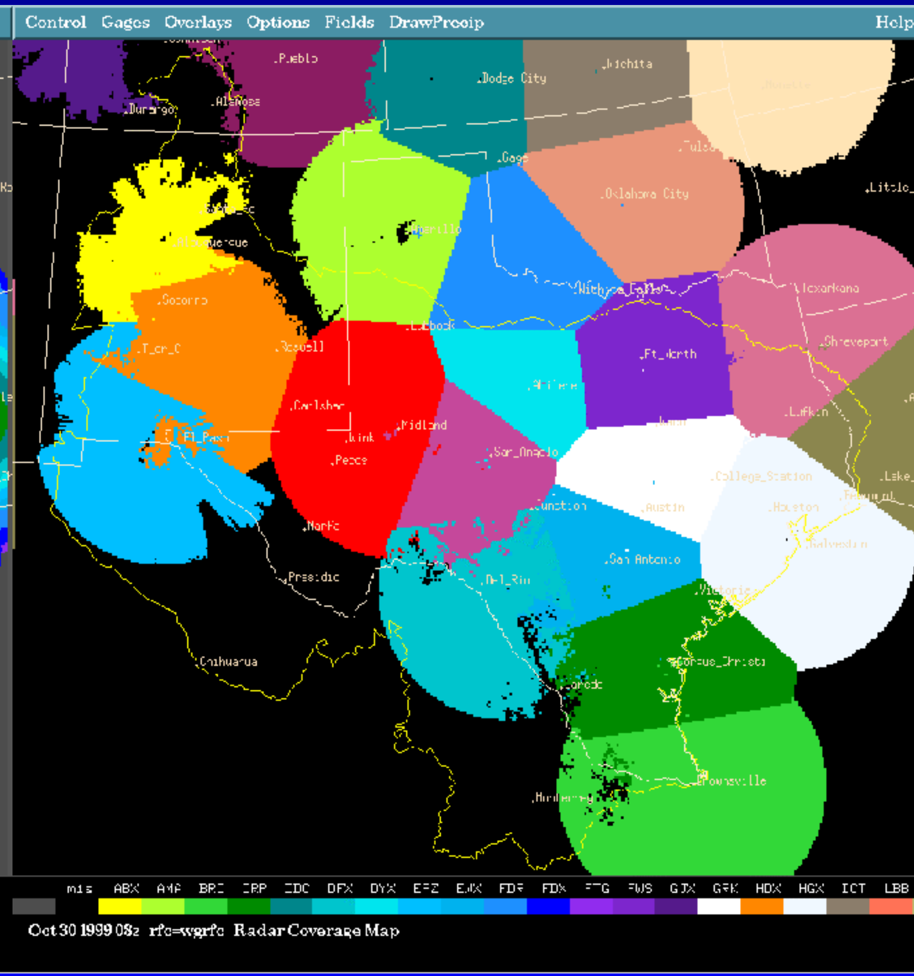


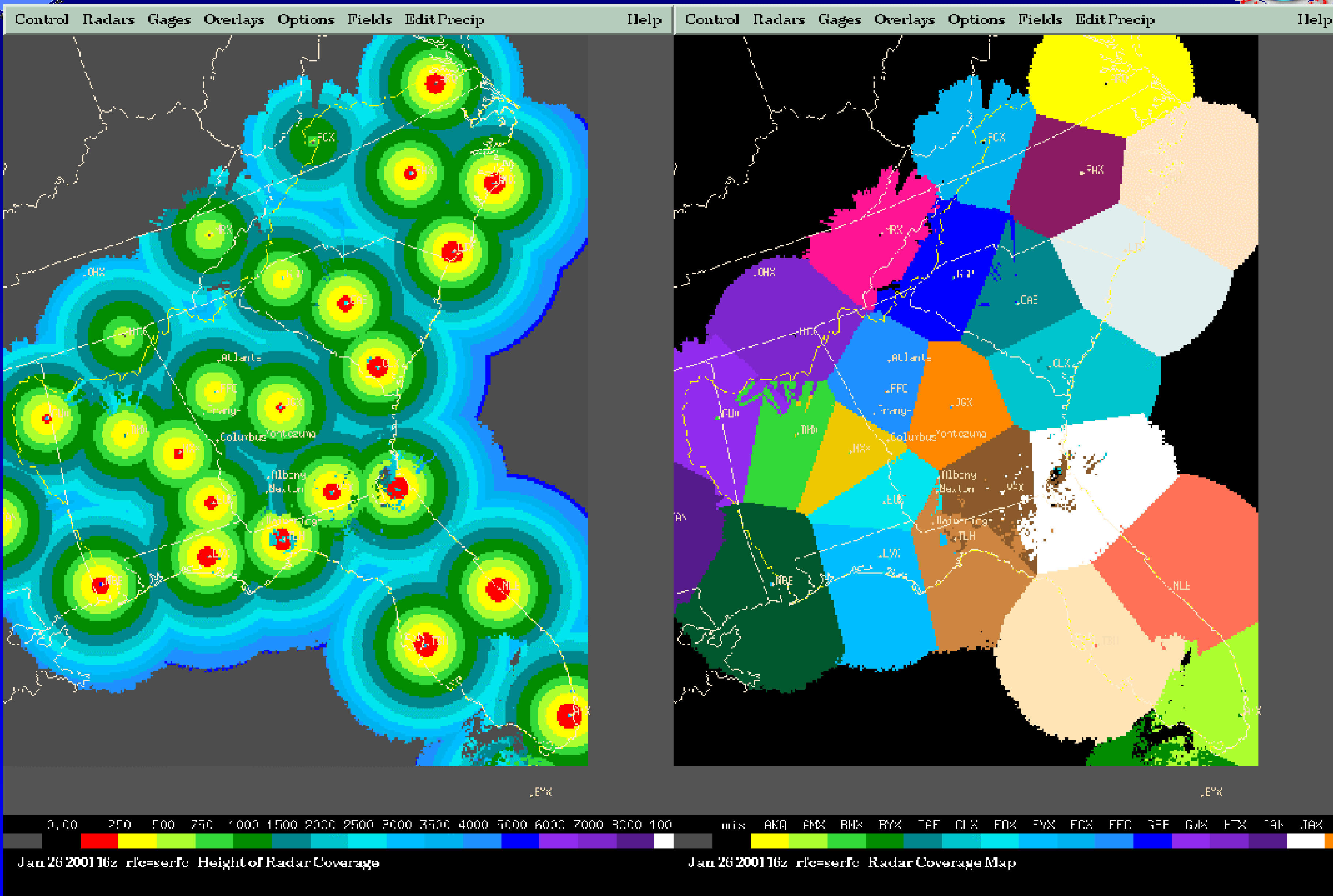
West Gulf River Forecast Center (WGRFC)

Height of Lowest Unobstructed Sampling Volume



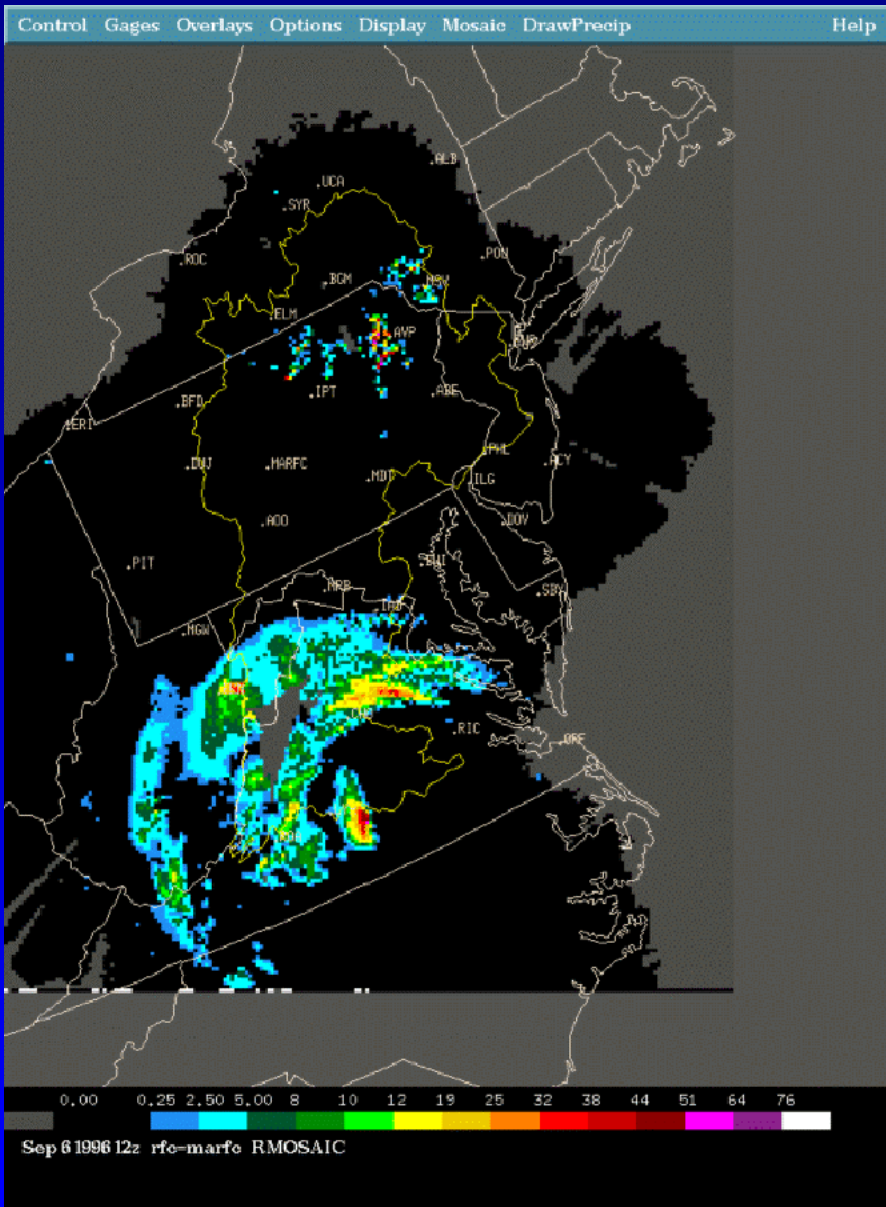
Radar Coverage Map



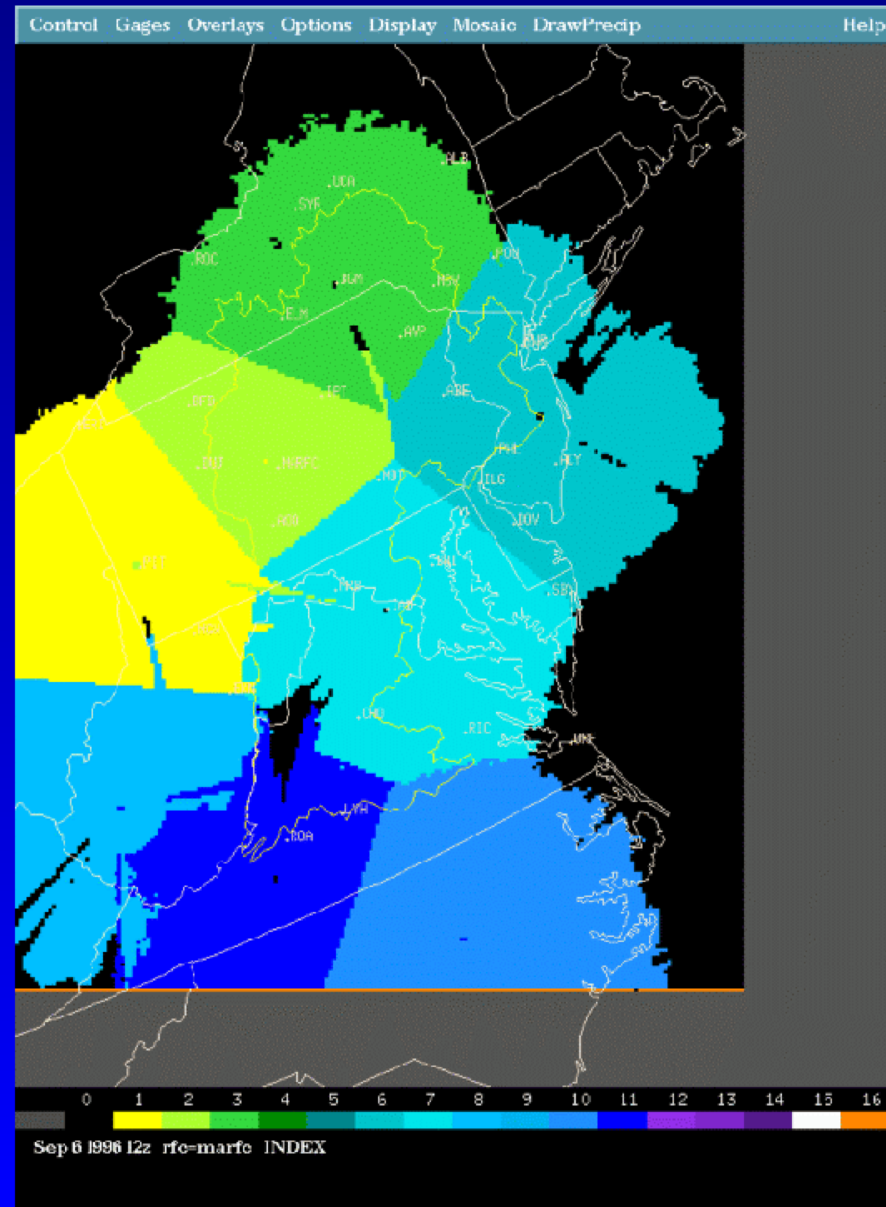


Control Radars Gages Overlays Options Fields Edit Precip Help
Control Radars Gages Overlays Options Fields Edit Precip Help
Atlanta
Columbus
Montezuma
Albany
Jan 26 2001 16z rfc=serfc Height of Radar Coverage
Jan 26 2001 16z rfc=serfc Radar Coverage Map

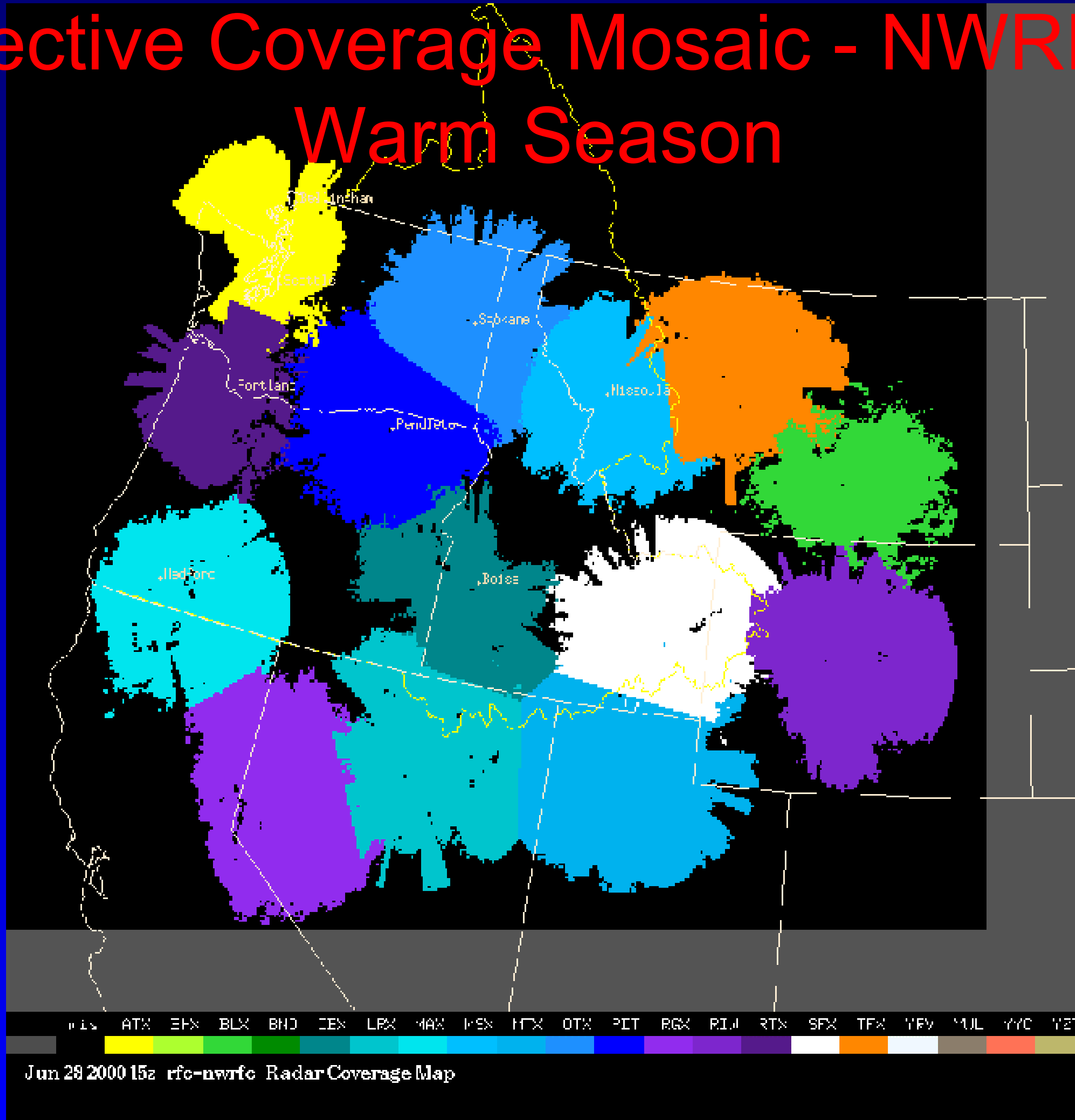
PRECIPITATION MOSAIC



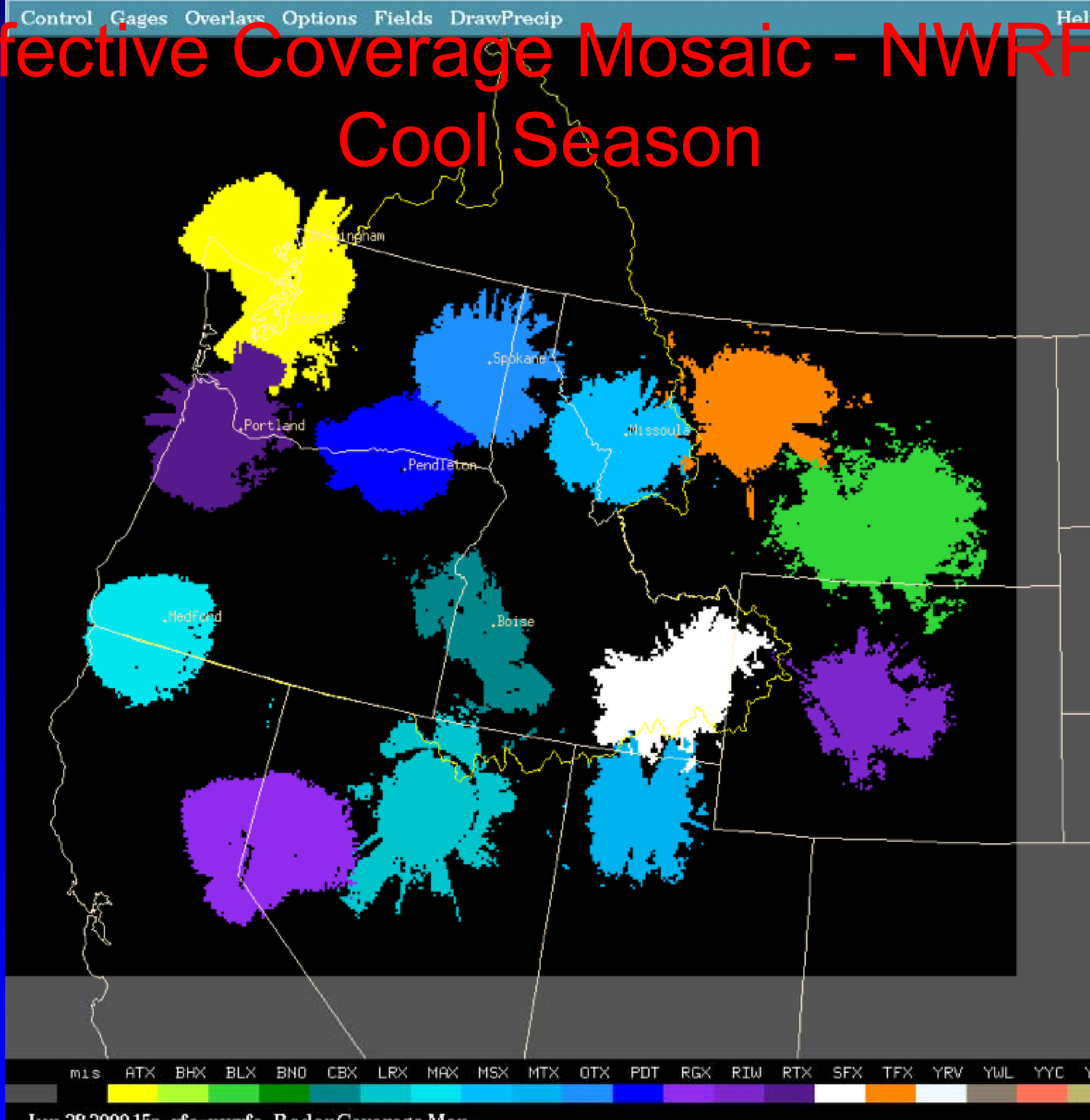
RADAR COVERAGE MAP



Effective Coverage Mosaic - NWRFC Warm Season



Effective Coverage Mosaic - NWRFC Cool Season



Mean-Field Bias Adjustment

- Addresses Issue 2
- Based on (near) real-time rain gauge data
- Equivalent to adjusting the multiplicative constant in the Z-R relationship for each radar; $Z = A(t)\ R^b$

Mean field bias adjustment

$$\$_k \approx \frac{A_c^{-1}\ I_{Ac}\ g(u,t)\ du}{A_c^{-1}\ I_{Ac}\ r(u,t)\ du}$$

where A_c is the area commonly identified as raining by both radar and gauges within the effective coverage of the radar

$$\$_k^{*} = N^{-1} \mathop{E}_{i=k-L}^{k} \mathop{E}_{j=1}^{n_i} g_{ij} \,/\, N^{-1} \mathop{E}_{i=k-L}^{k} \mathop{E}_{j=1}^{n_i} r_{ij}$$

where L is the moving average window

From Seo et al. (1999)

Bias Table

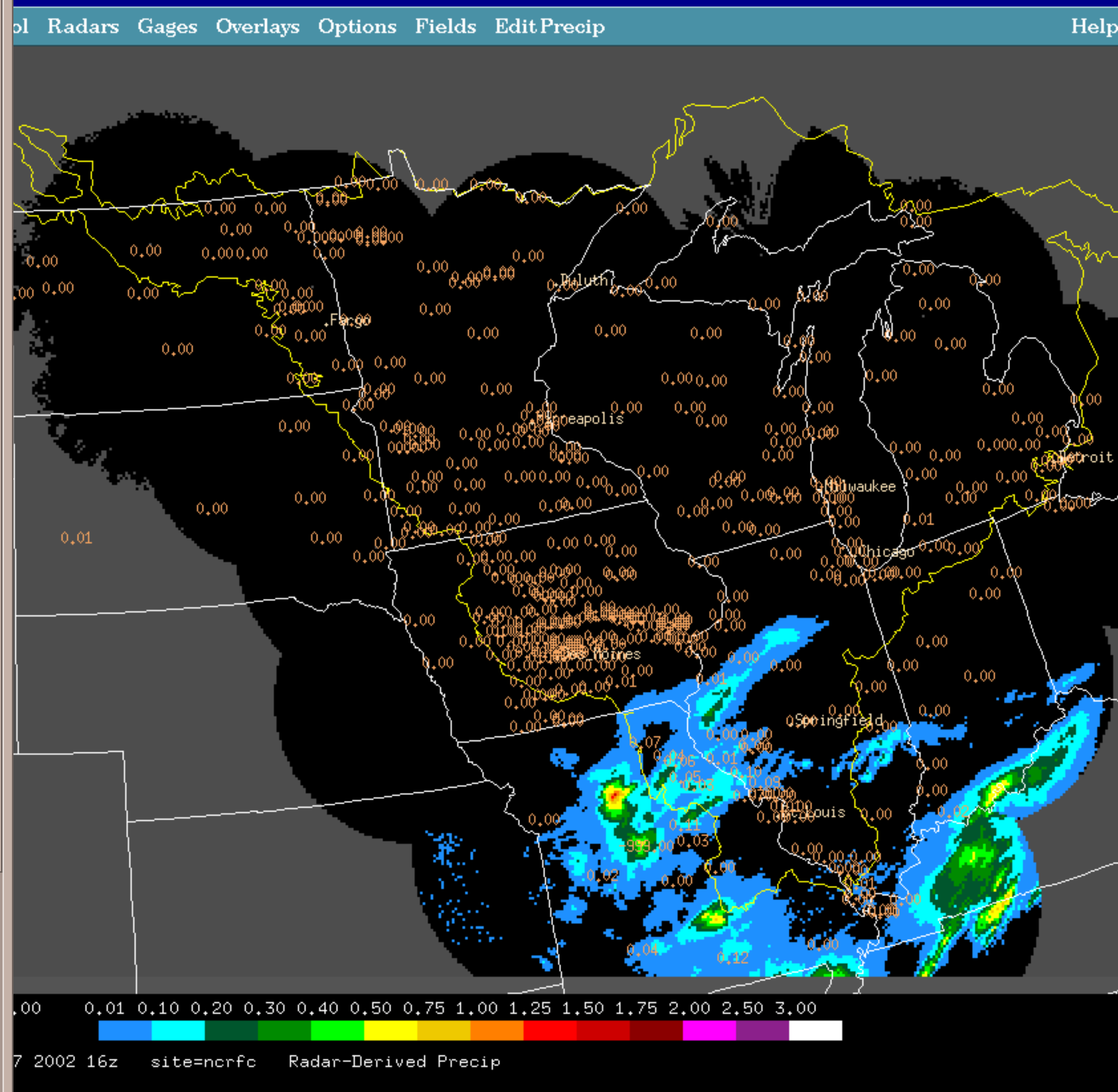
Memory Span (hrs)	Bias	Effective sample size
1	1.53	6.3
10	1.44*	30.6
50	1.40	43.5
100	1.29	63.5
500	1.13	316.8
1000	1.11	741.7
2000	1.11	1438.4

- Produced in MPE in AWIPS Build 5.2.2
- Shipped to ORPG
- Appended to DPA

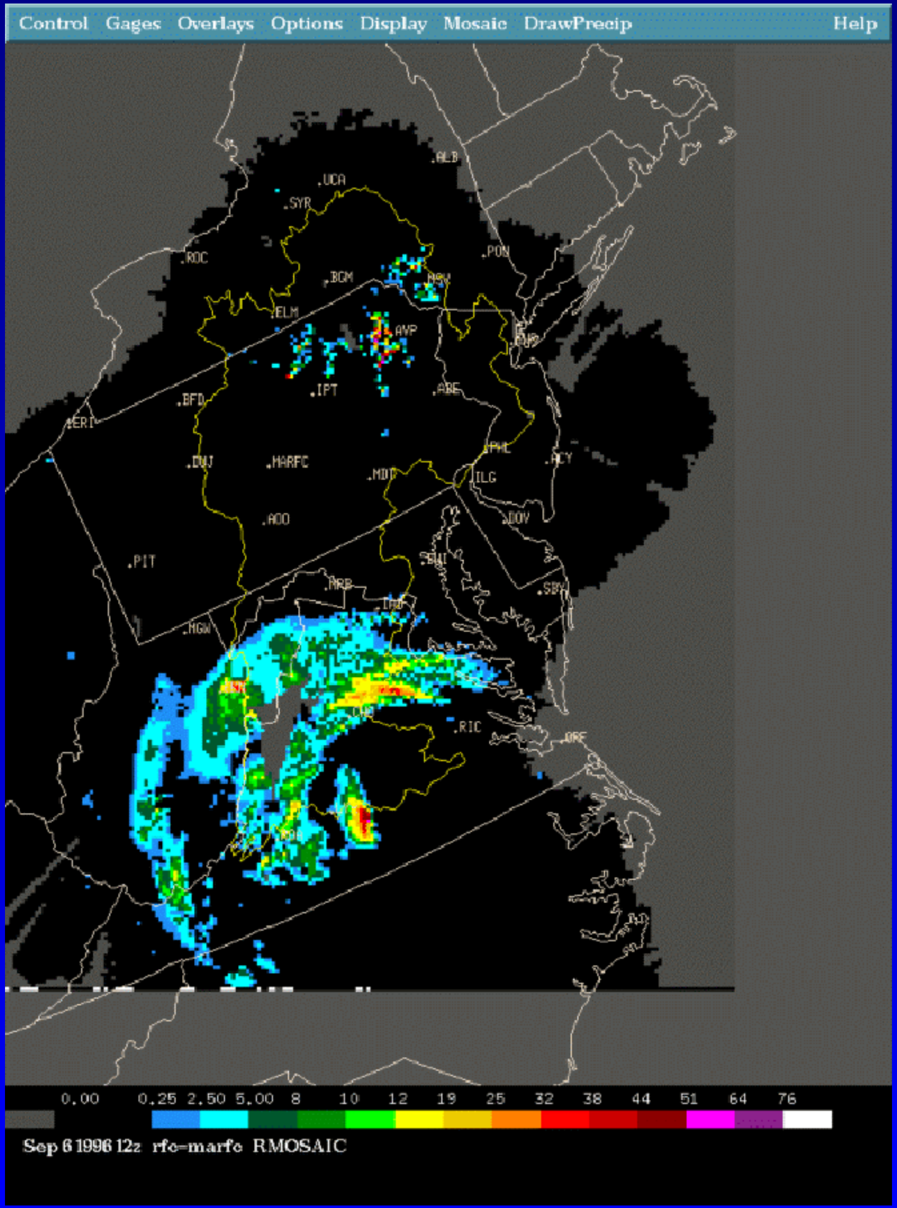
MFB and Z-R List

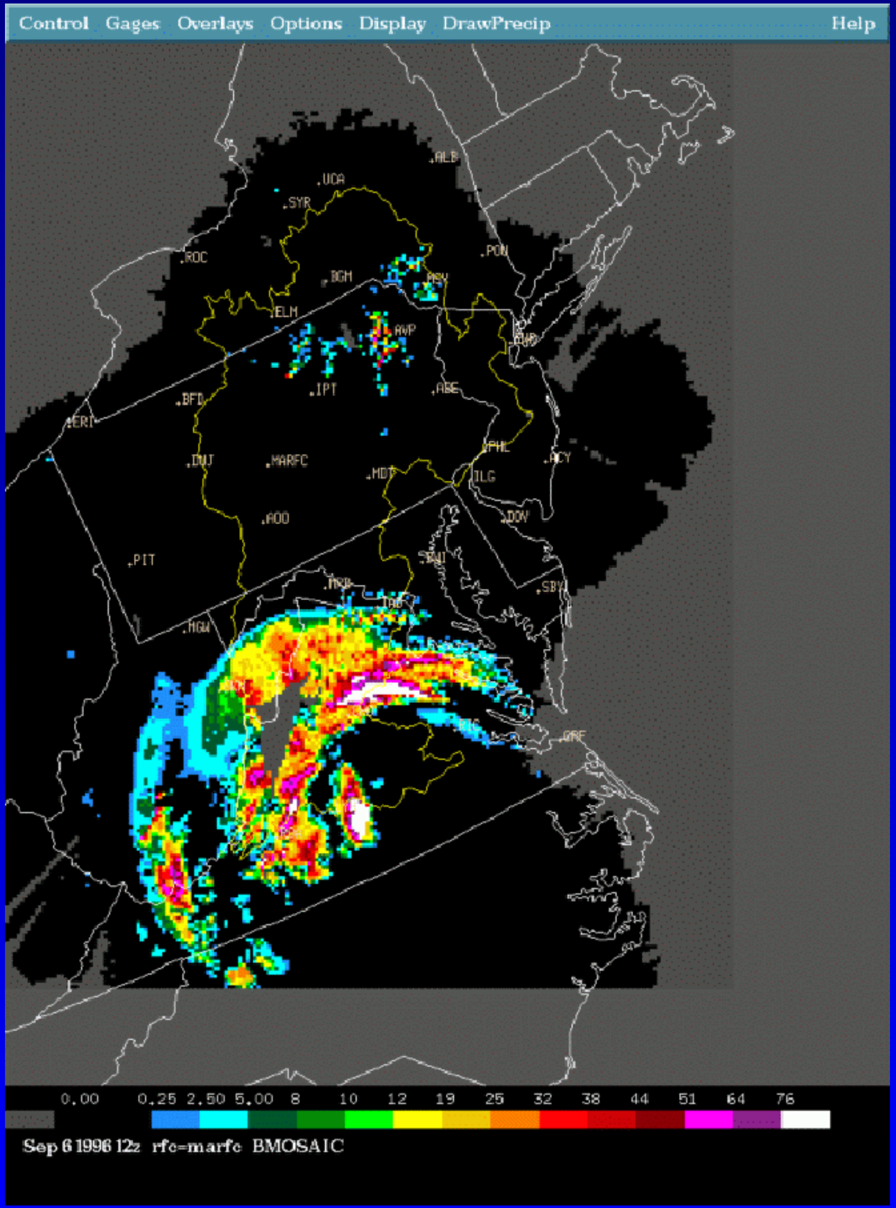
CLOSE APPLY HELP May 17 2002 16z

Radar	Bias : Manually Specified		A	B
ABR	0.91	NO	300	1.40
APX	1.00	NO	300	1.40
ARX	0.72	NO	300	1.40
BIS	1.00	NO	300	1.40
CLE	0.92	NO	300	1.40
DLH	0.97	NO	200	1.60
DMX	0.74	NO	300	1.40
DTX	0.90	NO	300	1.40
DVN	1.00	NO	300	1.40
EAX	0.70	NO	300	1.40
FSD	0.75	NO	300	1.40
GGW	1.00	NO	300	1.40
GRB	0.79	NO	300	1.40
GRR	1.31	NO	N/A	N/A
ILX	0.94	NO	300	1.40
IND	1.19	NO	300	1.40
IWX	1.18	NO	300	1.40
LOT	0.95	NO	300	1.40
LSX	0.67	NO	300	1.40
MBX	1.00	NO	300	1.40

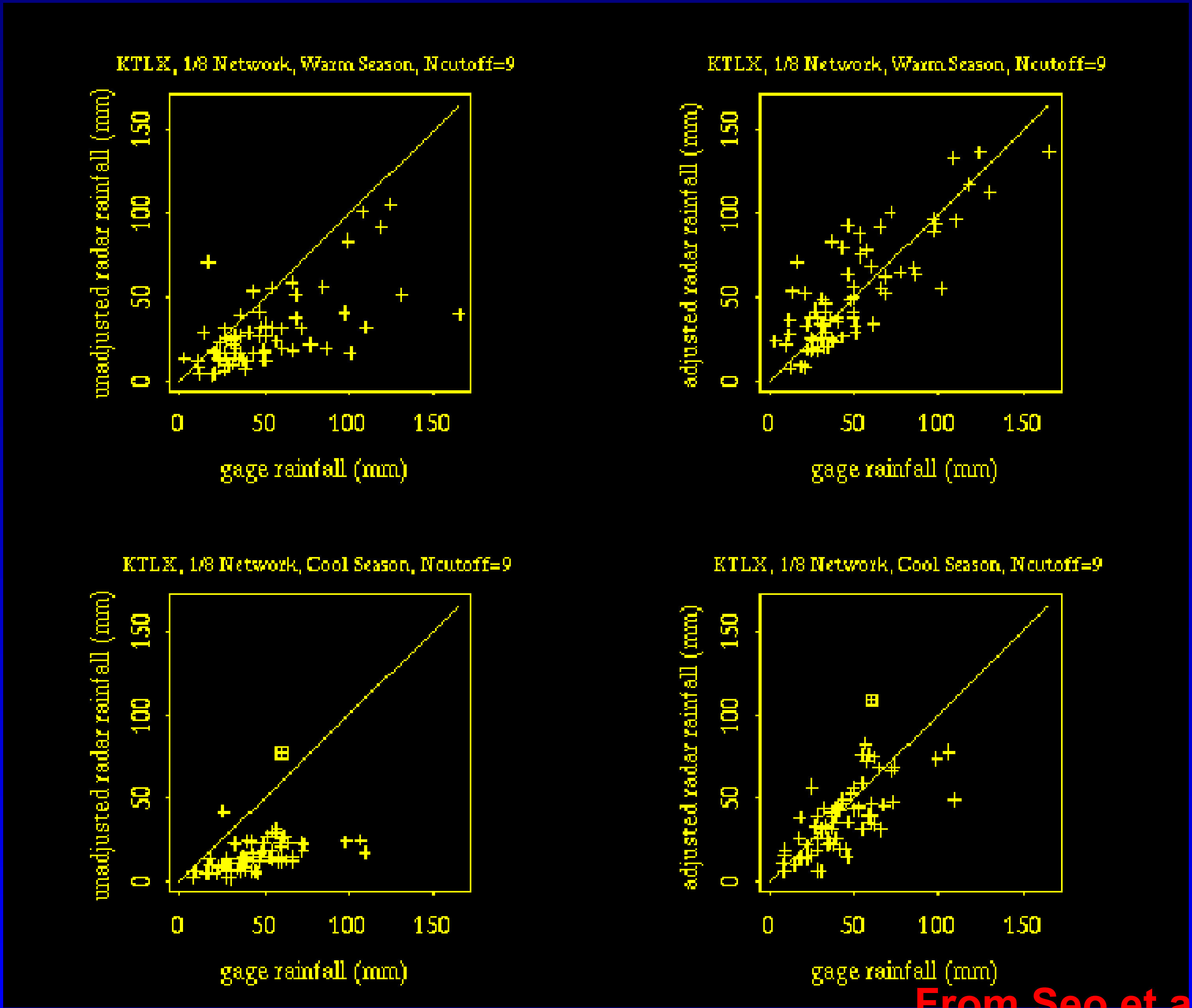


MEAN FIELD BIAS (MFB) ADJUSTMENT





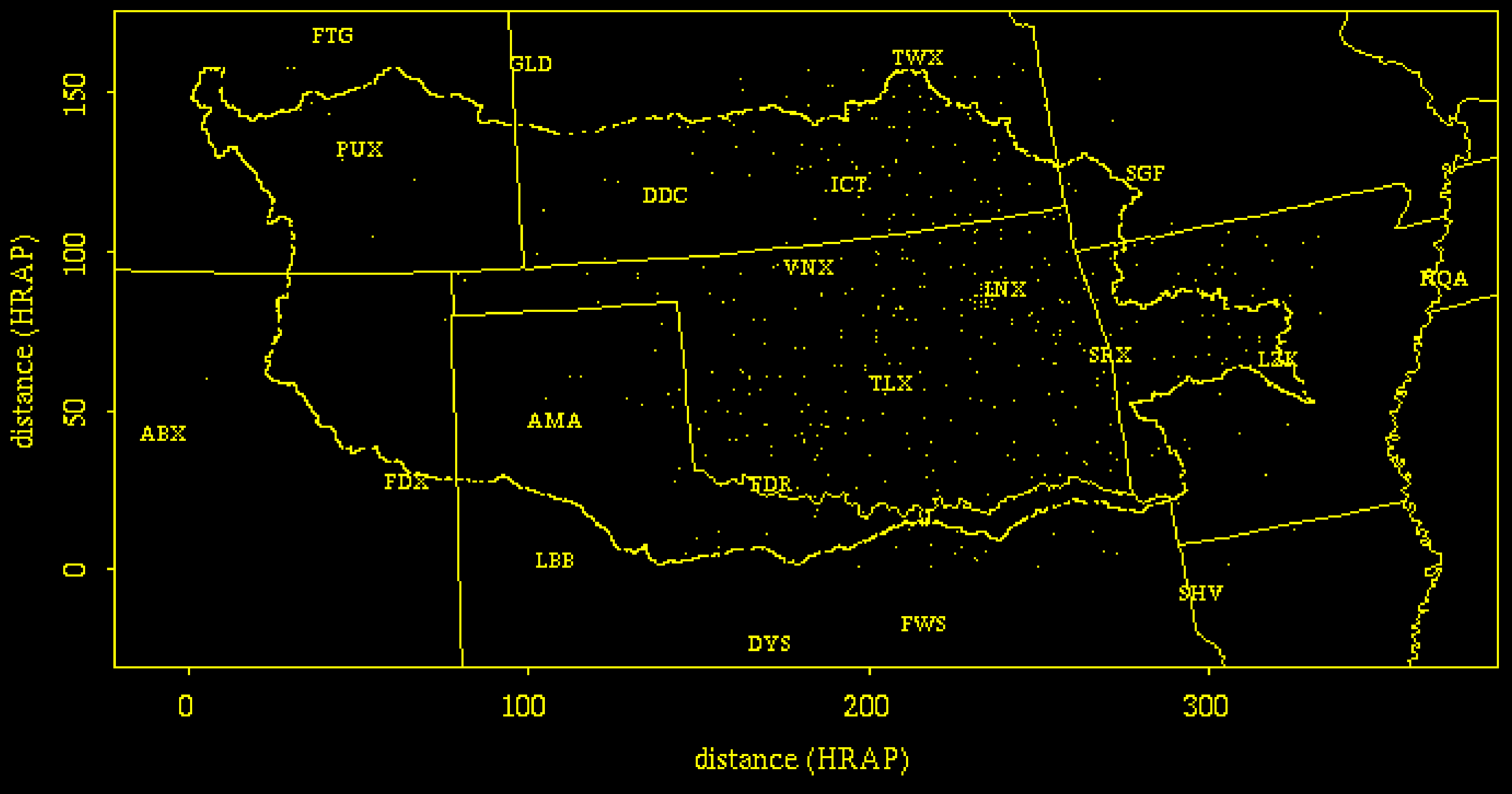
Effect of Bias Adjustment



From Seo et al. 1999

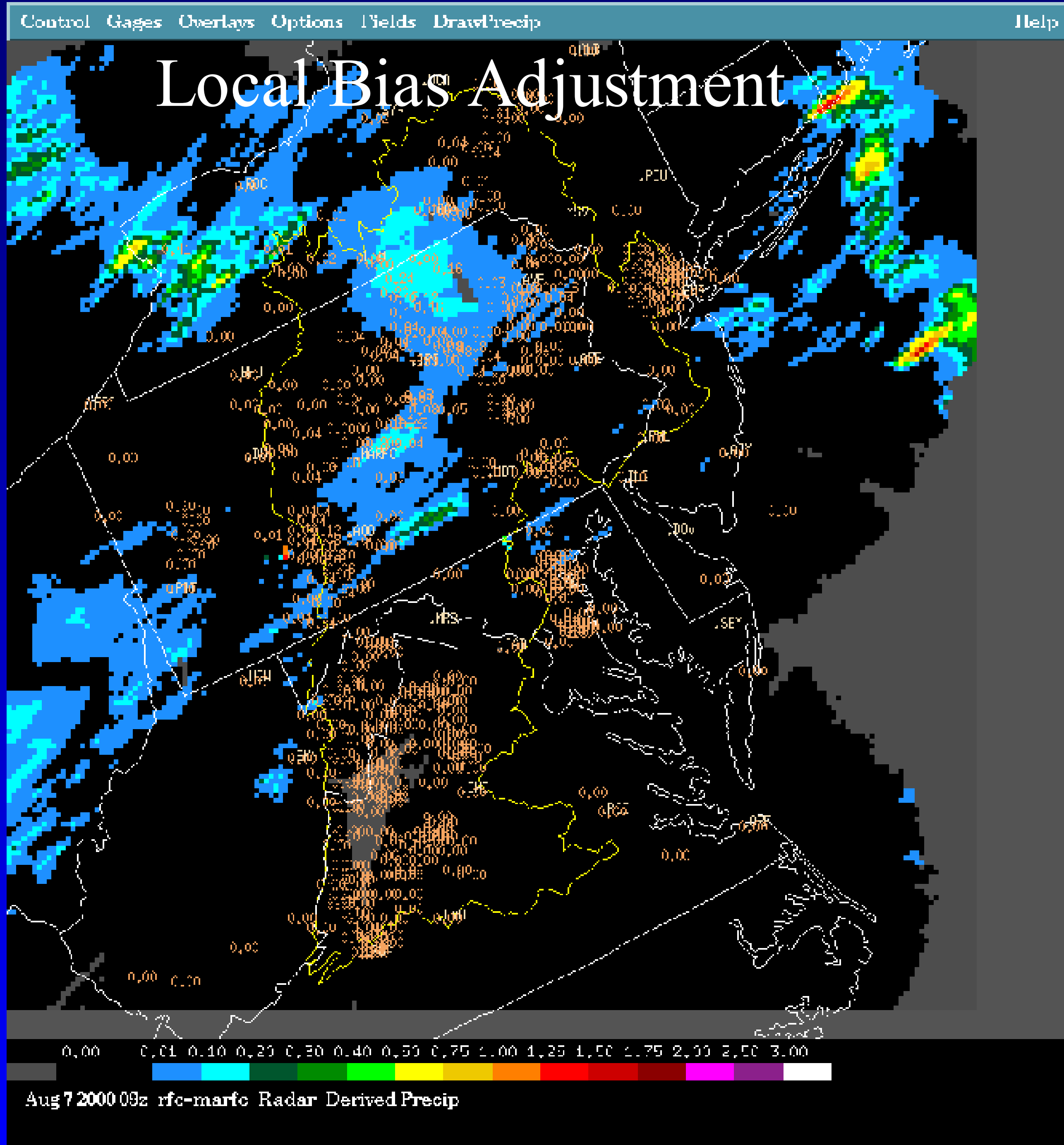
Local bias adjustment

- Addresses Issue 3
- Bin-by-bin application of the mean field bias algorithm
- Reduces systematic errors over small areas
- Equivalent to changing the multiplicative constant in the Z-R relationship at every bin; $Z = A(x,y,t)\ R^b$
- More effective in gauge-rich areas

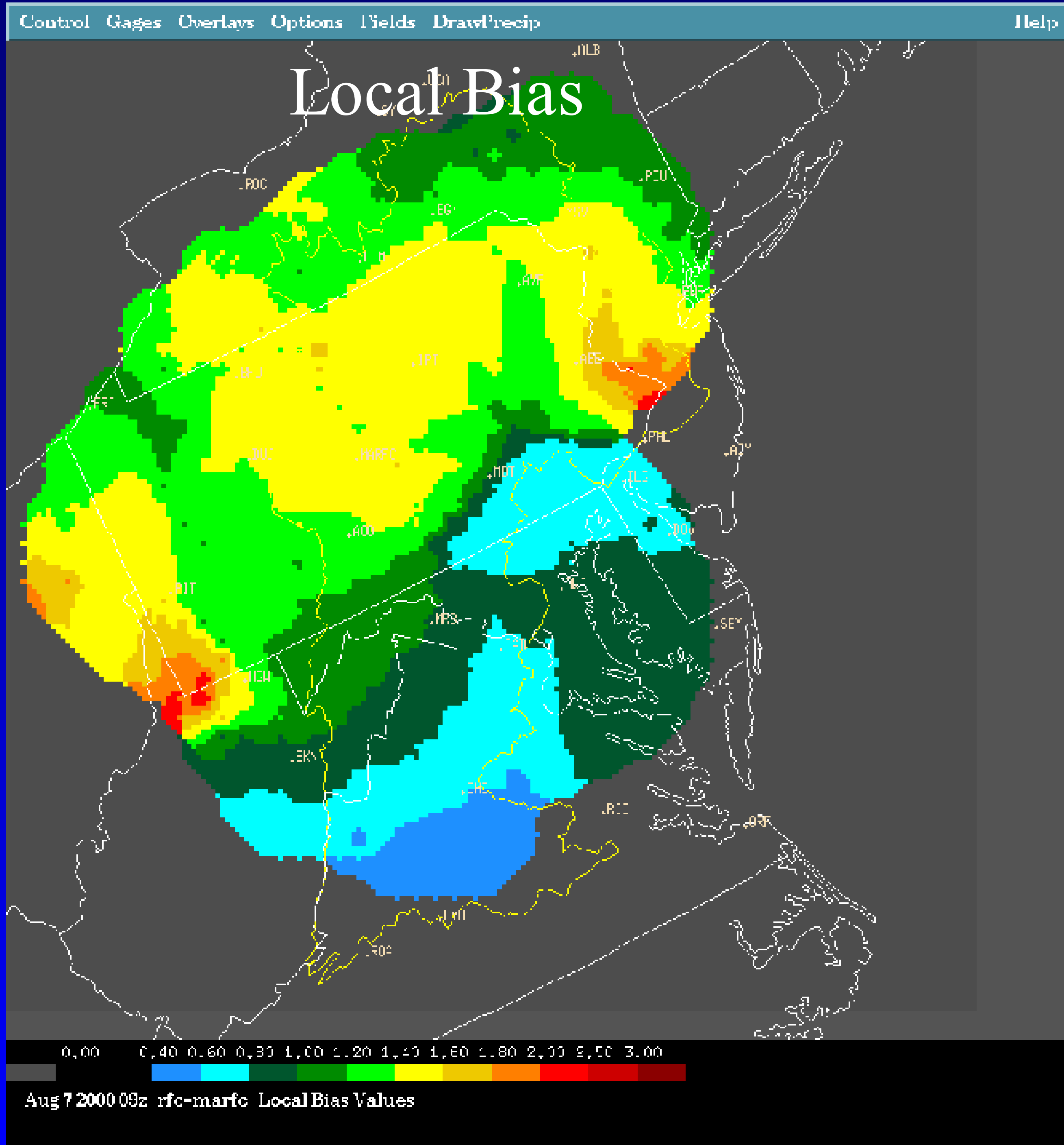


From Seo and Breidenbach 2002

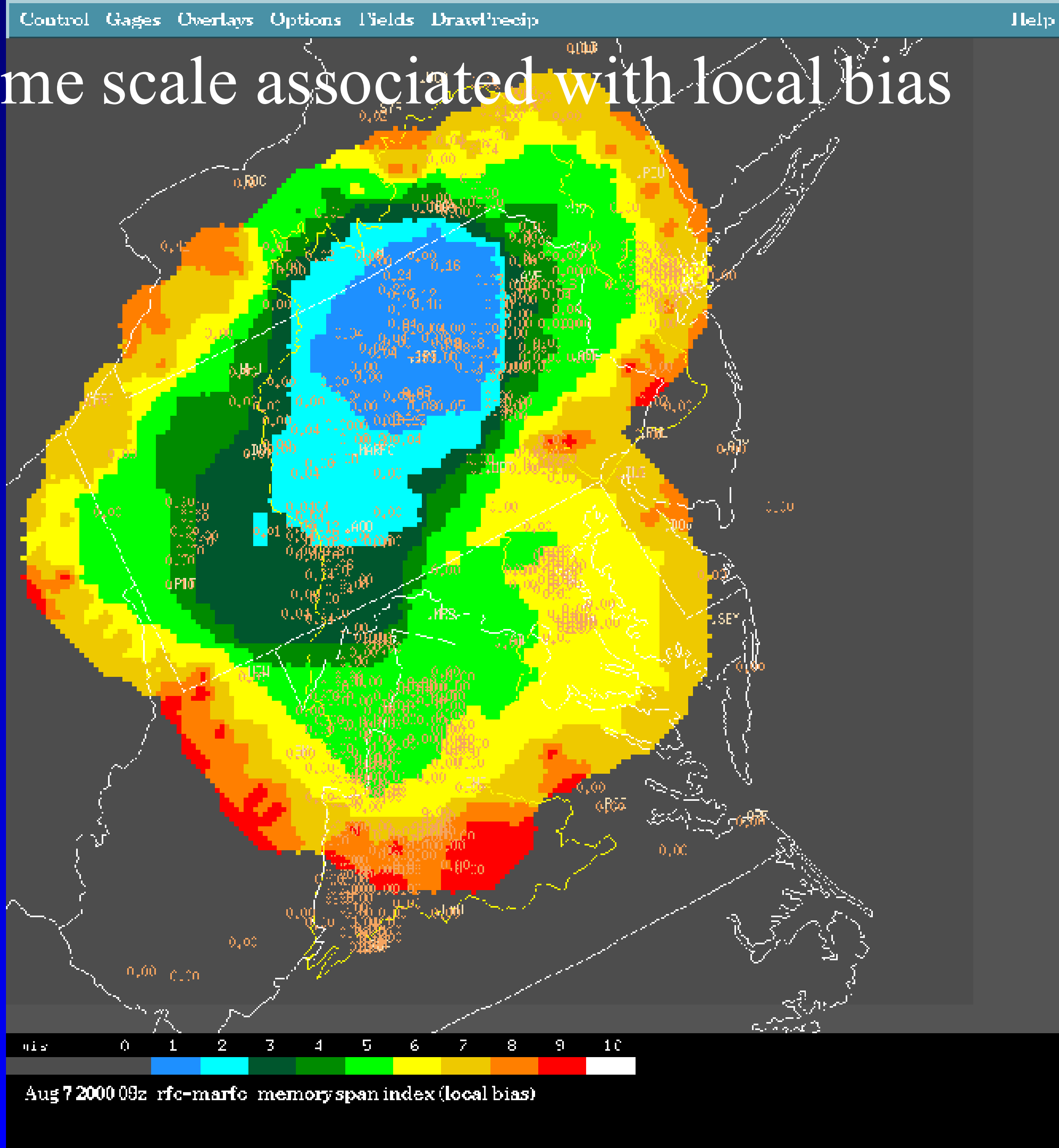
Local Bias Adjustment

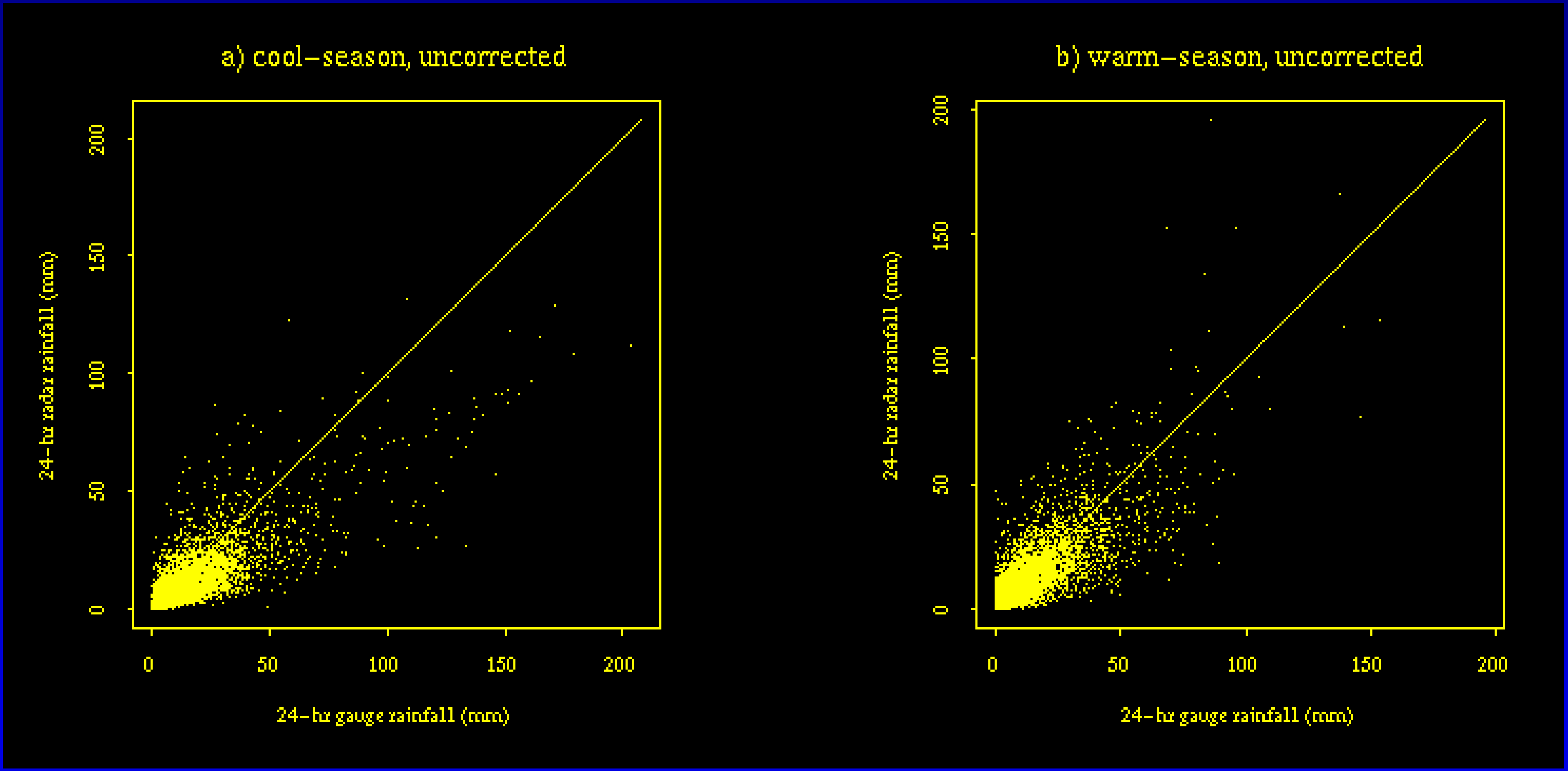


Local Bias


Control Gages Overlays Options Fields DrawPrecip Help
0.00 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00
Aug 7 2000 09z rfc-marfc Local Bias Values

Time scale associated with local bias





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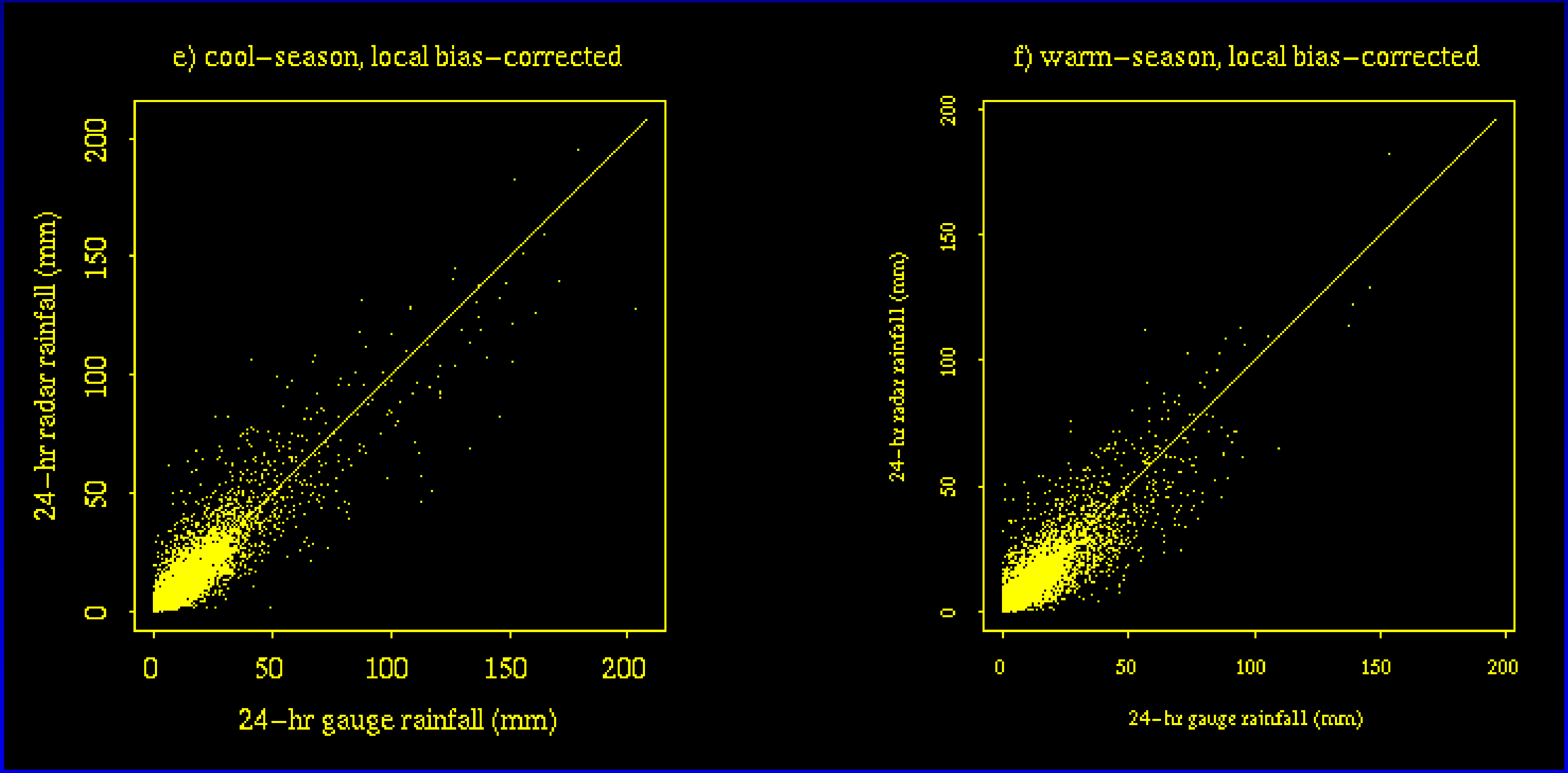


From Seo and Breidenbach 2002

Radar-Gauge Merging

$$G_{ko}^{*} = \overset{n_{Gk}}{\underset{i=1}{E}}\ 8_{Gki}\ G_{ki} + \overset{n_{Rk}}{\underset{j=1}{E}}\ 8_{Rkj}\ (\$_{k}\ R_{kj})$$

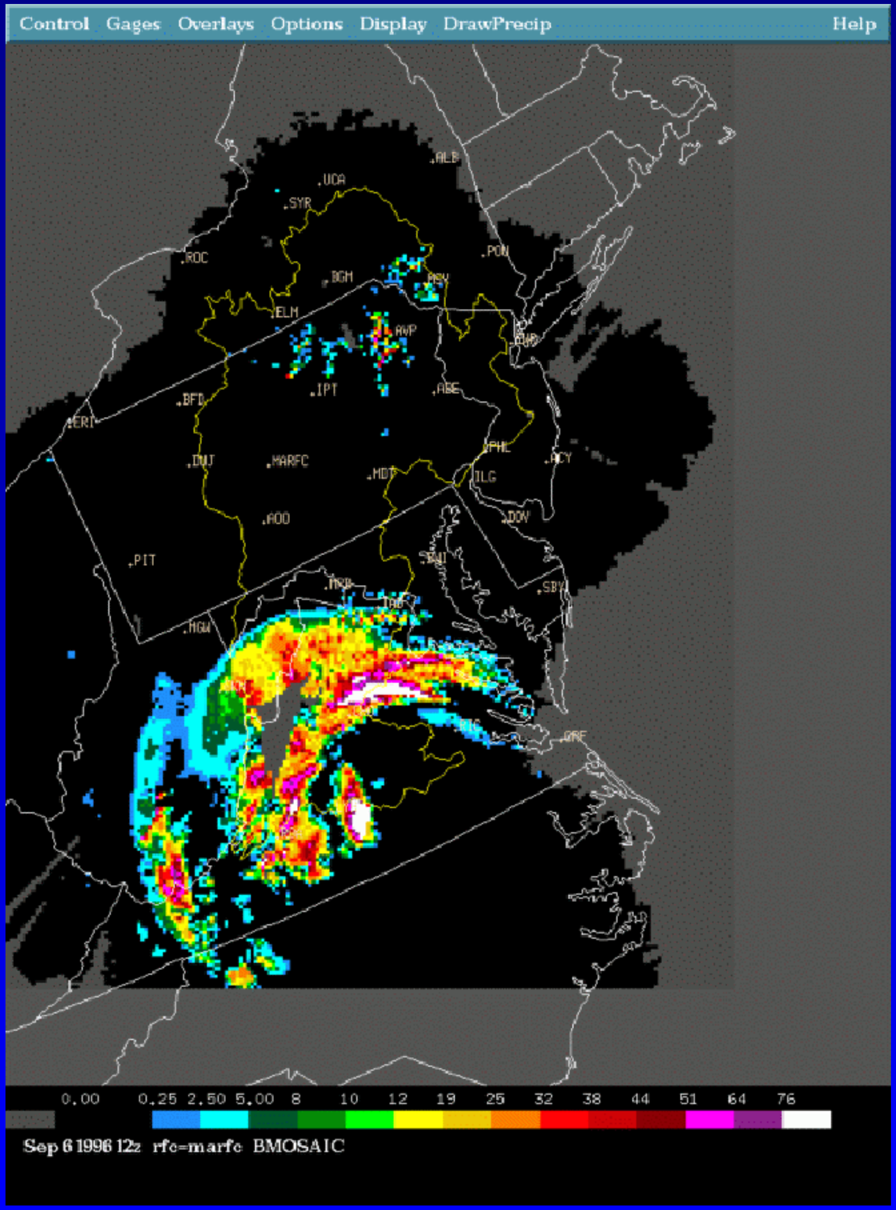
The weights, 8_{Gki} and 8_{Rkj}, are solved for from:

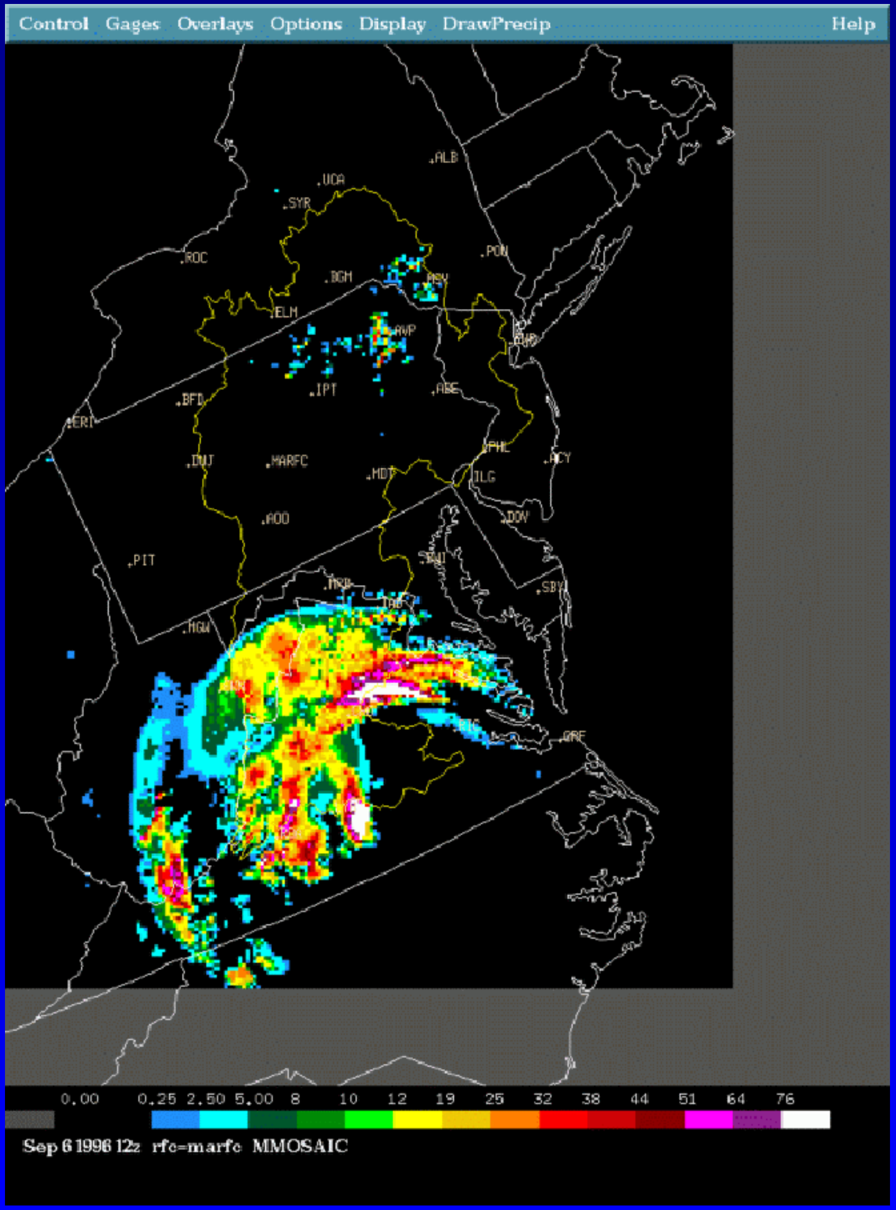
minimize $E[G_{ko}^{*} - G_{ko}]^{2}$

subject to $\overset{n_{Gk}}{\underset{i=1}{E}}\ 8_{Gki} + \overset{n_{Rk}}{\underset{j=1}{E}}\ 8_{Rkj} = 1$

From Seo 1998

MULTISENSOR ESTIMATION FILLS MISSING AREAS





Climatological Unbiasedness

$$G_{ko}^{*} = \overset{n_{Gk}}{\underset{i=1}{E}}\, 8_{Gki} \frac{m_{Go}}{m_{Gi}} G_{ki} + \overset{n_{Rk}}{\underset{j=1}{E}}\, 8_{Rkj} \frac{m_{Go}}{m_{Gj}} (\$_{kj}\, R_{kj})$$

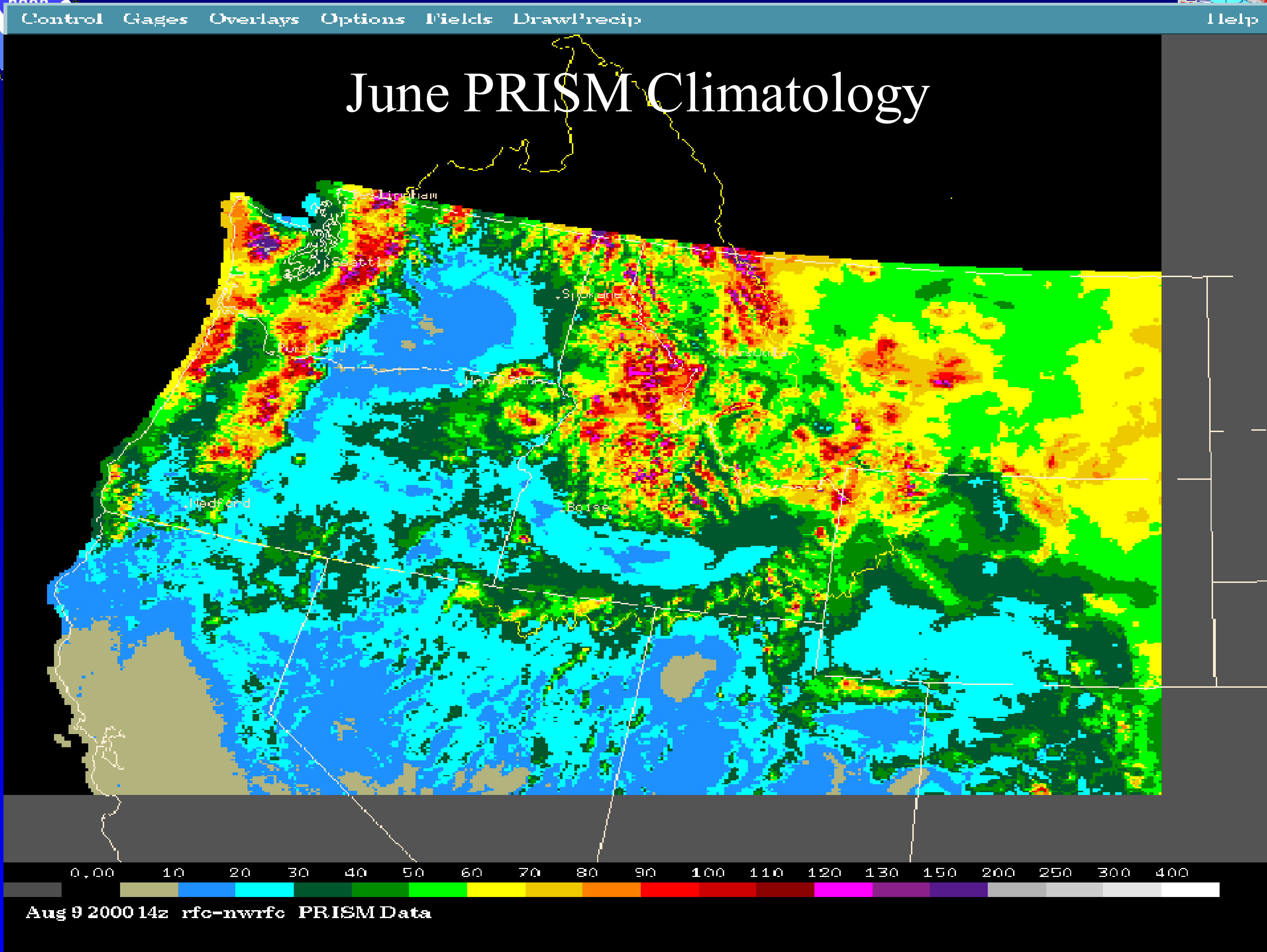
where

m_{Gi} is the climatological mean gauge rainfall* at location u_i and

$\$_{kj}\, R_{kj}$ is the bias-adjusted radar rainfall at hour k at location u_j

* PRISM data used in MPE

June PRISM Climatology



MPE products

- RMOSAIC - mosaic of raw radar
- BMOSAIC - mosaic of mean field bias-adjusted radar
- GMOSAIC - gauge-only analysis
- MMOSAIC - multi-sensor analysis of BMOSAIC and rain gauge data
- LMOSAIC - local bias-adjusted RMOSAIC
- hourly, HRAP (●4x4km^2)

Human Input via Graphical User Interface

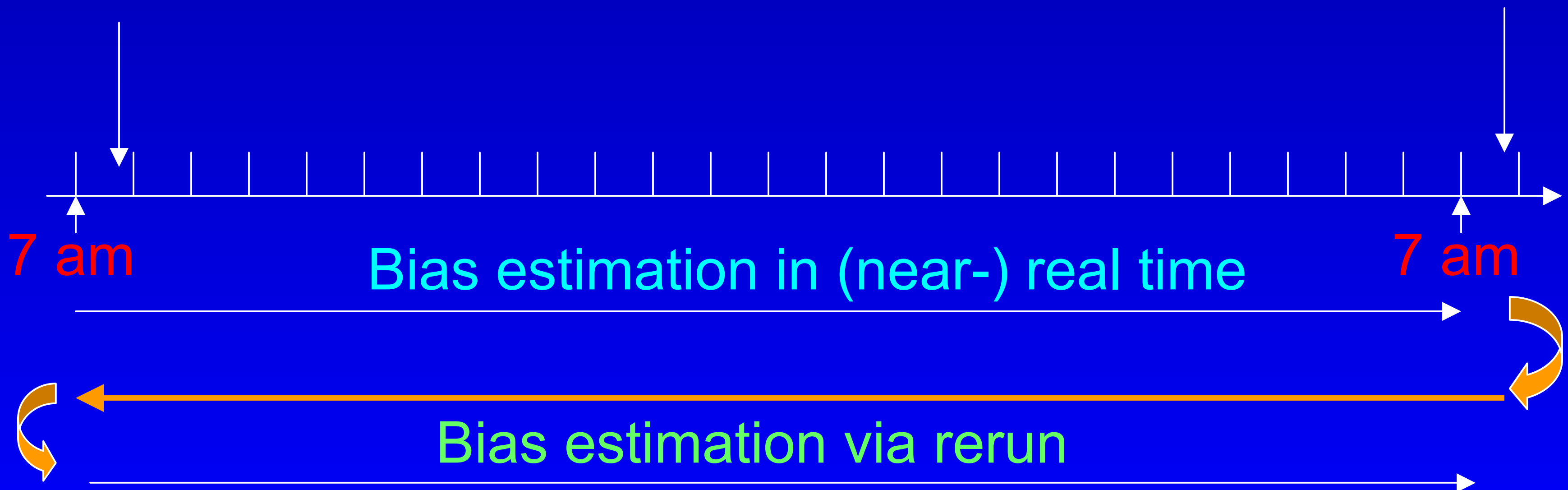
- By the Hydrometeorological Analysis and Service (HAS) forecasters
- Quality control of data, analysis and products
- Manual reruns (i.e. reanalysis)
- The current GUI a hold-over from Stage III
- New GUI in AWIPS 5.2.2

Upcoming improvements

- Bring in additional data sources
- Quality-control the data
- Objectively integrate them into the multi-sensor estimation framework

Use of Multi-Hourly Gauge Data

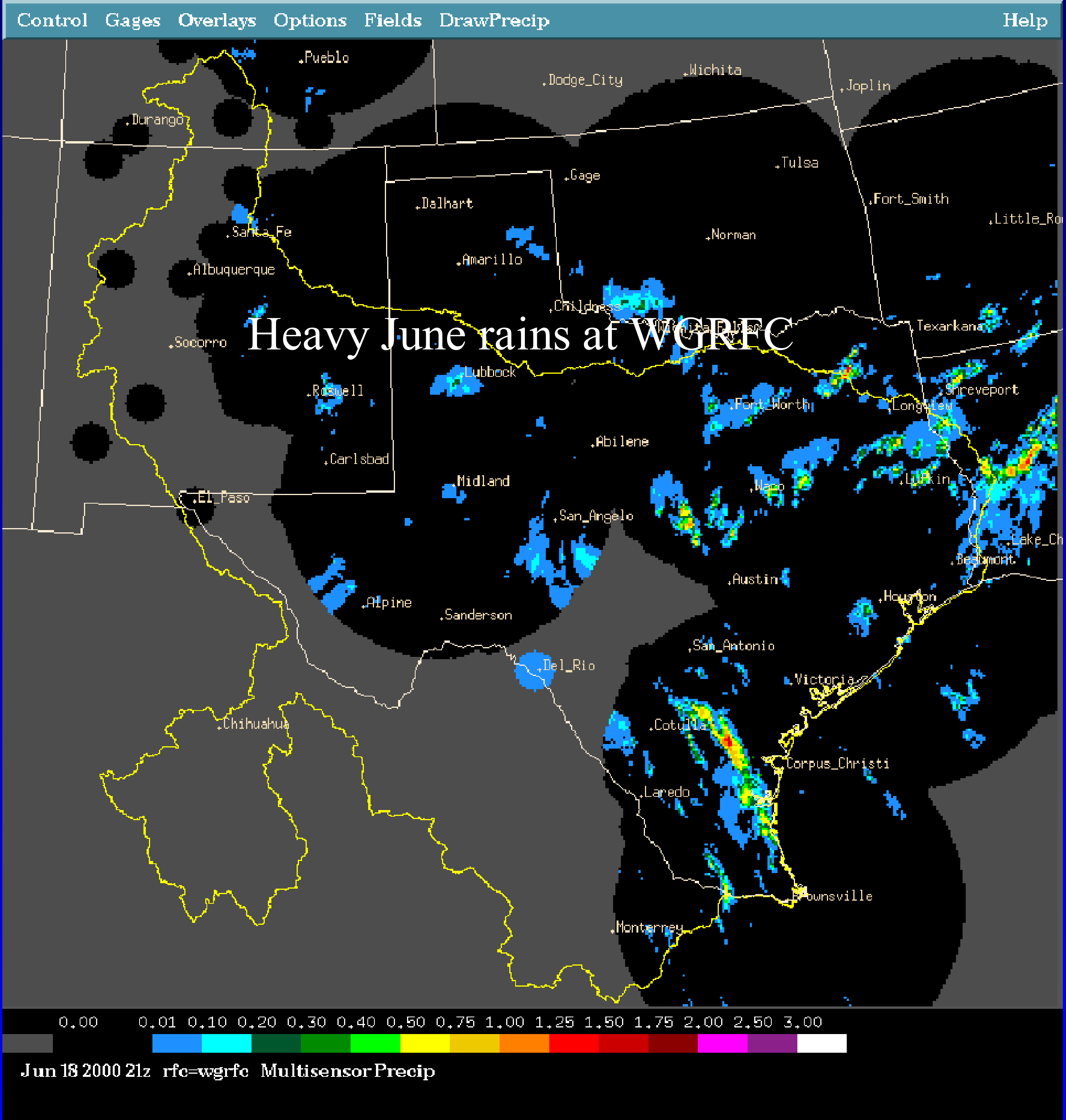
- Being software-engineered
- Disaggregate multi-hourly into hourly, and update bias estimates in the rerun mode
- To improve MPE estimates in areas with sparse hourly gauges



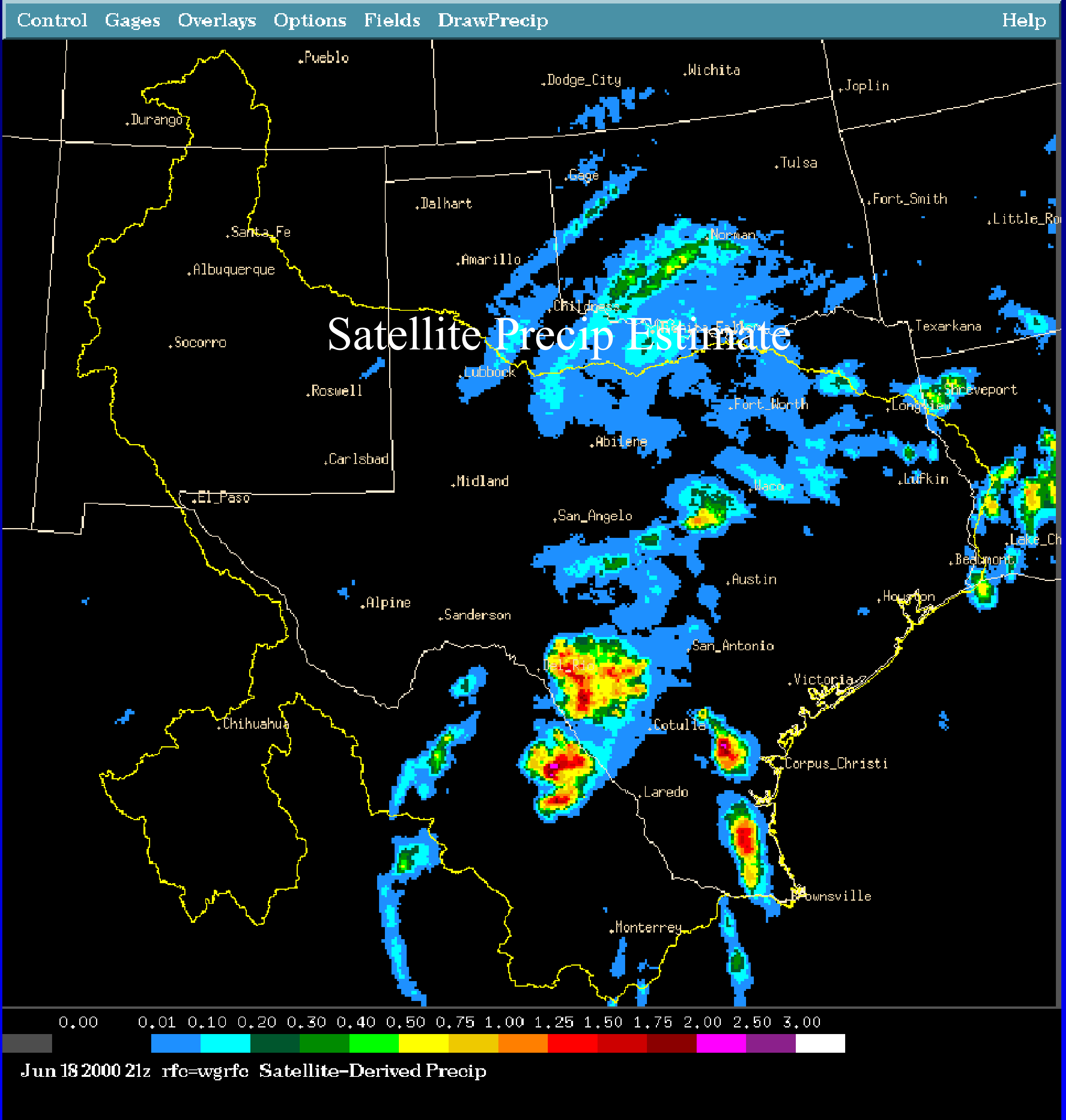
Use of satellite data-derived precipitation estimates

- MPE can only display the hourly HydroEstimator product from NESDIS
- Local bias correction using rain gauge data being evaluated (Michael Fortune)
- Objective merging with radar, rain gauge and lightning data under development (Chandra Kondragunta)

Heavy June rains at WGRFC

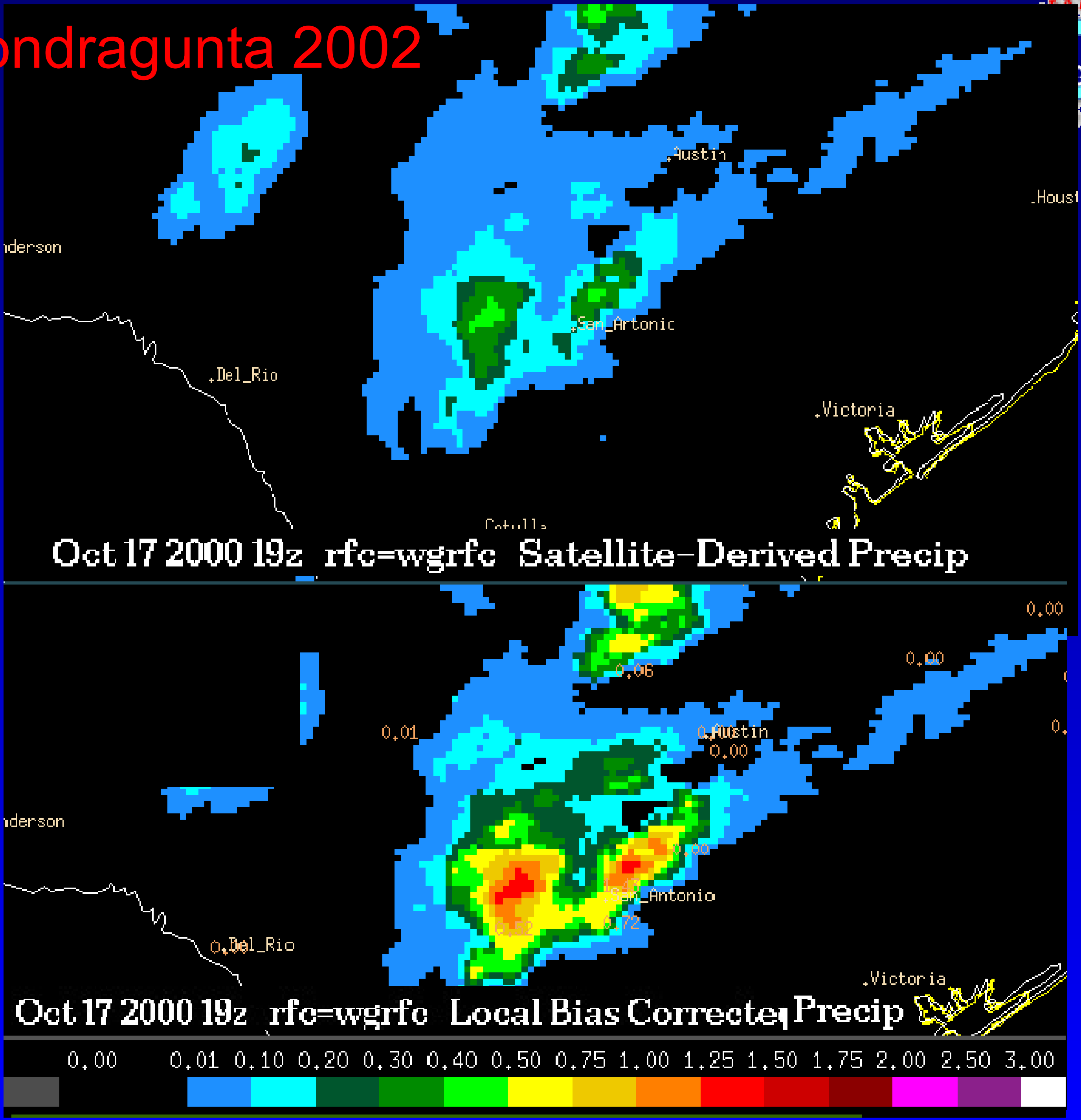


Satellite Precip Estimate

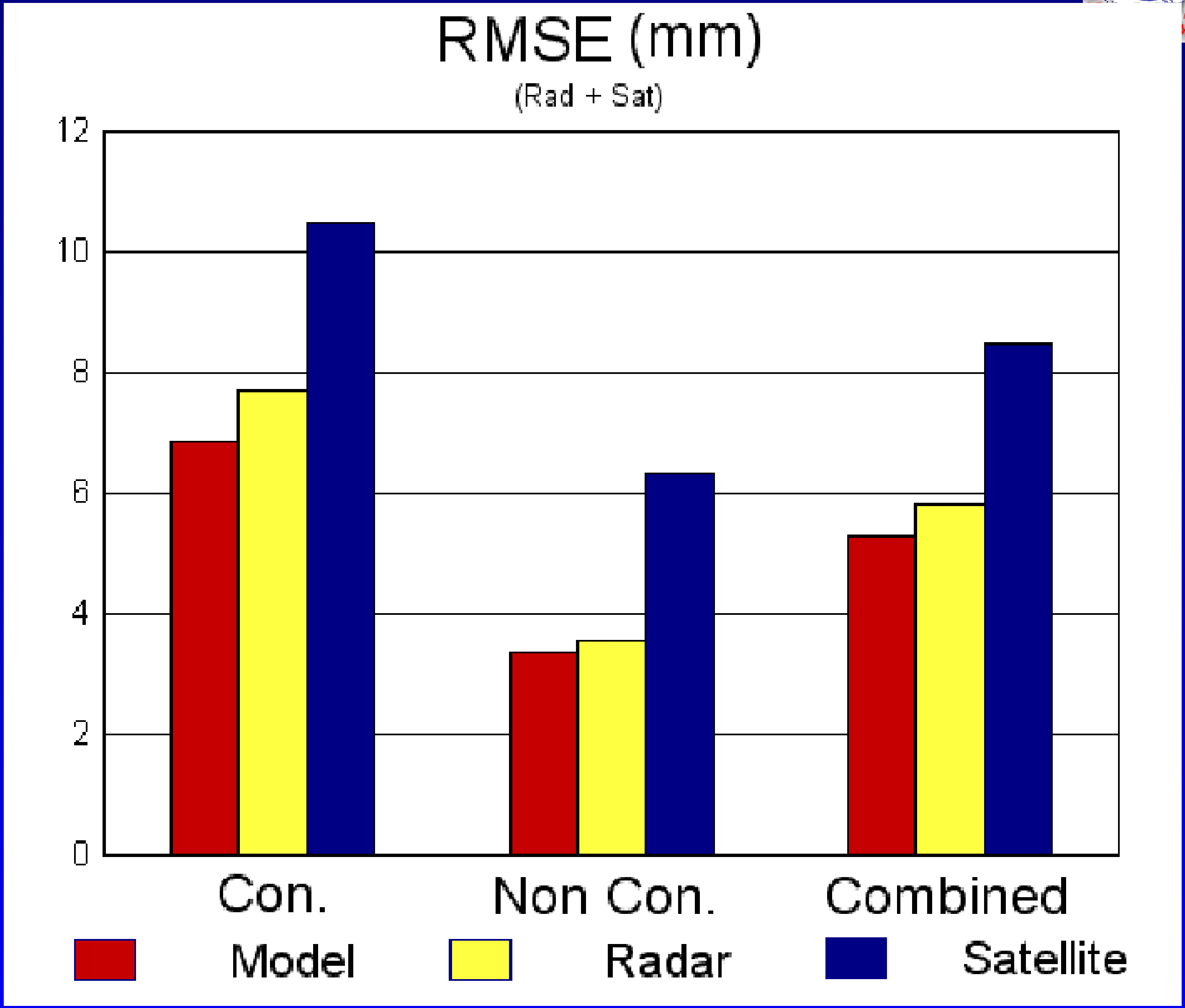


From Kondragunta 2002

After Bias Correction ö



Merging radar, rain gauge, satellite and lightning data



From Kondragunta 2002

Quality control of rain gauge data

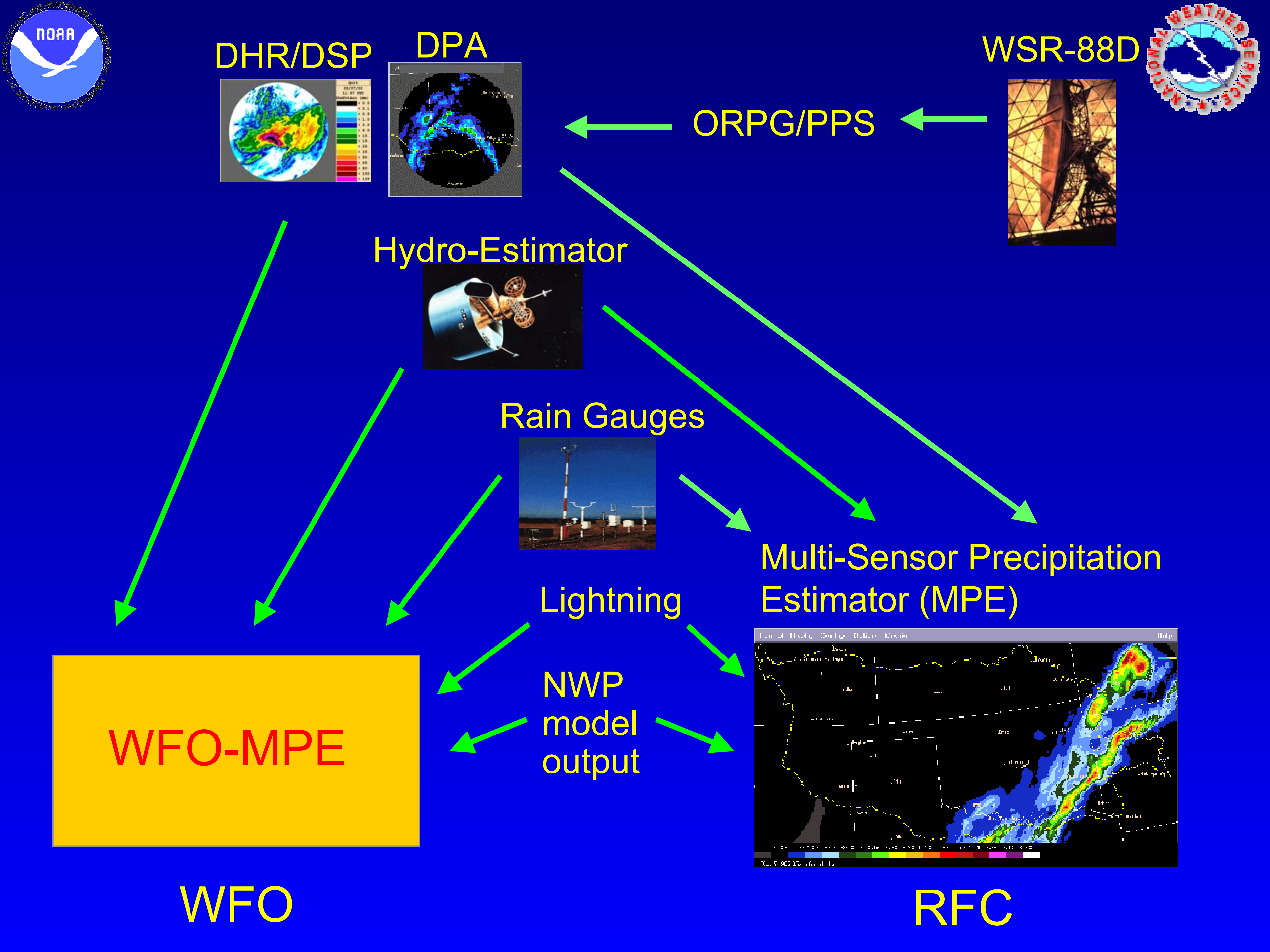
- By far the most labor-intensive part of the HAS (Hydrometeorological Analysis and Service) operation at the RFCs
- HL (Chandra Kondragunta) has developed/is developing automatic and interactive tools for quality control of daily and hourly rain gauge data

Use of environmental data

- NWP model output
- sounding data
- surface obs

Meeting the flash flood forecasting requirements: WFO-MPE

- Future plans
  - Operate at the highest space-time resolution afforded by the WSR-88D data
  - Digital Hybrid-Scan Reflectivity (DHR) product (1 km x 1↓)
  - Digital Storm Total Precipitation (DSP) product (2 km x 1↓)


DHR/DSP
DPA
WSR-88D
ORPG/PPS
Hydro-Estimator
Rain Gauges
Multi-Sensor Precipitation Estimator (MPE)
Lightning
NWP model output
WFO-MPE
WFO
RFC

To help get there

- In addition to in-house R&D (supported by NPI and AWIPS)
- Collaborative research and development
  - Princeton University
  - University of Iowa
  - Baltimore Flash Flood Project
  - Florida State University
  - FSL, NCEP
- AHPS
  - Ensemble/probabilistic QPE
- Intercomparison projects
  - OHD-NSSL QPE Intercomparison Project

In Closing

- Radar-based/aided precipitation estimation activities are driven by the accuracy requirements for flood forecasting that span a wide range of space-time scale
- Current and near-term efforts are direct to;
  - improve the accuracy of the estimates (bias reduction in particular)
  - provide information on the quality of the estimates
- Planned and future improvements reflect where the science of hydrologic prediction is headed;
  - distributed hydrologic models (requirement for hydro forecasts for smaller basins)
  - ensemble/probabilistic prediction (requirement for forecast uncertainty)

For more details

- Http://www.nws.noaa.gov/oh/hrl/papers/papers.htm#wsr88d