National Mosaic and Quantitative Precipitation Estimation Project (NMQ)

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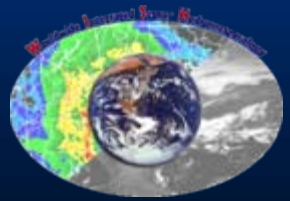
National Severe Storms Laboratory

Dr. DJ Seo and David Kitzmiller

National Weather Service, OHD

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.



Strategic Partnerships

Federal Aviation Administration

Convective Weather PDT

Chuck Dempsey, Jason Wilhite and Dr. Robert Maddox

SRP, Salt River Project, Tempe, AZ, USA

Dr. Paul Chiou, Dr. Chia Rong Chen, and Dr. Pao-Liang Chang

Central Weather Bureau, Taipei, Taiwan

Weather Decision Technologies, Norman, Oklahoma, USA

Scientific Collaborators

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NOAA, Environmental Technology Laboratory

Andy Edman and Kevin Warner

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NWS Office of Climate, Water, and Weather Services

Steve Hunter

USGS, Bureau of Reclamation

Dr. Robert Kuligowski

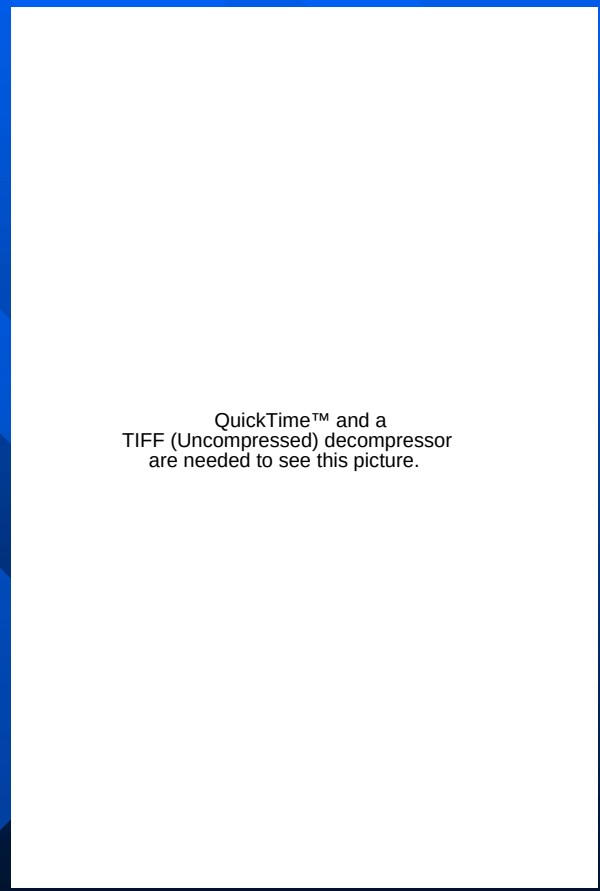
NOAA National Environmental Satellite, Data and Information Service

Dr. Curtis Marshall

NOAA National Center for Environmental Prediction

Basic Challenges of water, floods and water resource management

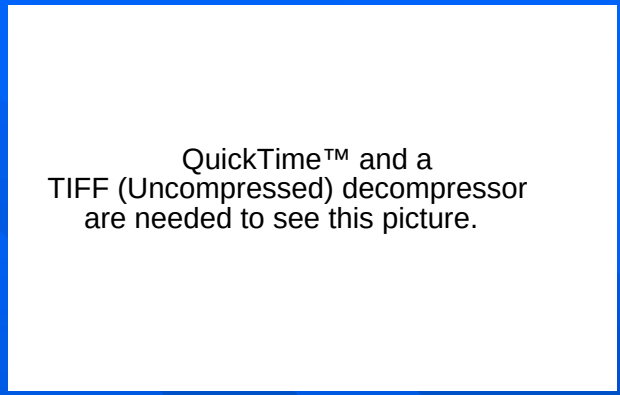
- Too little too late (drought)
- Too much too soon (flash flood)



What is NMQ?

- The National Mosaic and QPE (NMQ) project is a joint initiative between NSSL, FAA, NCEP and the NWS/Office of Hydrologic Development (OHD) and the NWS/Office of Climate, Water, and Weather Services (OCWWS) to address (among others) the pressing need for
  - high-resolution national 3-D radar mosaics for atmospheric data assimilation and severe weather identification and prediction
  - multi sensor QPE and short term QPF for all seasons, regions, and terrains in support of operational hydrometeorological products and distributed hydrologic modeling
  - Research to operations infusion pathway

Relevance of NMQ?



- Monitoring and prediction of water underpins the nation's health, economy, security, and ecology.
- However there exists no seamless high resolution systematic monitoring of fresh water resources in North America
- The scientific and political challenges are significant requiring a community based and multi-faceted approach for fresh water monitoring and prediction.

Objectives of NMQ

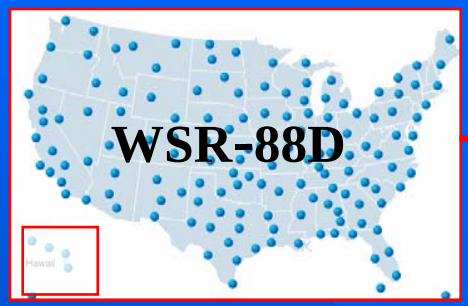
- Create the infrastructure for community-wide research and development (R&D) of hydrometeorological applications in support of monitoring and prediction of freshwater resources in the U.S. across a wide range of space-time scales
- Through the NMQ infrastructure, facilitate community-wide collaborative R&D and research-to-operations (RTO) of new applications, techniques and approaches to precipitation estimation (QPE), short-range precipitation forecasting (QPF), and severe weather
- Maintain a scientifically sound, physically realistic real-time system to develop and test techniques and methodologies for physically realistic high-resolution rendering of hydrometeorological and meteorological processes

NMQ_xrt Polar Ingest (1 km to 250 meter)

Radar Data Sources

Polar Processing

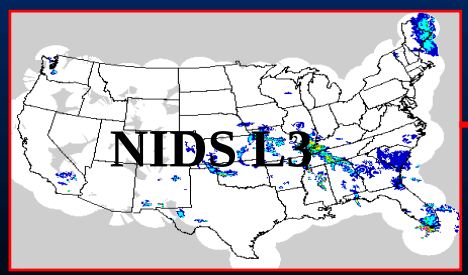
Product Generation



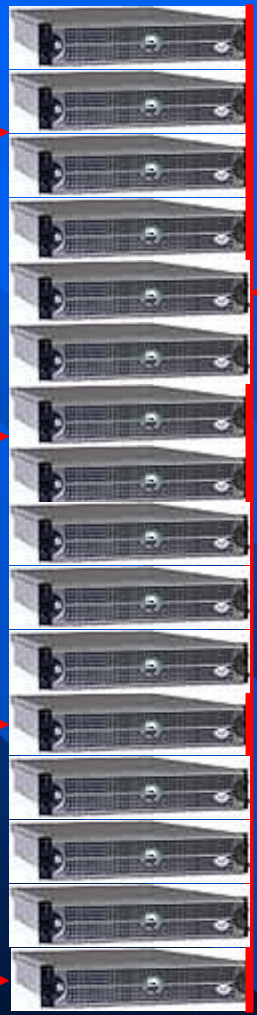
LDM

LDM

LDM



FTP

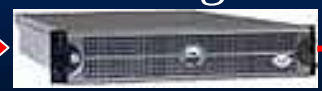


14 - rt
2 - hs

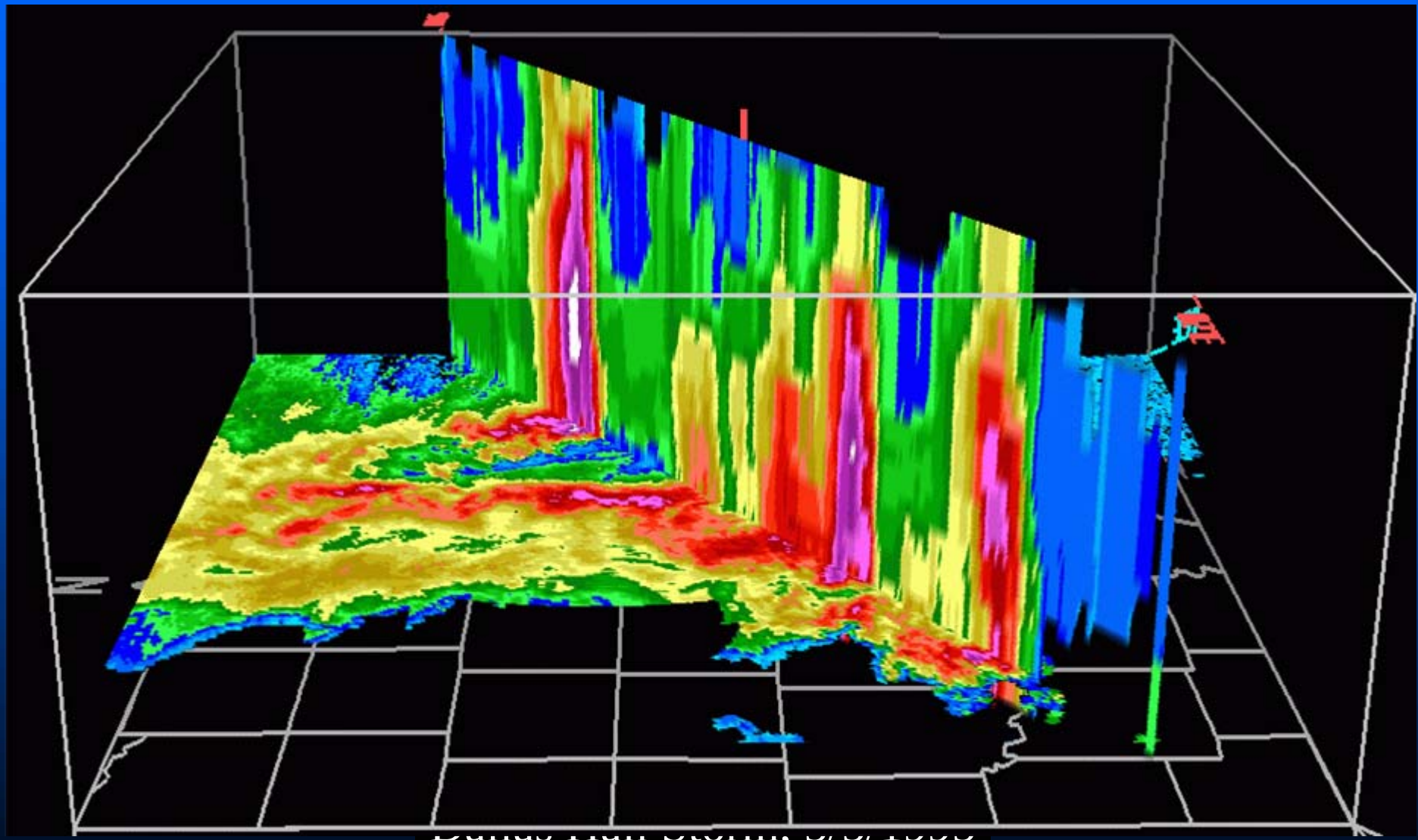
Primary Server

Mosaic Servers

External Data Ingest



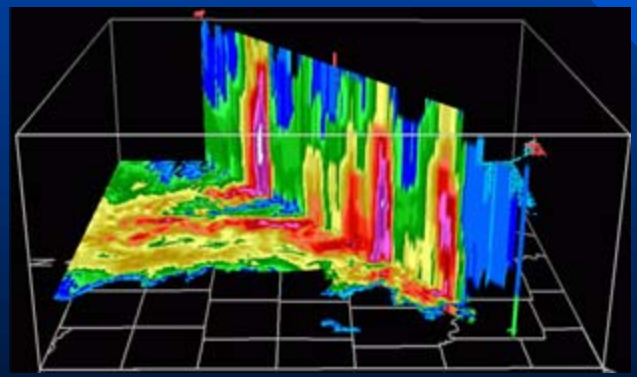
Cross Sections from 3-D Mosaic



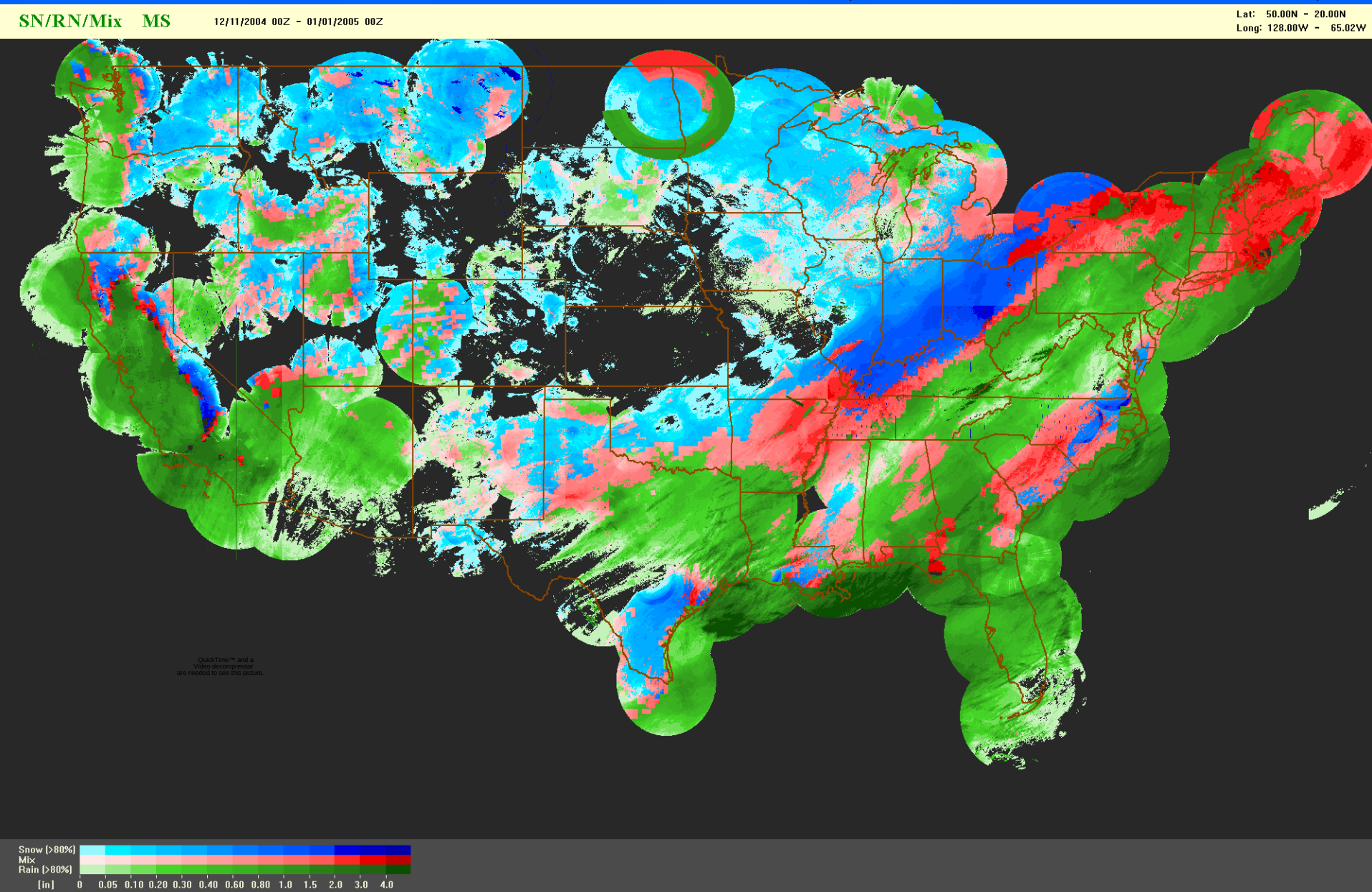
Dallas Hail Storm, 5/5/1995

NMQ ‘Real Time’ CONUS

QuickTime™ and a
Video decompressor
are needed to see this picture.

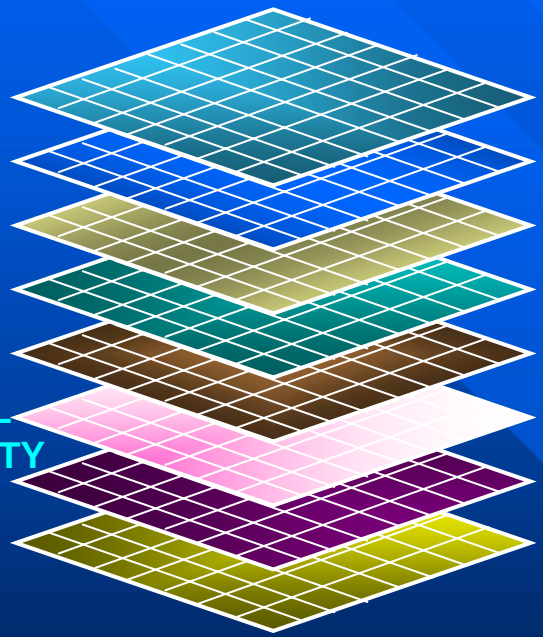


Snow/Rain Mix MS PCP (Dec. 11- Jan. 1)



NWS Water Science Vision: Integrated Products and Services

a) NWS-NDFD High-Resolution Gridded Water Resources Product Suite (WRPS)



U.S. FOCUS

GLOBAL CAPABILITY

- Precipitation
- Snowpack
- Soil Moisture, Runoff
- Evaporation
- Groundwater
- River flow
- Surface Storage
- Water Quality
- Others

Applications

Drought

Flood Management

Flash Flood Prediction

Water Supply

Transportation

Emergency Management

Agriculture

Debris Flows

Ecosystems Management

Research

Customers

NWS

NOAA

Federal Agencies

Tribal Agencies

State Agencies

Local Agencies

Private Sector

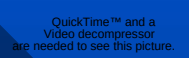
Academia

The WRPS includes a comprehensive suite of high-resolution (1-10 km) gridded hydrologic state variable and flux datasets and derived products to support a wide range of future applications and services. Temporal characteristics of WRPS range from current-hour analyses to forecasts of several months. Datasets include rainfall, snowfall, snow water equivalent, snowpack temperature, snowmelt, soil moisture, soil temperature, evaporation, sublimation, streamflow, and surface storage. Other hydrologic variables such as groundwater, fuel moisture, soil stability (e.g. debris flows potential), water quality, etc. are also possible in this framework.

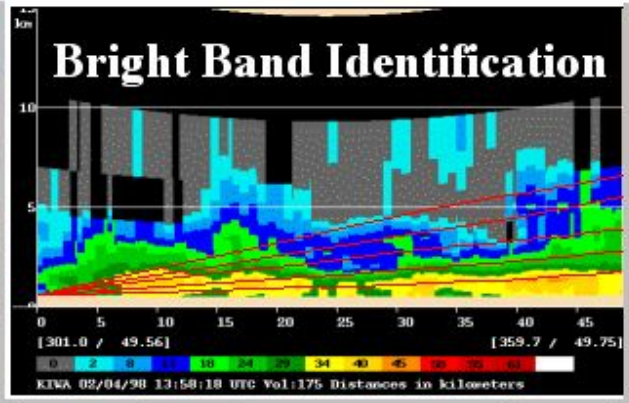
From NWS Integrated Water Science Plan (2004)

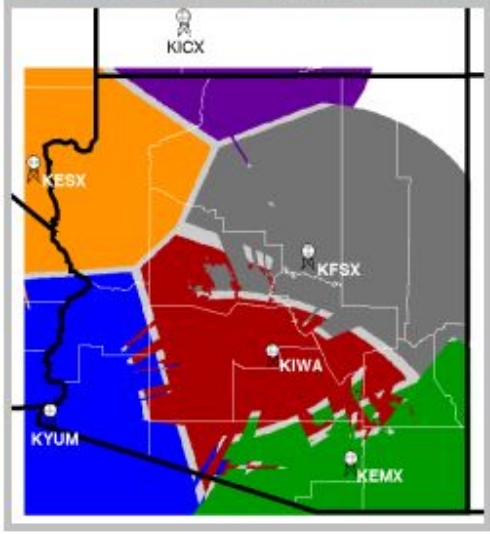
NMQ

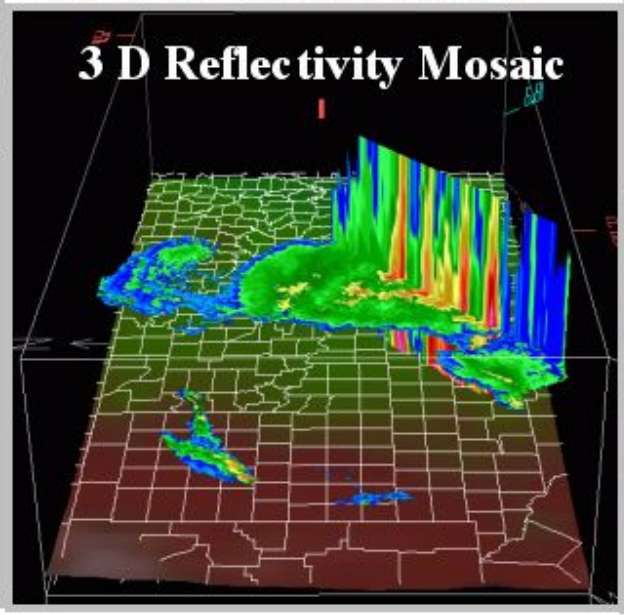
National



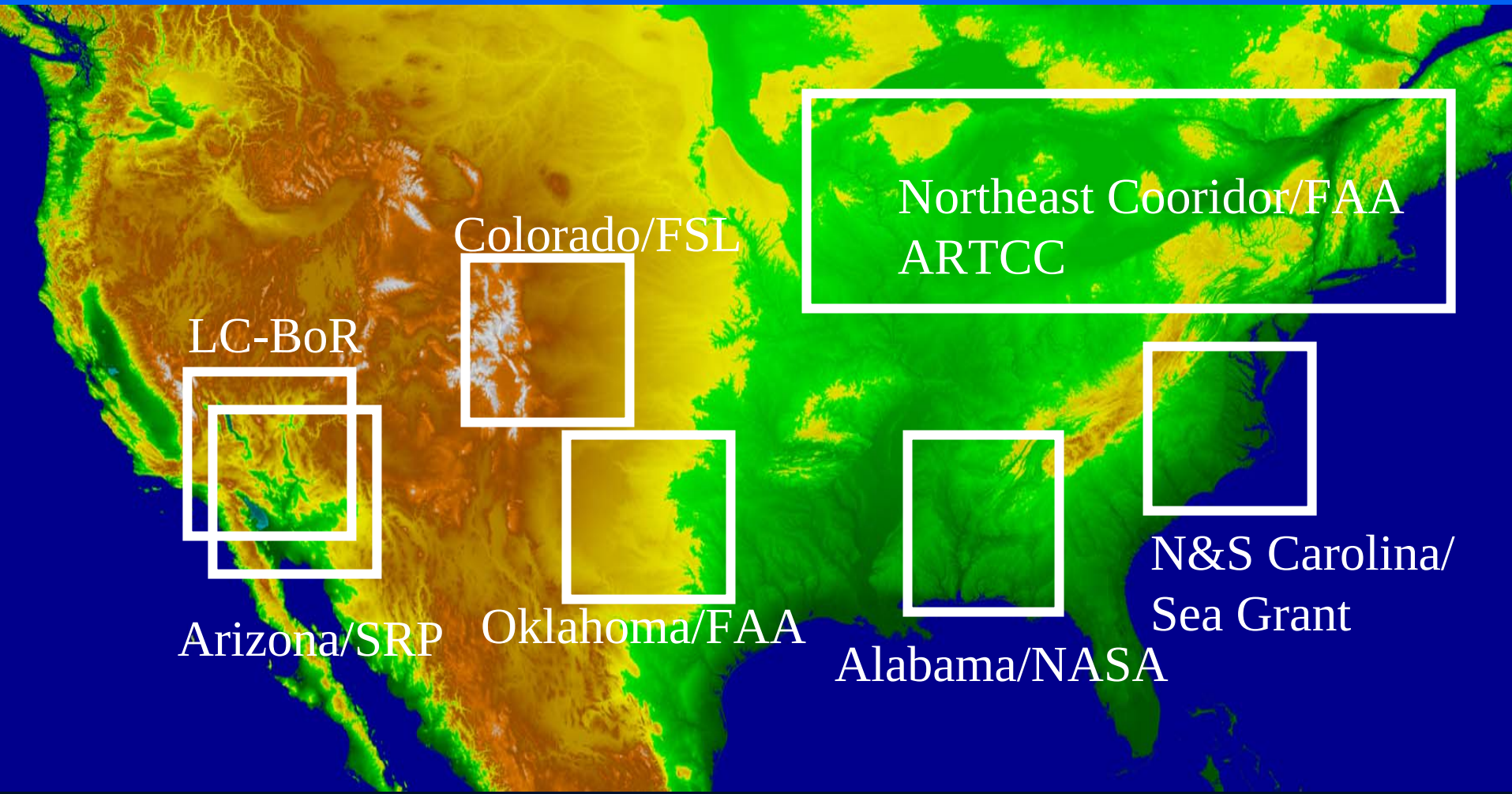
Quantitative Precipitation Estimation and Segregation Using Multiple Sensors



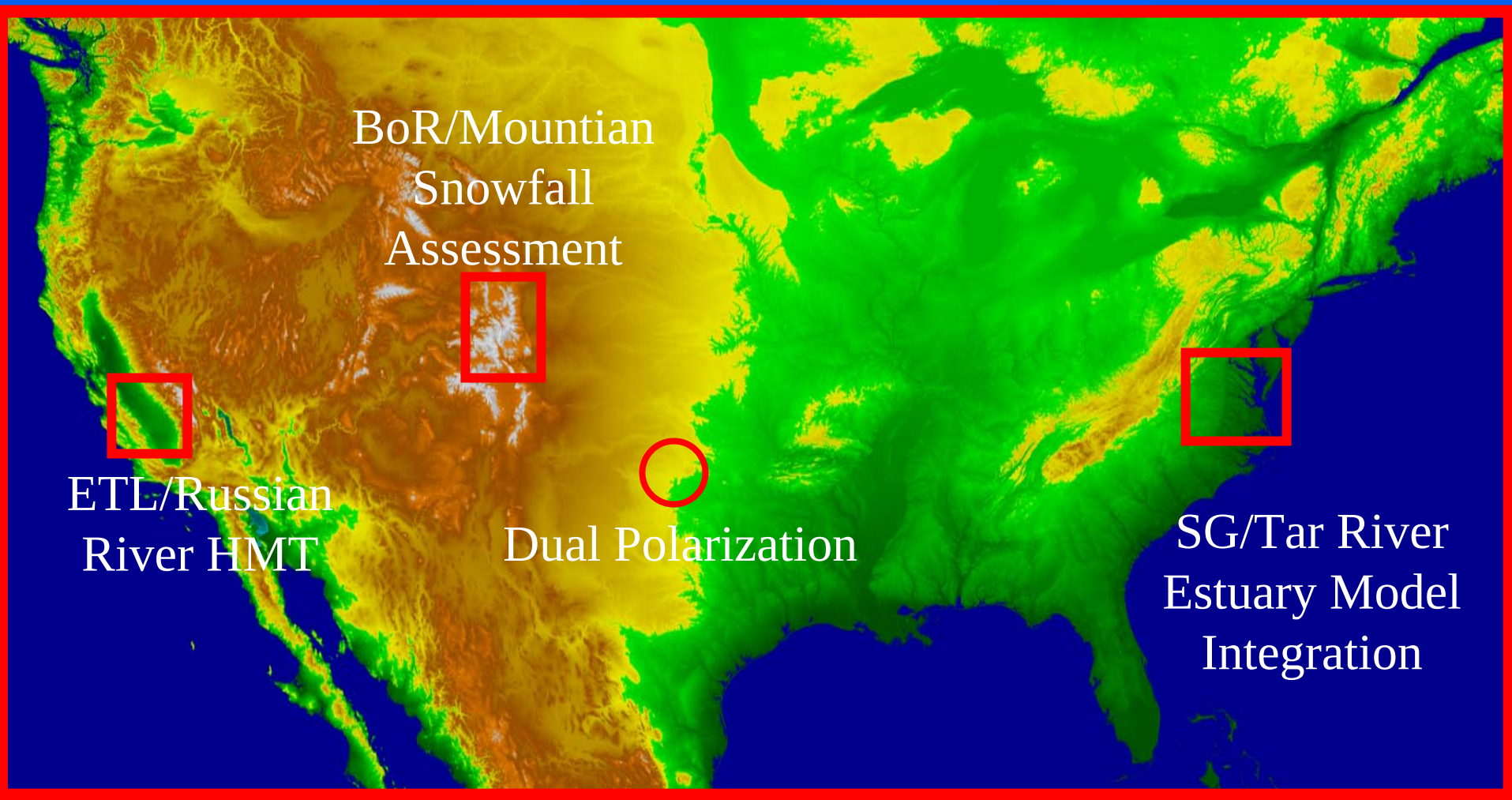




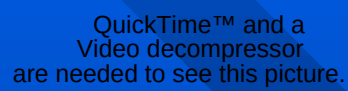
NSSL/WISH 3D Mosaic and QPESUMS Deployments



NSSL/WISH NMQ and nested 'Micro' Testbeds Deployments

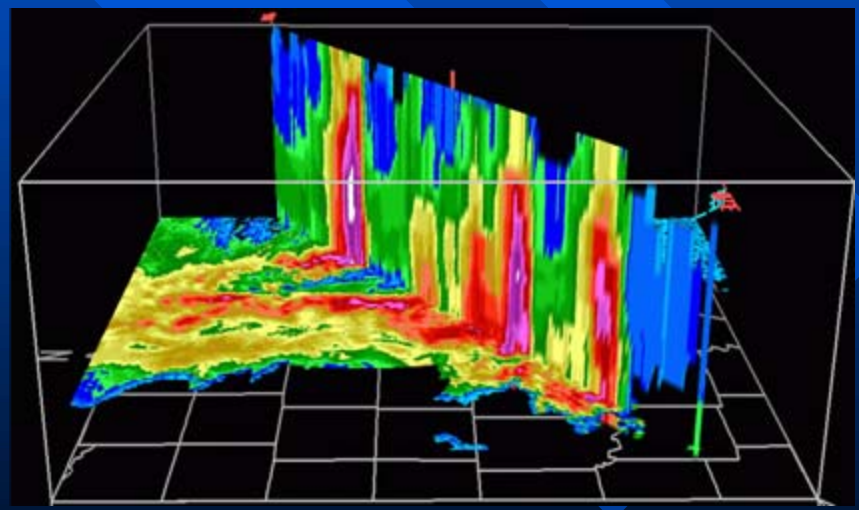


‘Real Time’ CONUS Test Bed



NMQ

3-D and 2-D Mosaic

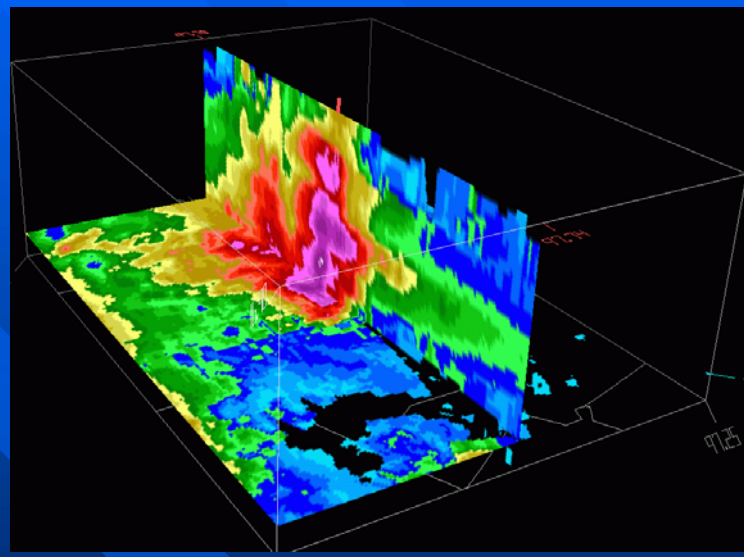


NMQ Motivation

- Weather systems span over multiple radar umbrellas
- Forecasters are often responsible for large warning areas that require multiple radar coverage (e.g., NWS CWA, and FAA ARTCC)
- 3D mosaic can facilitate:
  - » Better depiction of storm characteristics than 2D depictions
  - » Better understanding of microphysical processes leading to more accurate QPE and QPF
  - » 3-D data assimilation for storm-scale numerical weather prediction
  - » Development of robust MS severe storm applications and algorithms

NMQ Objectives

- To create and to provide users with ‘real time’ 3D reflectivity mosaic over conterminous US
  - Base data (level-II) ingest from NWS, FAA, Canadian and others
  - Optimum and directed quality control of radar data
  - Objective analysis is designed for
    - » Retaining high-resolution info in raw data
    - » Minimizing radar-sampling artifacts

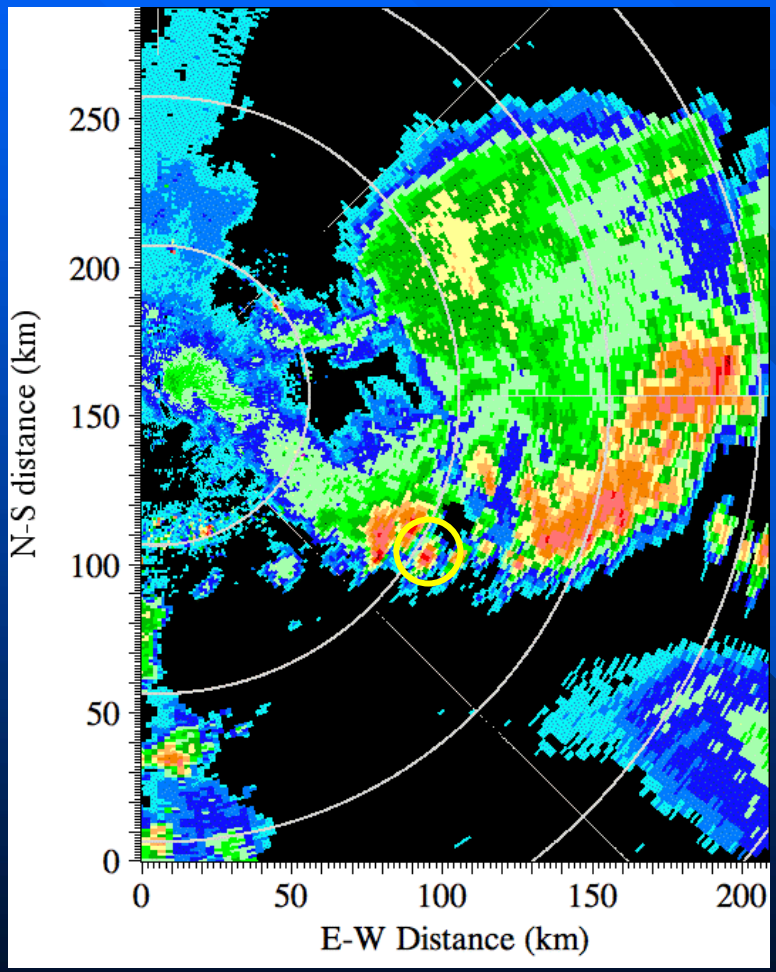


  - High-resolution: 1 km horizontal, 500m - 1 km 21 vertical levels evolving to 250 meter horizontal and 35 vertical levels
  - Rapid update: approx 5 minutes to 1 minute

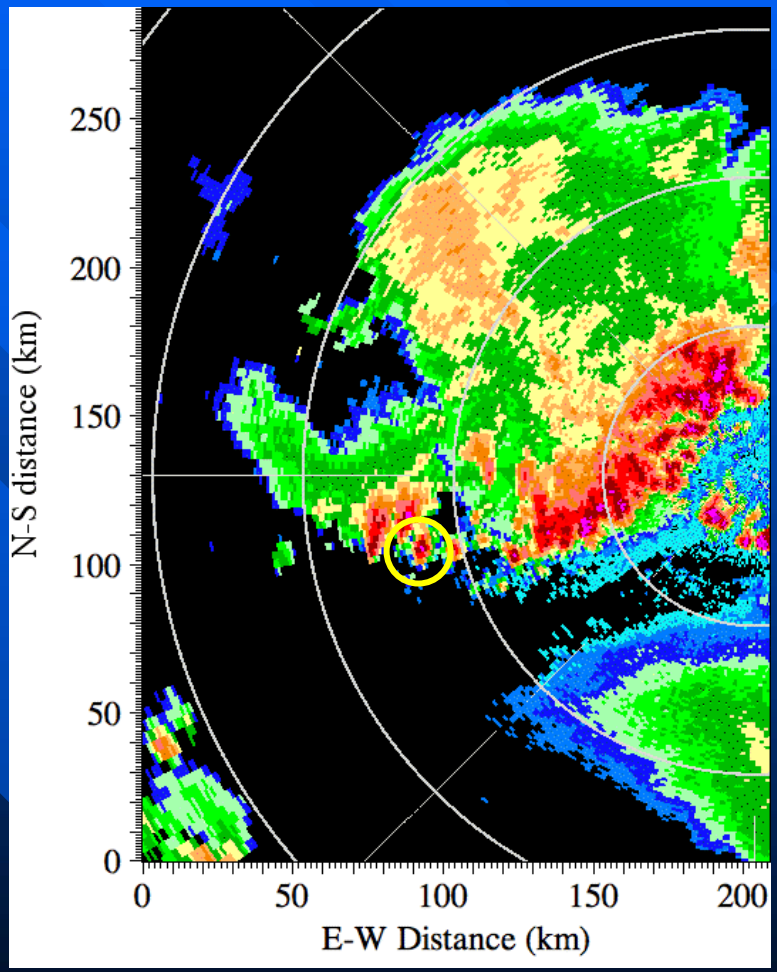
NMQ Challenges

- Spatially non-uniform data resolution
- Non-meteorological echo contamination/quality control
- Calibration differences among radars
- Synchronization among radars
- Computational efficiency for real-time applications

Convective Case : 6/25/02, 2036Z
KLOT and KIWX

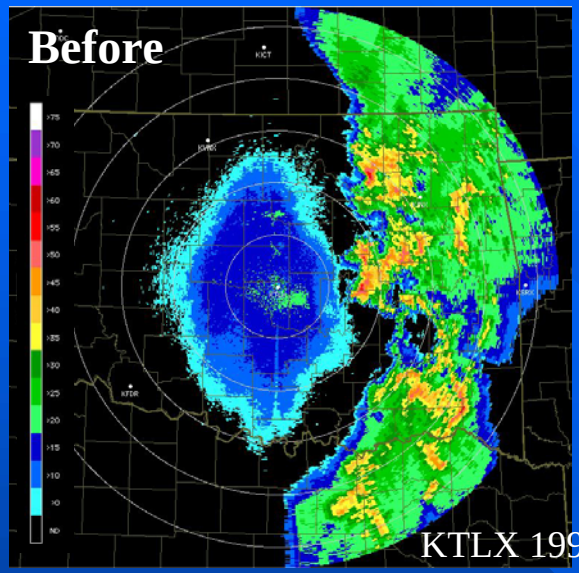


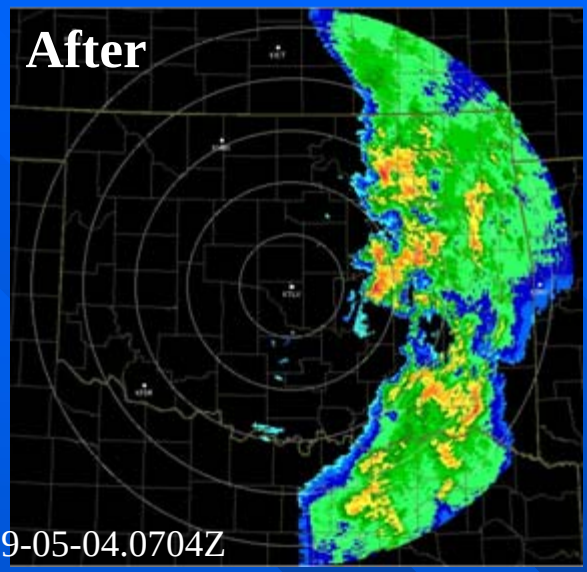
CREF_KLOT



CREF_KIWX

Examples of Reflectivity QC

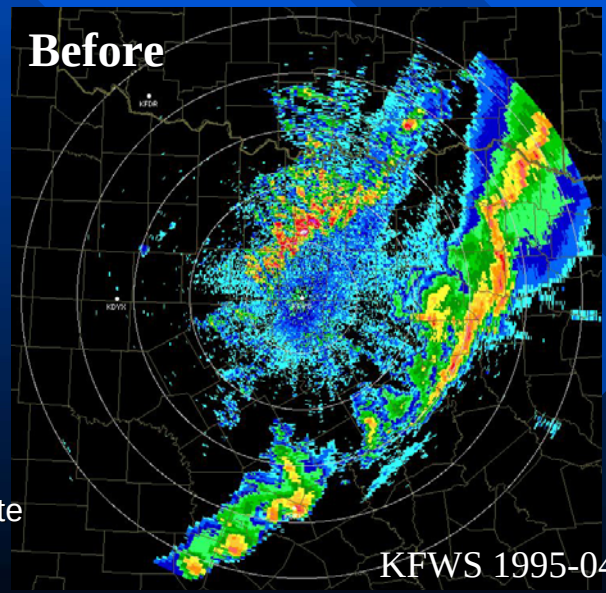


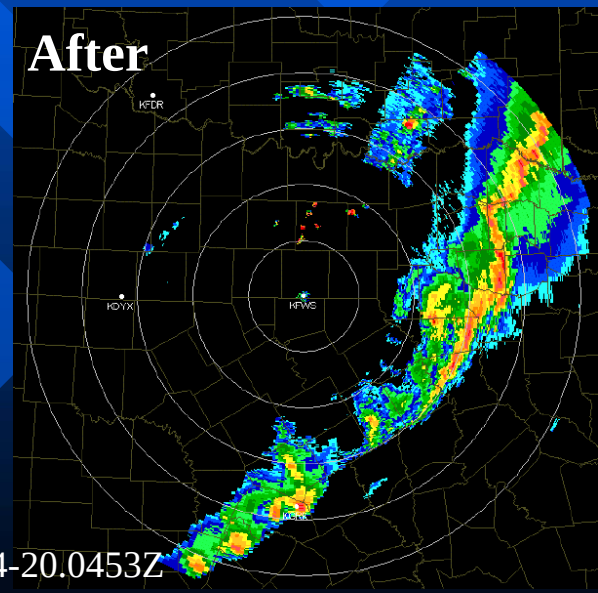


KTLX 1999-05-04.0704Z

Clear Air Echoes

- Low intensity
- Shallow depth
  - May not be segregated from very shallow stratiform precip/snow using refl structure only
  - Require velocity info





KFWS 1995-04-20.0453Z

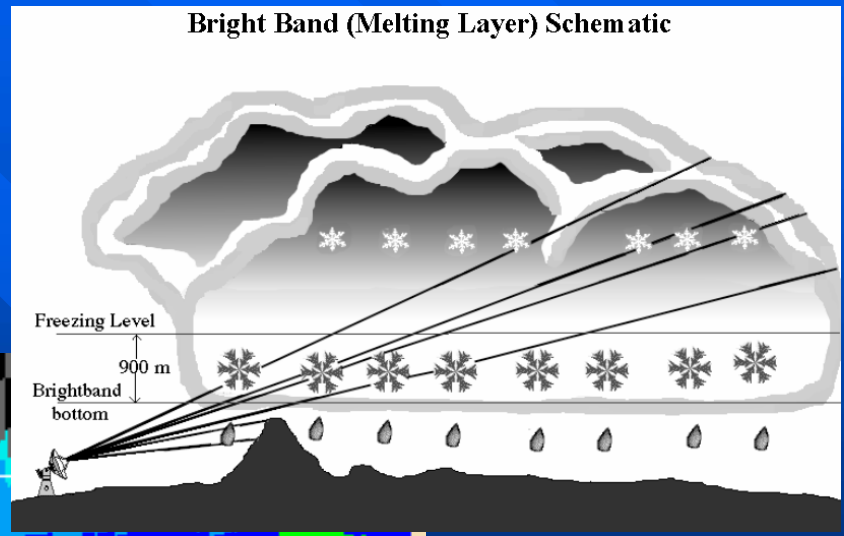
AP Echoes

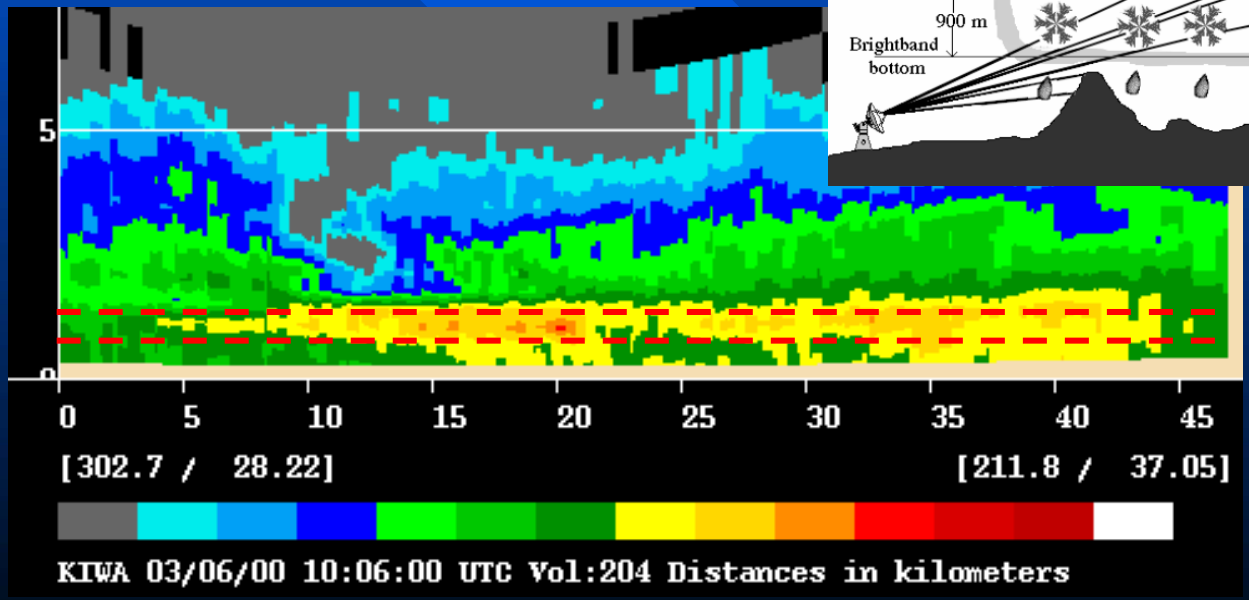
- Lack of vertical continuity
- Rough texture
  - AP at far ranges can not be segregated from shallow precip by using refl structure only
  - Need additional info such as satellite

Bright-Band Identification (BBID)

(Gourley and Calvert, 2003)

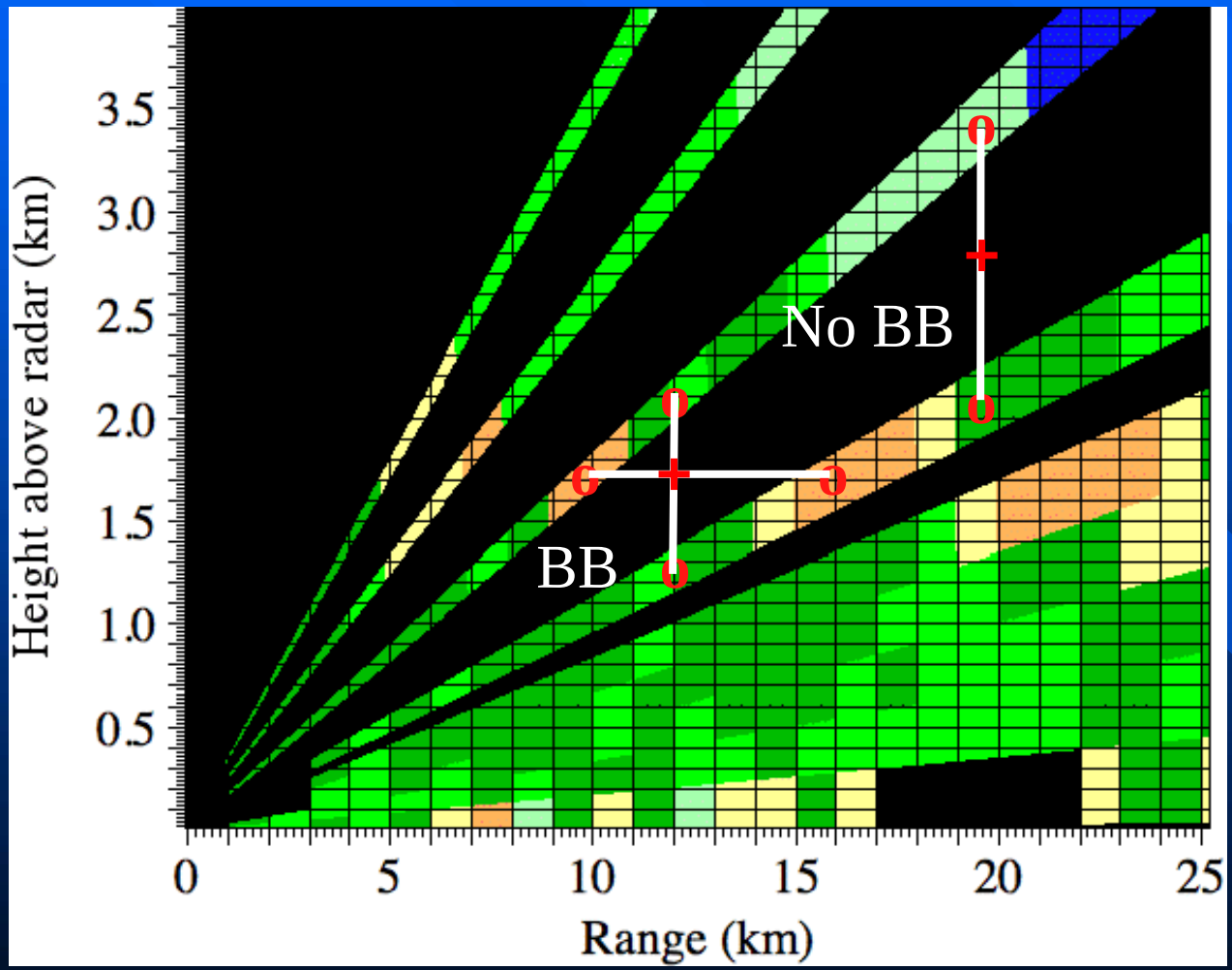
- BB info will impact choice of objective analysis methods
- BBID steps:
  - 3-D Reflectivity Field
  - Find Layer of Higher Reflectivity
  - Vertical Reflectivity Gradient
  - Spatial/Temporal Continuity





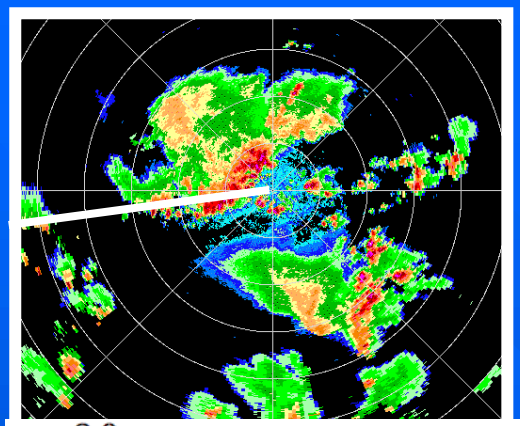
3-D Spherical to Cartesian Transformation

(Zhang et al. 2003)

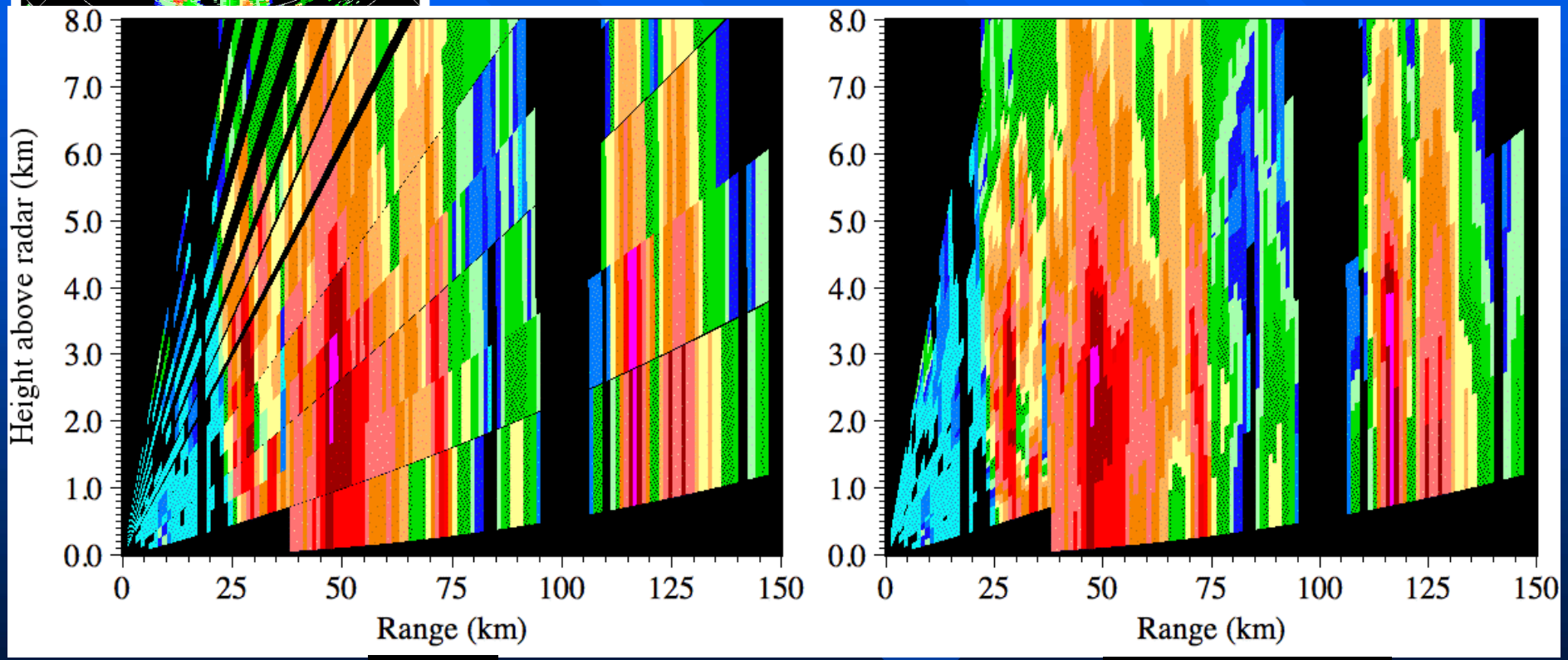


No BB:
Vertical linear interpolation

BB exists:
Vertical and horizontal linear interpolation

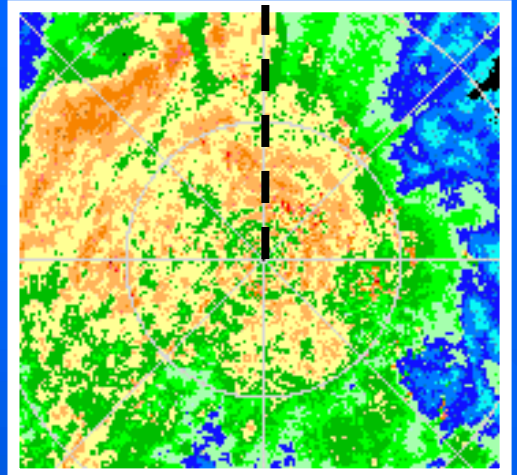


Convective Case1: RHI, 263°

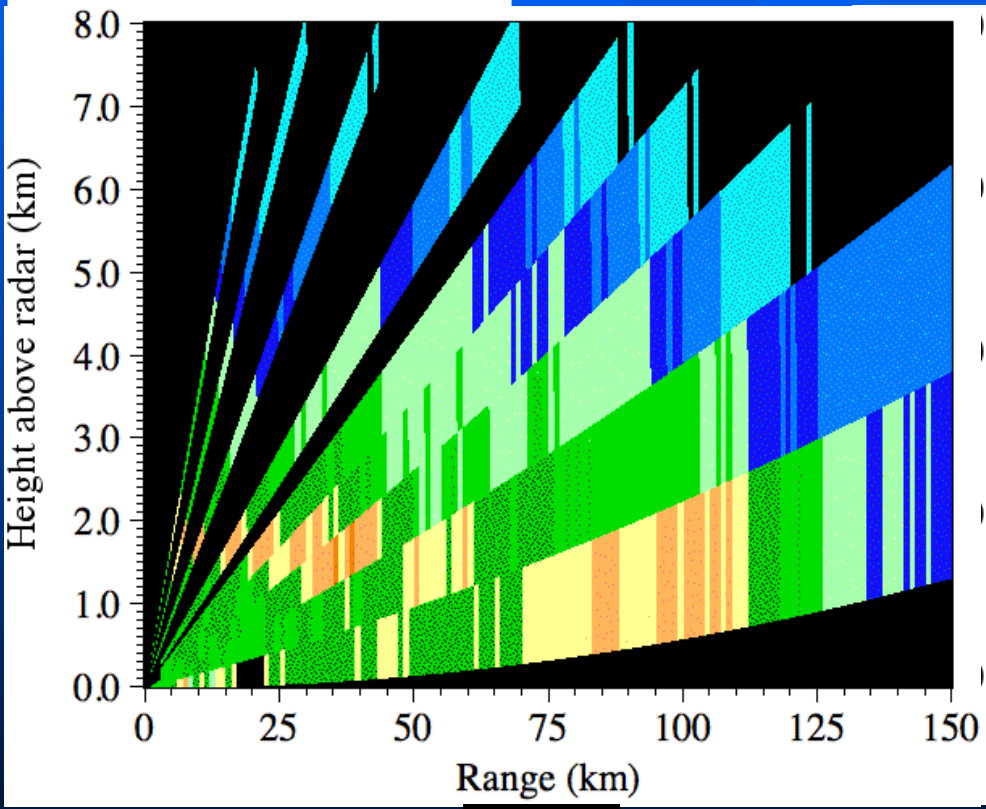


Raw

Interpolated



Stratiform Case 2: RHI, 0°



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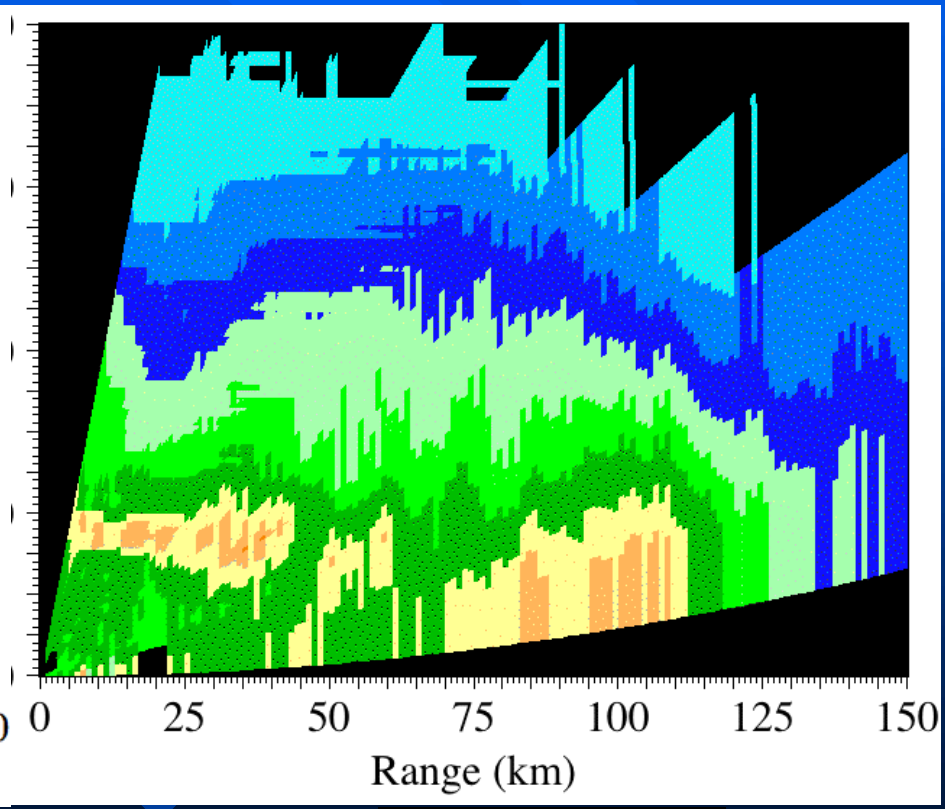
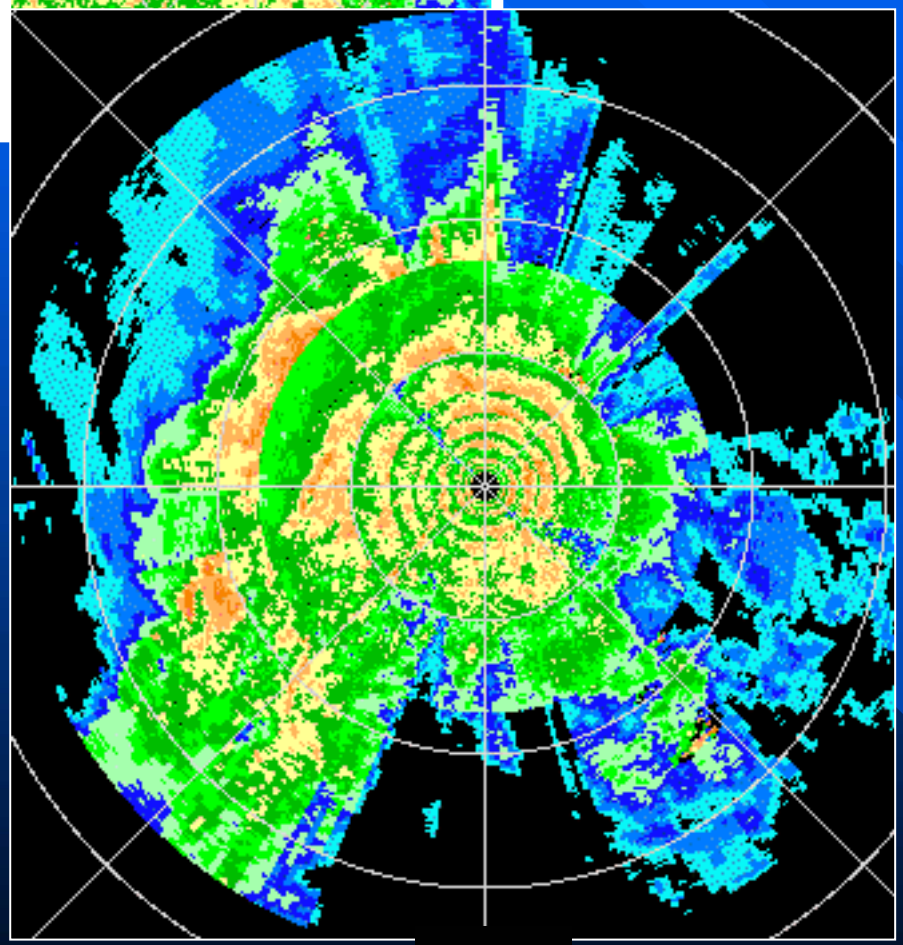


Interpolated

Stratiform Case

CAPPI at 2.3km



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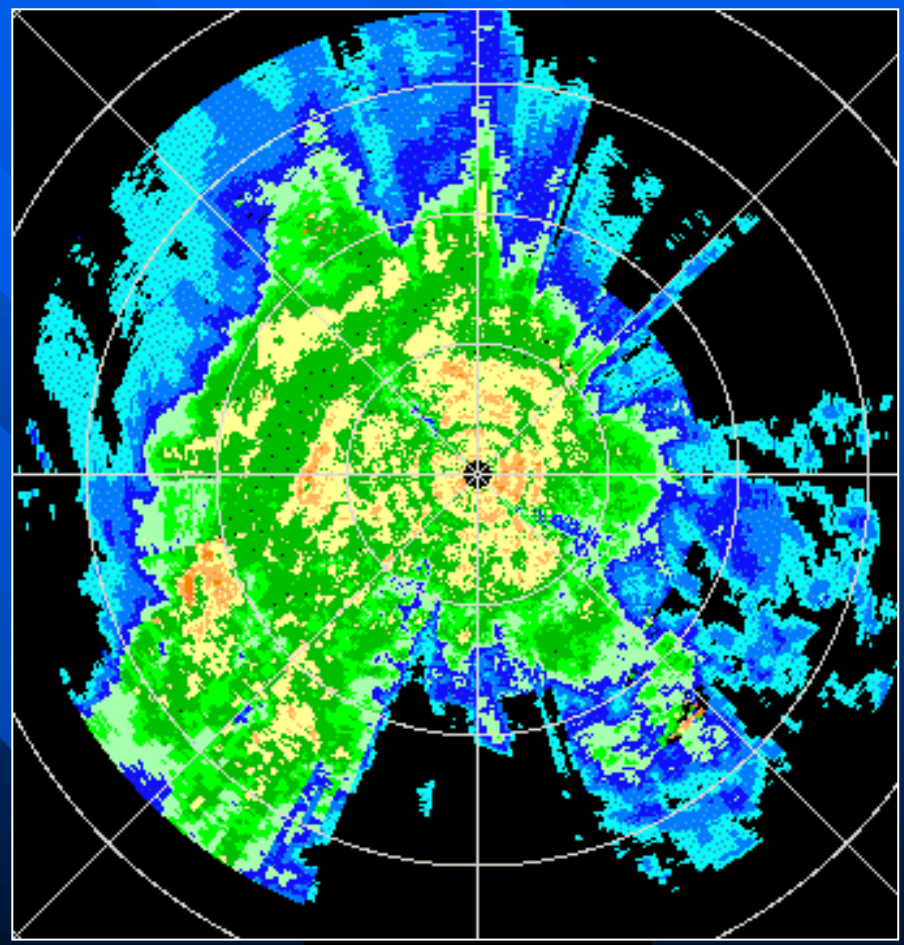
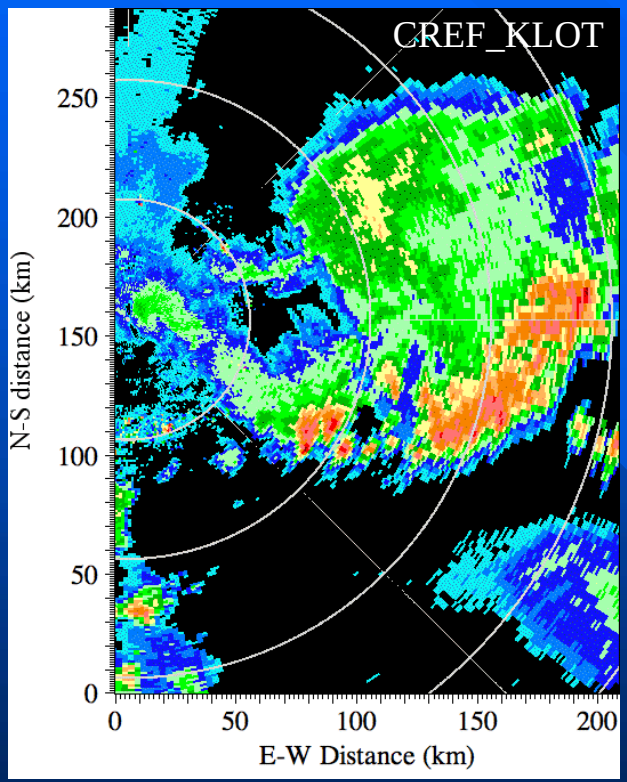
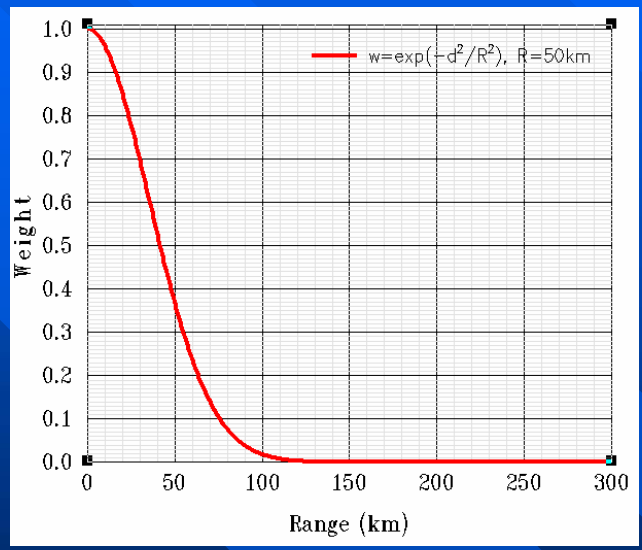
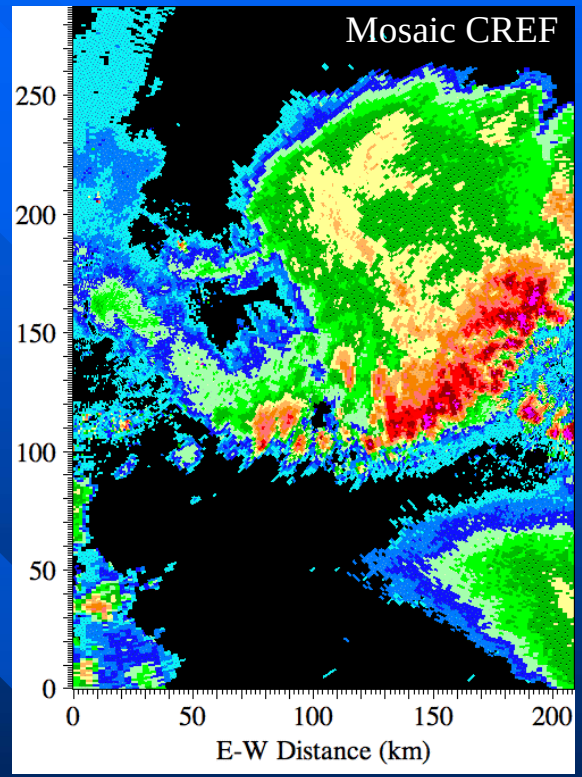


Interpolated

Distance Weighting

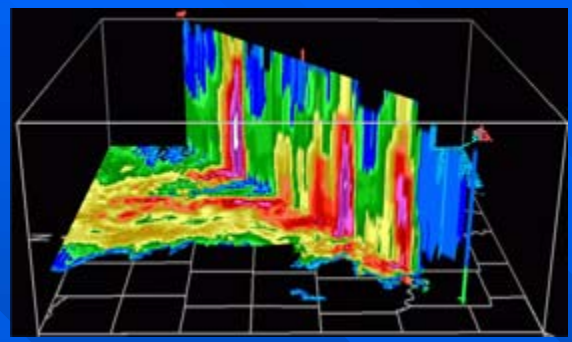






Applications and Products Based upon the 3D Mosaic

- 2D and 3D products and Multi-sensor Severe Storm Attributes
  - Composite Refl., Height of Comp. Refl.
  - Hybrid Scan Refl, Height of Hyb scan refl.
  - Refl on constant T-levels
  - Gridded VIL
  - Gridded Hail products
  - Echo top



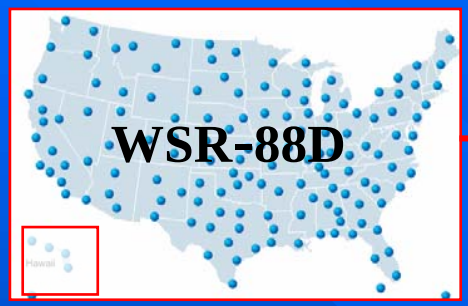
- Multi-sensor Quantitative Precipitation Estimation (in collaboration with OHD/NWS)
  - High-resolution, rapid update precipitation accumulations
  - Short term QPF
  - Flash-flood detection and warning
- Data Assimilation for Convective-scale Numerical Weather Prediction (in collaboration with NCAR, FSL, CWB and NCEP)
  - 3-D diabatic initialization
  - Reduce spin-up time and improve convective-scale QPF

NMQ Current

Radar Data Sources

Processing

Product Generation



LDM

Polar Ingest

3-D Mosaic

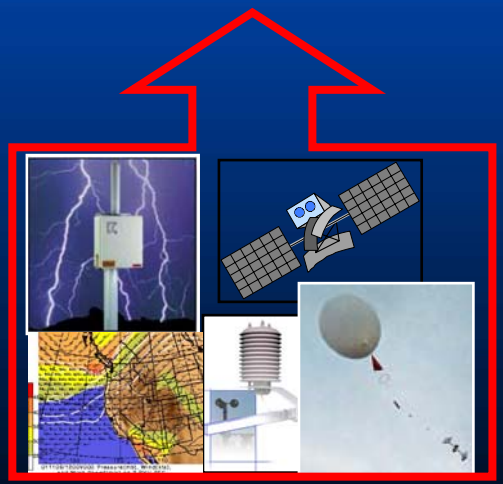
QPE

QPE LGC

Product Server

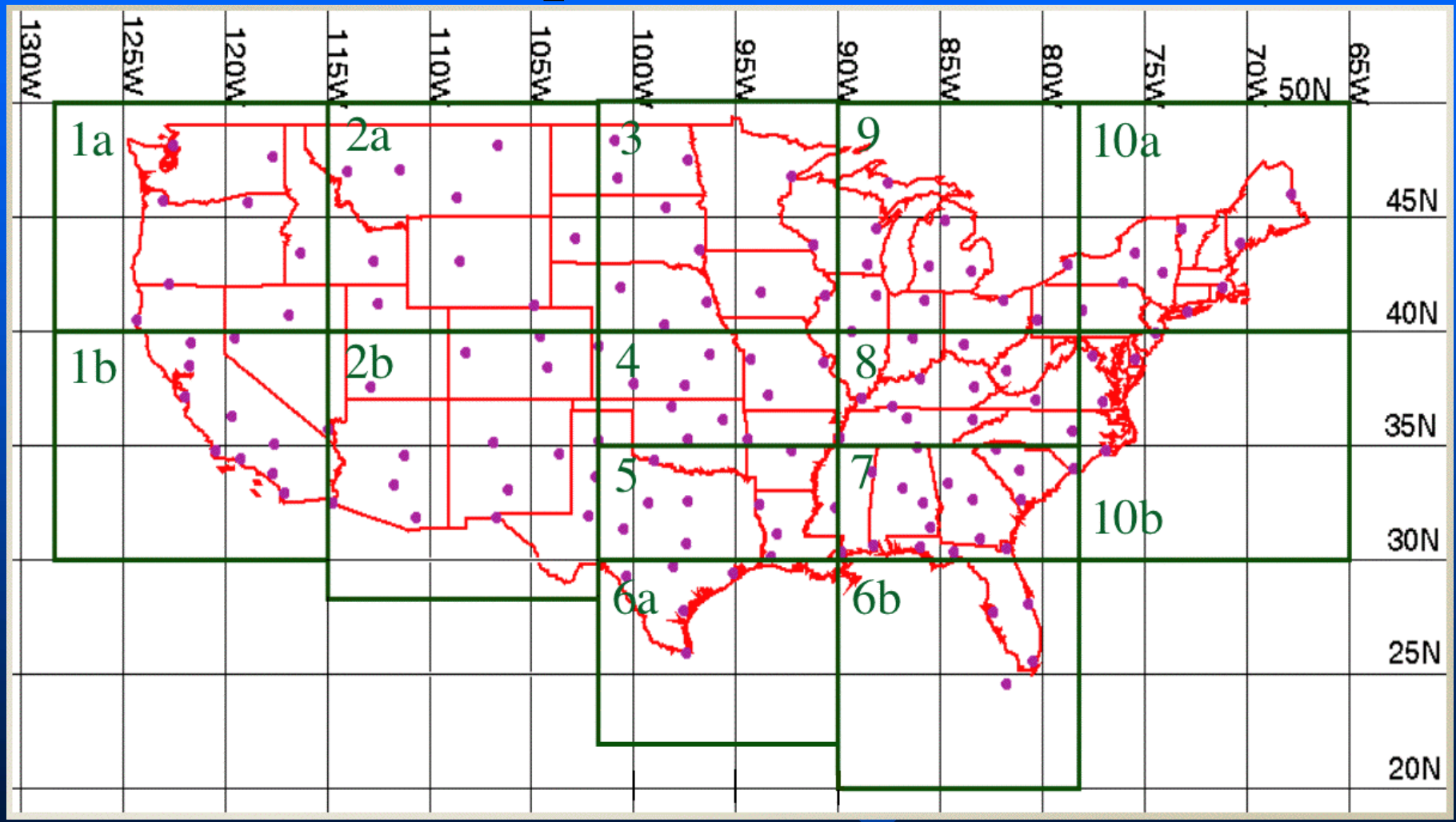
Verification

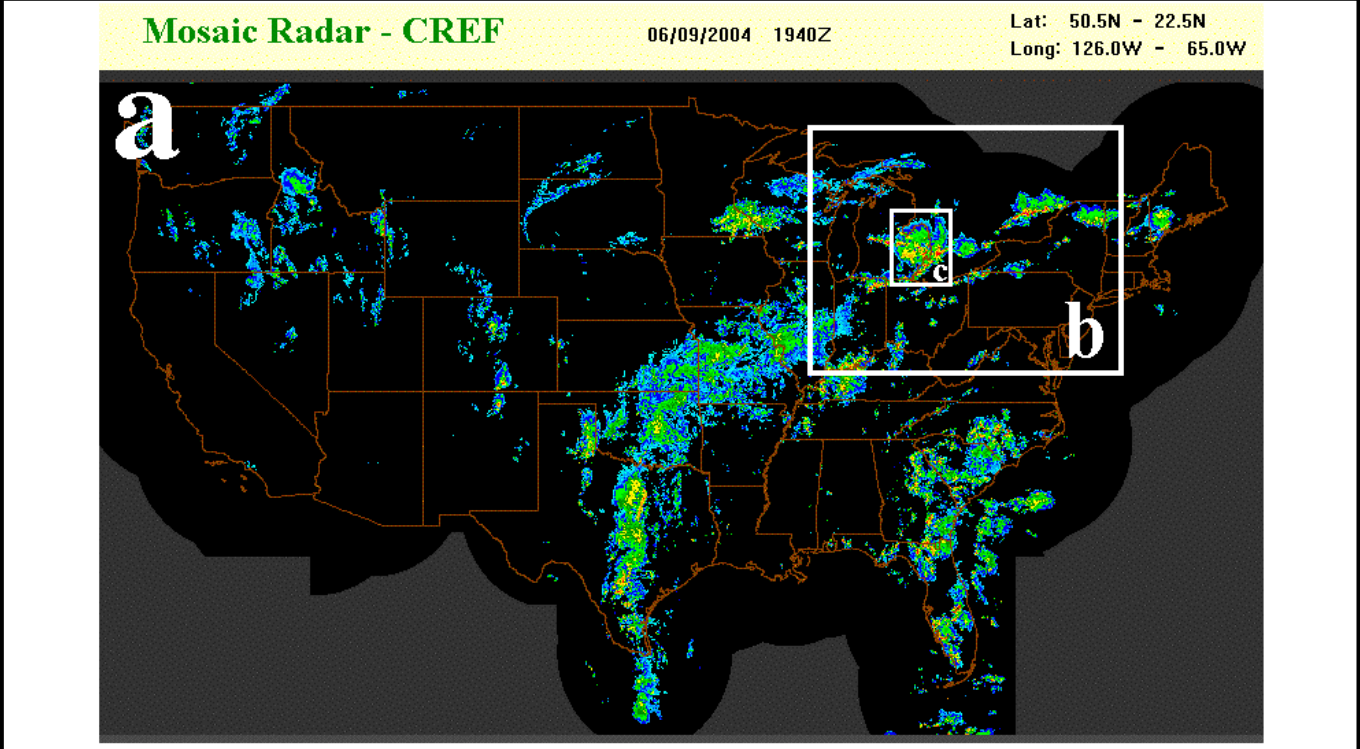
External Data Ingest

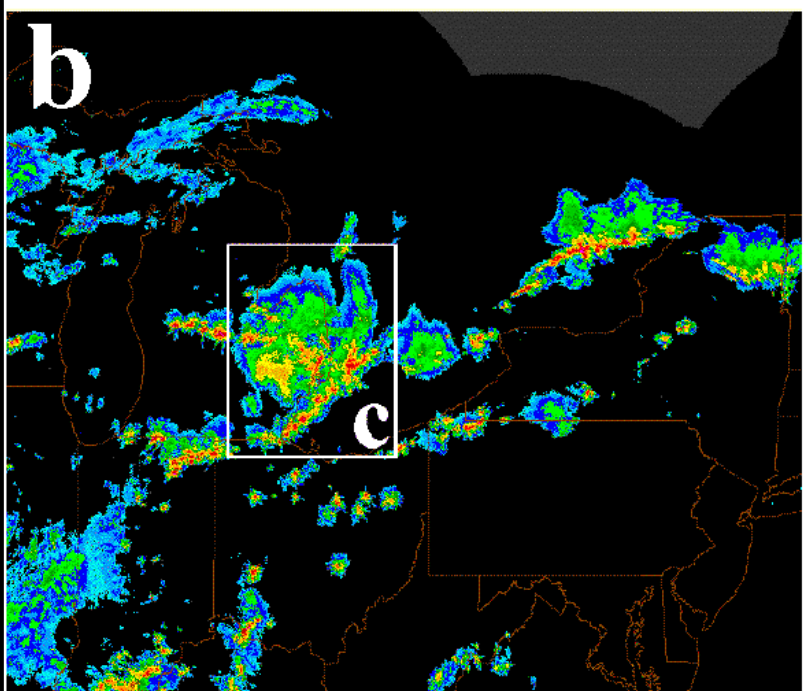


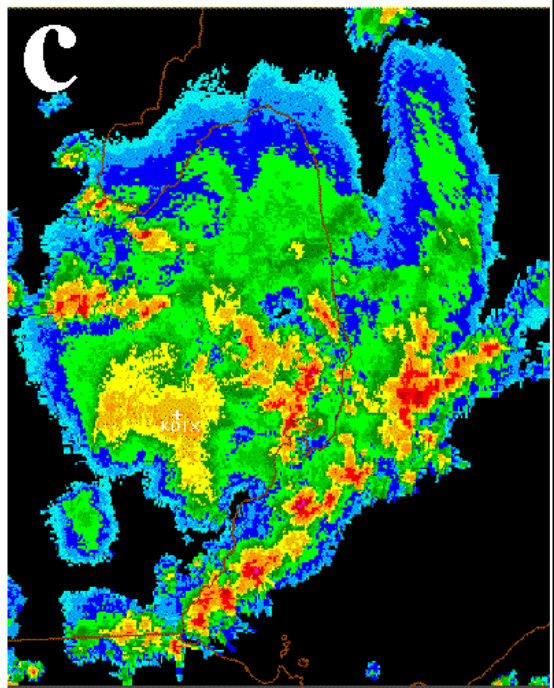
NOAA Port/Other Sources

Computational Tiles









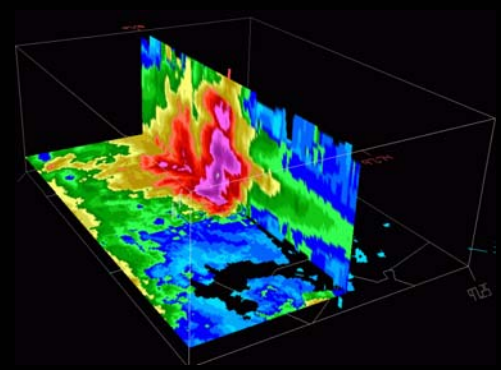
Real-time
CONUS
3-D Reflectivity
Mosaic

124+ Radars

1 km x 1 km x 500m

21 vertical levels

5 min update cycle



NMQ FY 06 Activities

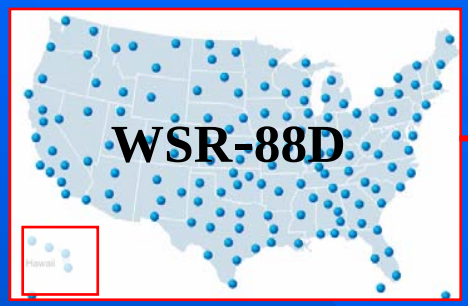
- QC improvements
  - GOES Satellite imagery and sounder data to remove AP
  - Diurnal variation of vertical reflectivity gradient (identification of biological targets)
  - Seasonal and geographical adaptive QC parameters
- Gap-filling
  - Incorporate level-III (NIDS) data when level-II data not available
  - Vertical Profile of Reflectivity (to fill data voids below lowest beams)
  - Additional radars (e.g., Canadian radars, TDWR, CASA, and mobile radars)
- Synchronization among individual radar scans and satellite imagery
- Improving and adding multi-sensor severe storm algorithms
- Short-term Advection of reflectivity feilds

NMQ_xrt Polar Ingest (1 km to 250 meter)

Radar Data Sources

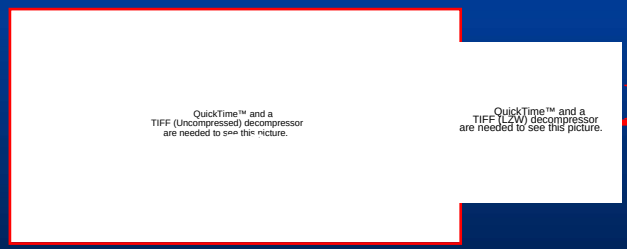
Polar Processing

Product Generation

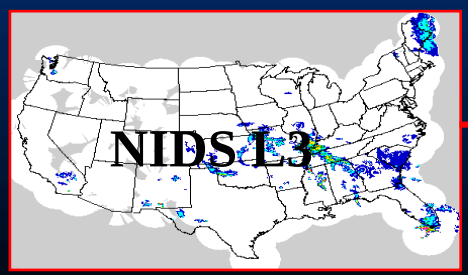


LDM

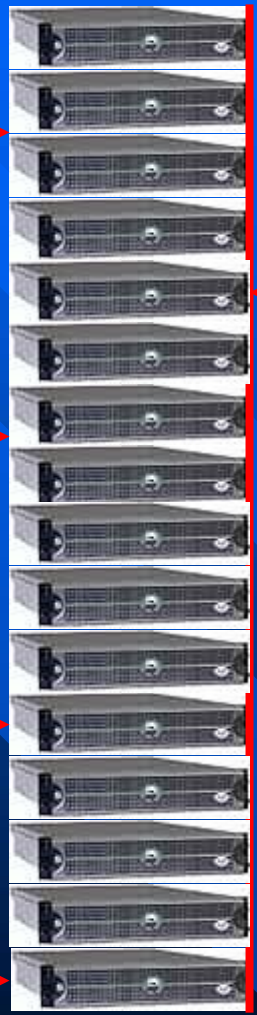
LDM



LDM



FTP

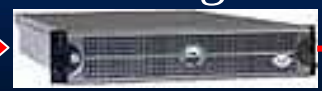


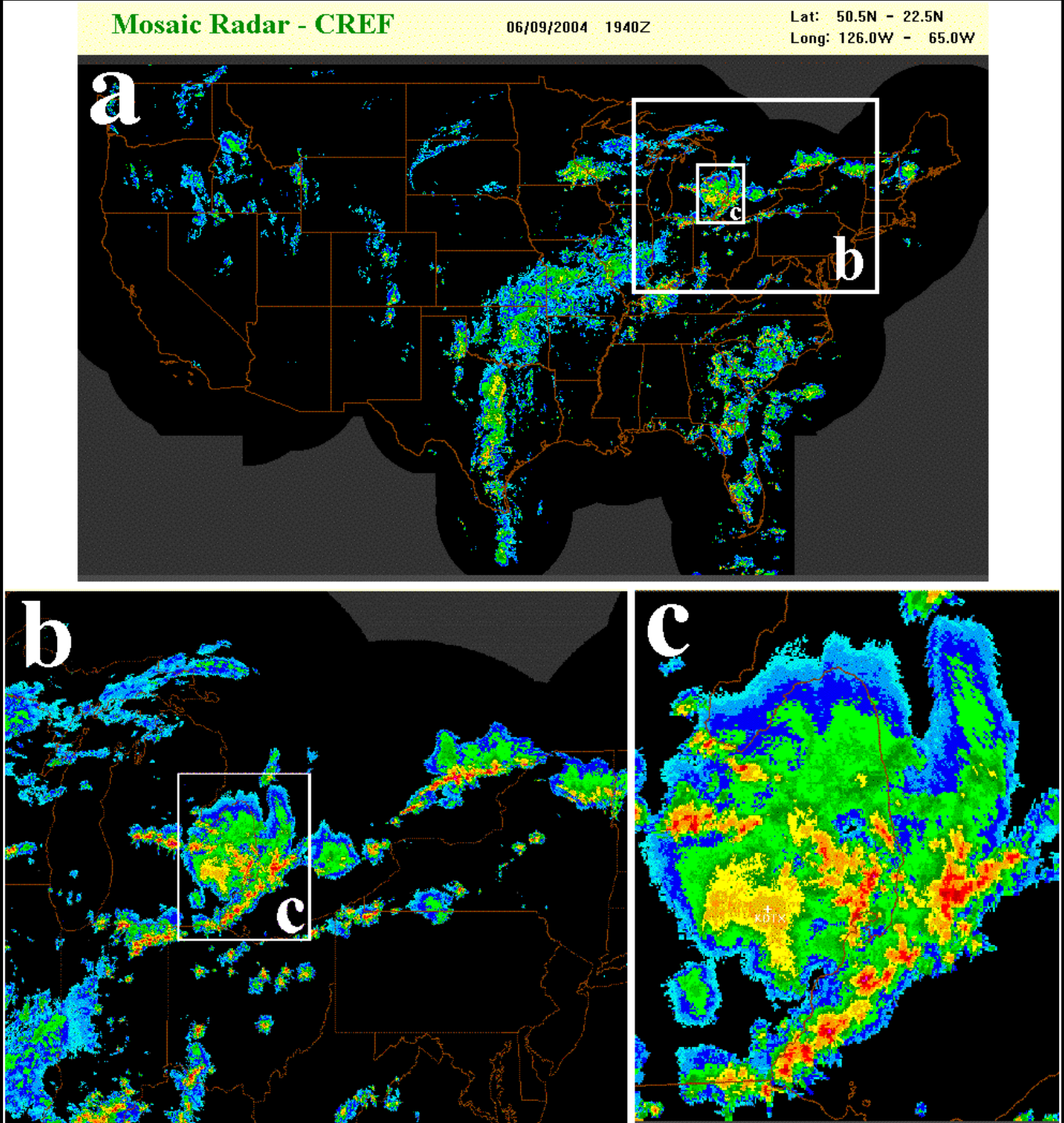
14 - rt
2 - hs

Primary Server

Mosaic Servers

External Data Ingest





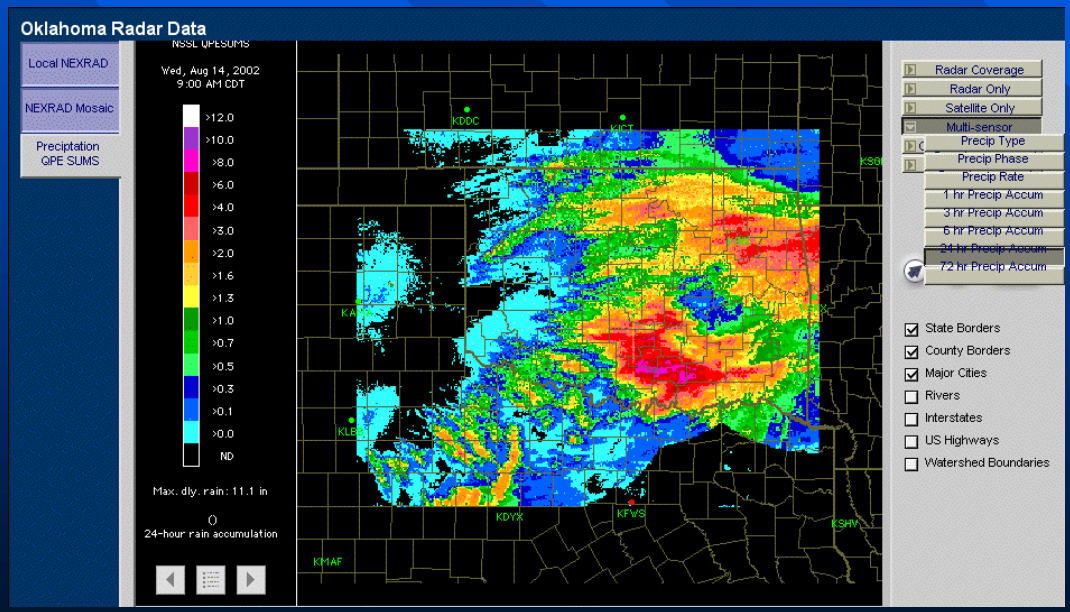
NMQ_XRT
Real-time
CONUS
3-D Mosaic

FY06
124+ Radars
1 km x 1 km x 500m
21 vertical levels
5 min updates cycle

FY07
180+ Radars
250 m x 250 m
30 vertical levels
<5 min update cycle

NMQ

Quantitative Precipitation Estimation



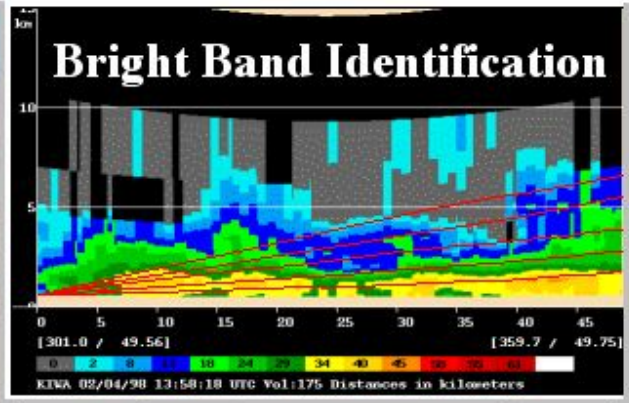
Challenges to Quantitative Precipitation Estimation (QPE) by Radar

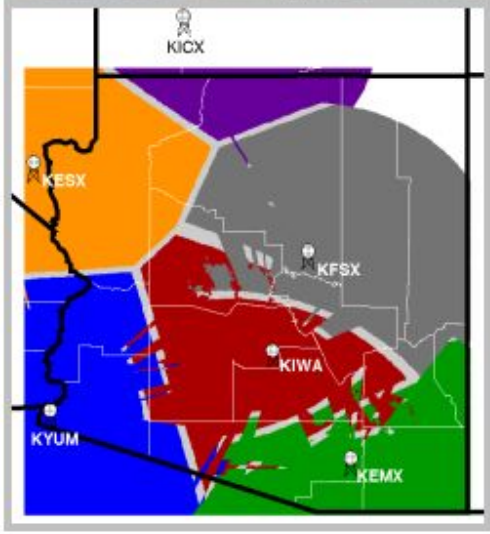
- Reflectivity to Rainfall Conversion Problems
  - Drop size distributions
  - Mass flux
- Sampling Problems
  - Anomalous propagation
  - Ground clutter
  - Beam overshooting
  - Mixed-phase sampling
  - Hail contamination
  - Bright band contamination
  - Radar coverage gaps (western US and coastal regions)

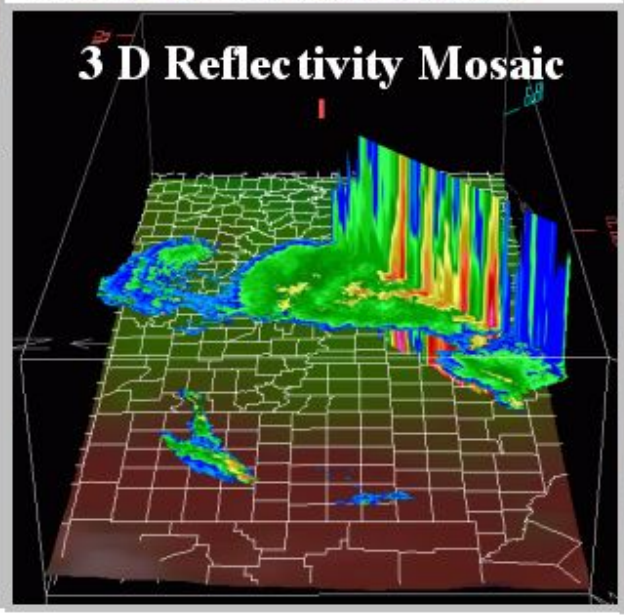
Evolving QPE Strategies and Techniques

1. Merging radar products with gauges and multisensor QPE - MPE - NWS OHD
2. Satellite-based QPE (Hsu et al. 1996; Vicente et al. 1998)
3. Correction of accumulations by using a Vertical Profile of Reflectivity (VPR; Joss and Waldvogel 1970)
4. Use of Dual-polarization variables (Ryzhkov et al. 1997)
5. Multisensor QPE for the western US - NSSL (Gourley et al. 2002)

Quantitative Precipitation Estimation and Segregation Using Multiple Sensors

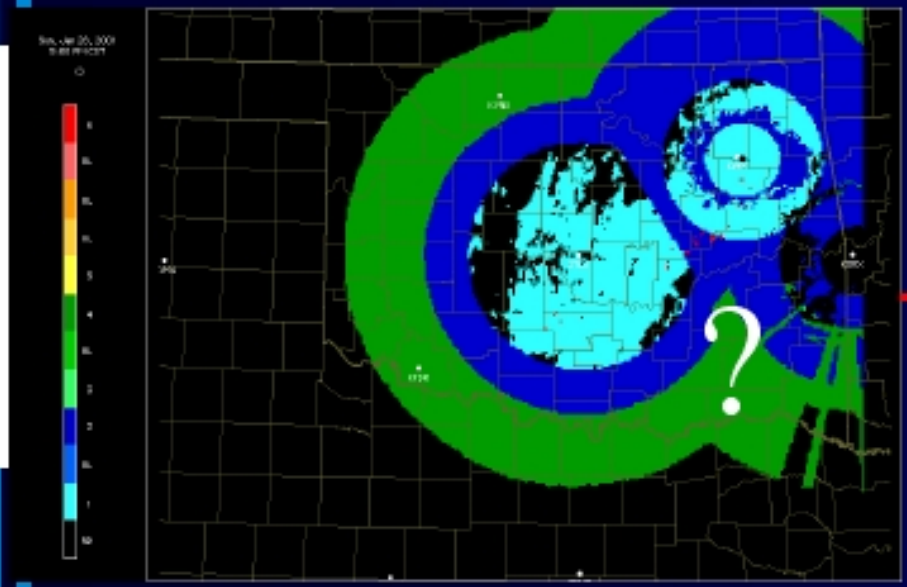




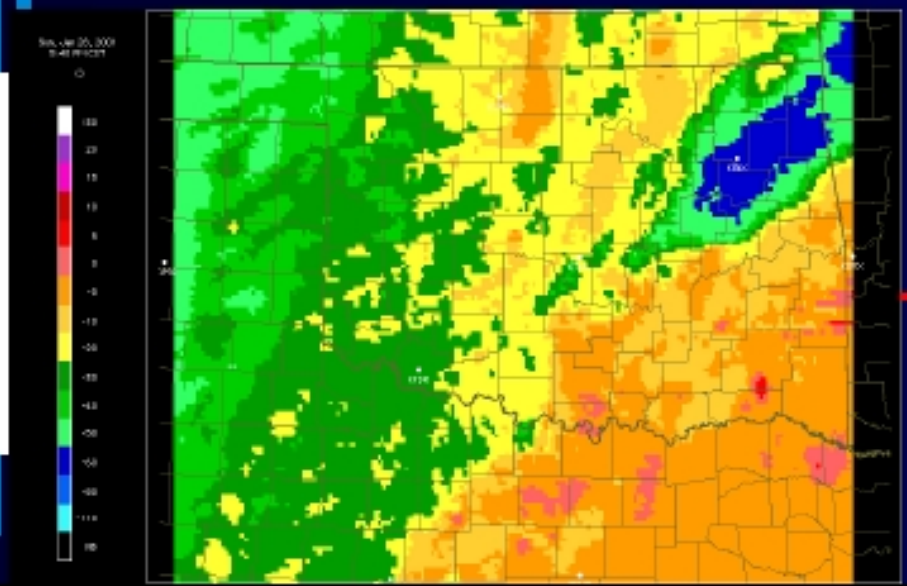


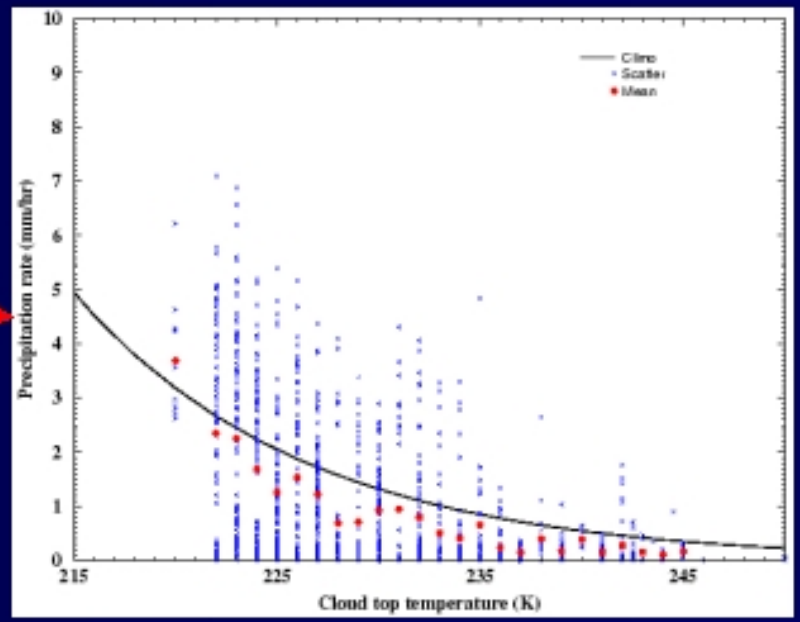
Satellite/Radar Regression

Radar Rainrate



Satellite CTT

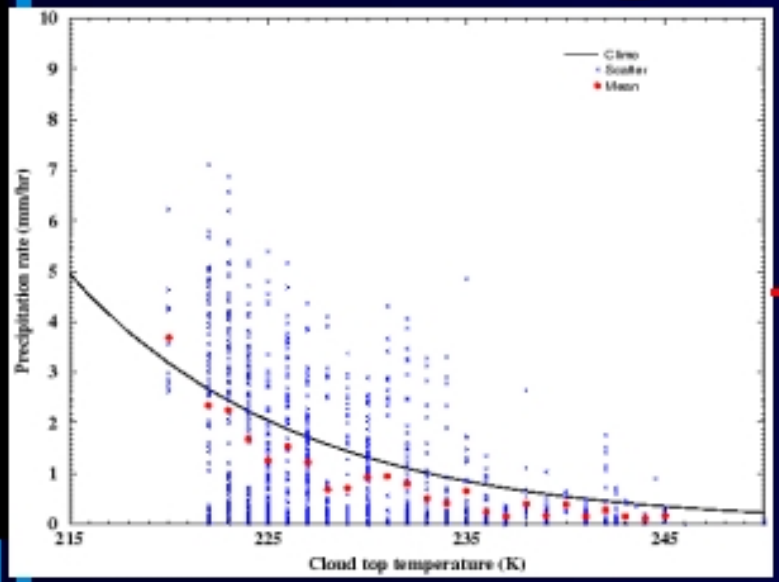




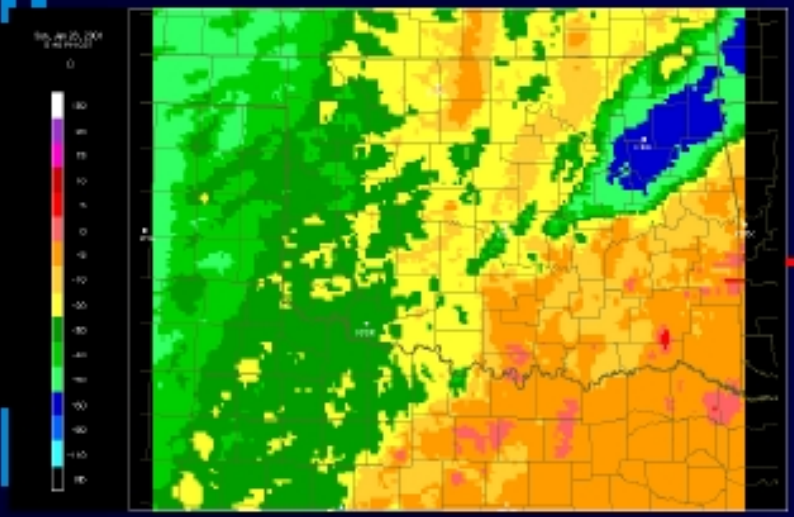
Regression Equation

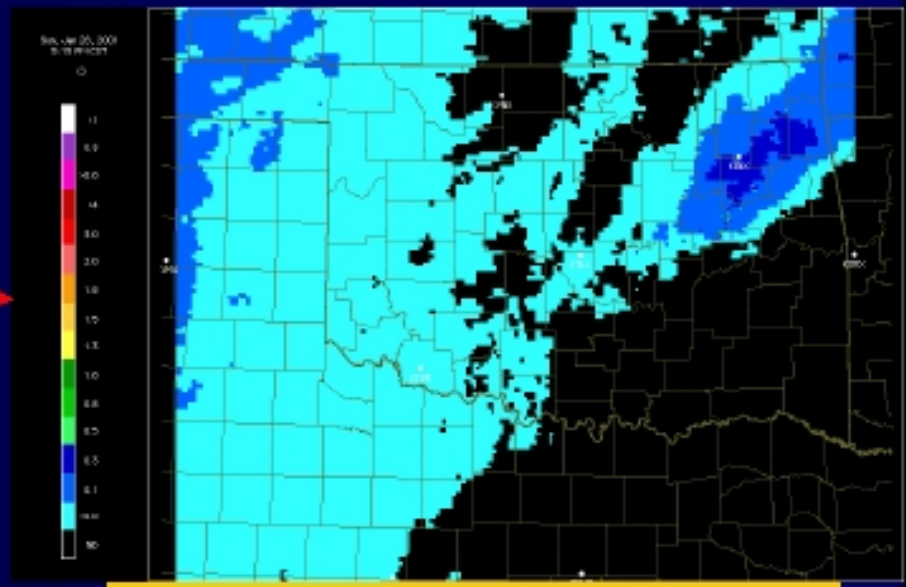
Generating Multisensor Field

Regression Equation



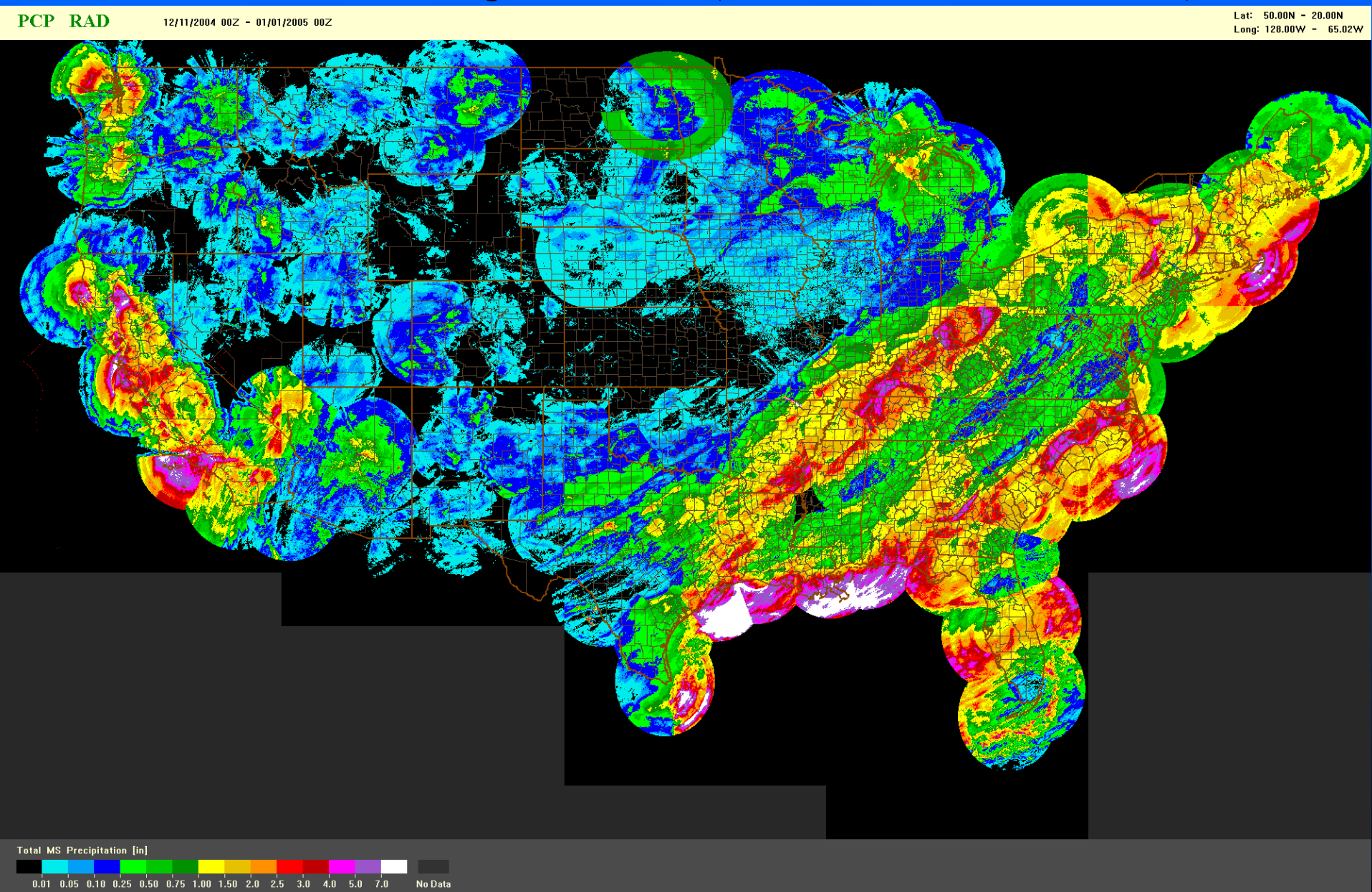
Satellite CTT



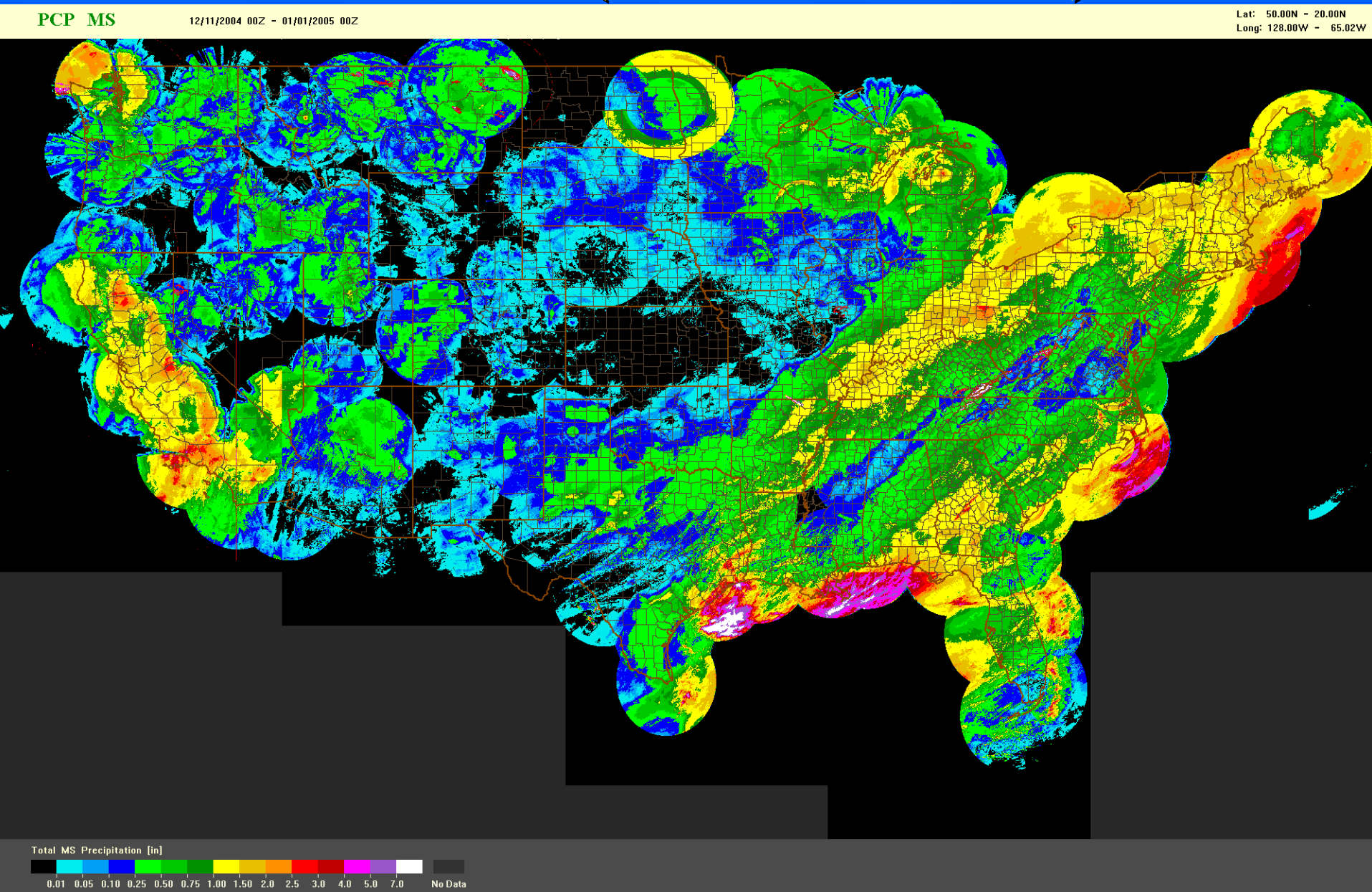


QPE SUMS Rainfall Rate

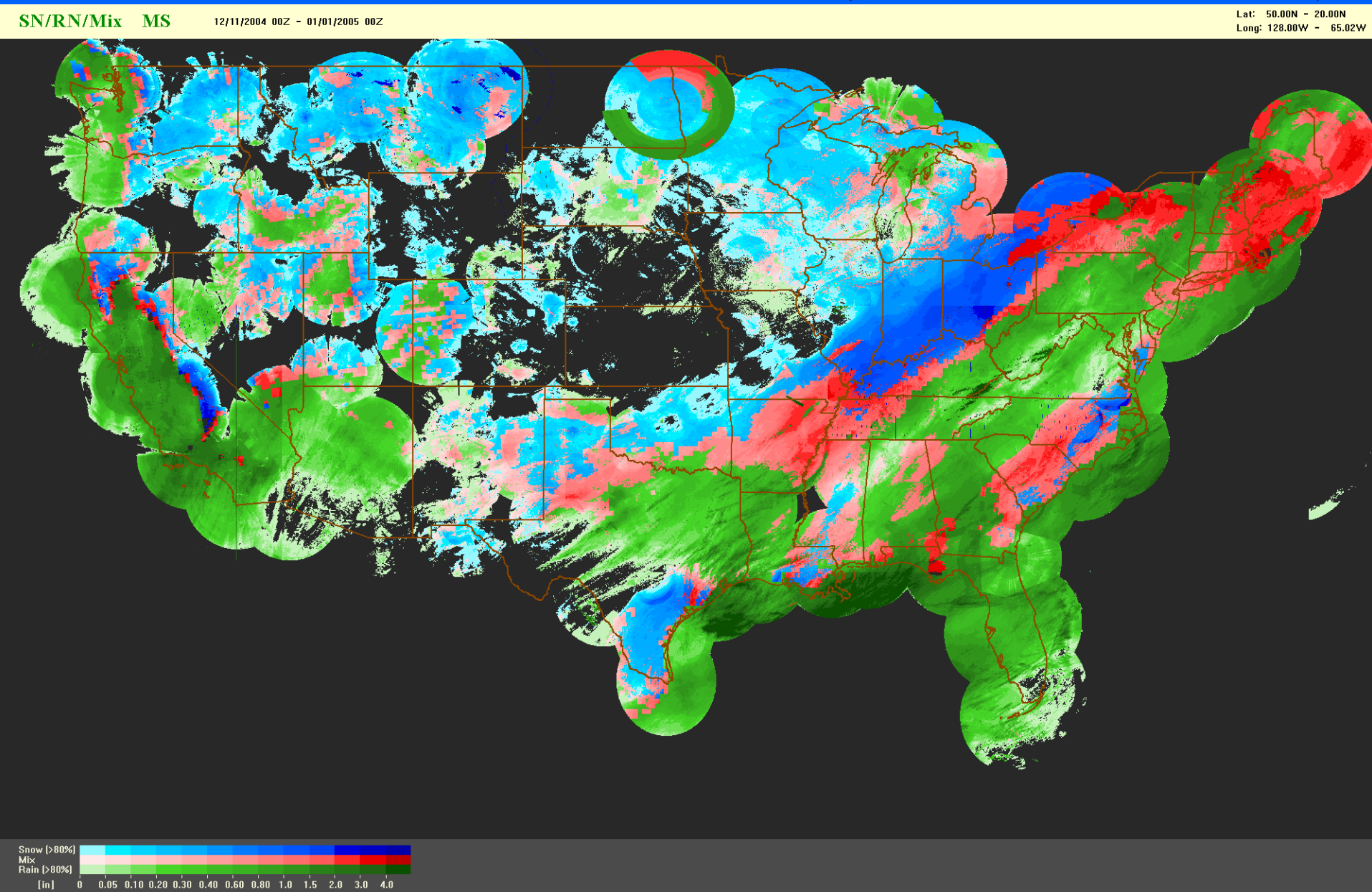
Radar Only PCP (Dec. 11- Jan. 1)



MS PCP (Dec. 11- Jan. 1)



Snow/Rain Mix MS PCP (Dec. 11- Jan. 1)



Current QPE SUMS

- Multisensor algorithm performs similarly to radar-only for convective events
- Differences arise where radar-only estimates of precipitation suffer:
  - Complex terrain
  - Stratiform precipitation
  - Orographic precipitation
- Multisensor approach offers ‘some’ hope in these “radar hostile” regimes

Next Generation QPE ‘Q2’

- Depart from radar centric precipitation typing to a true multi sensor approach focused on 3-D mosaic grids of radar, satellite, model and surface observations
- Improve logic for precipitation typing and masking
- Implementation of robust gap filling and VPR adjustments
- Robust synchronization of satellite imagery with radar for robust/ representative regressions
- Identification and precipitation rate adjustments for Orographic forced processes
- Optimization and mitigation of gage biasing latency through parallel QPE processing.

Q2 Timetable

- Initial version of Q2 running CONUS by June 1, 2005
- NSSL/OHD Q2 workshop June 20, 2005
- Phase out of QPESUMS by December 2005
- Q2 v 2.0 full implementation January 2006
- Short term QPF CONUS February 2006

NMQ Real Time Verification

NMQ Verification

http://172.16.20.180/~qpeverif/Internal/

NMQTest EmpExp Gmail Amazon News NPR NMQQPE NMQ Typhoons Weather NexRadMos NexSat Refd Phoenix NSSL Modis Apple NLocate

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison | Data Inventory | Events/Analysis | Data Retrieval

Product Group

Mosaic | Qpe | Gauge | Satellite

Time

Hour:Minute

22 Z : 00

Month/Day/Year

2 / 10 / 2005

Radar Products

CREF

Raw | QC | SM

Other

HSR | HSRH | SHI

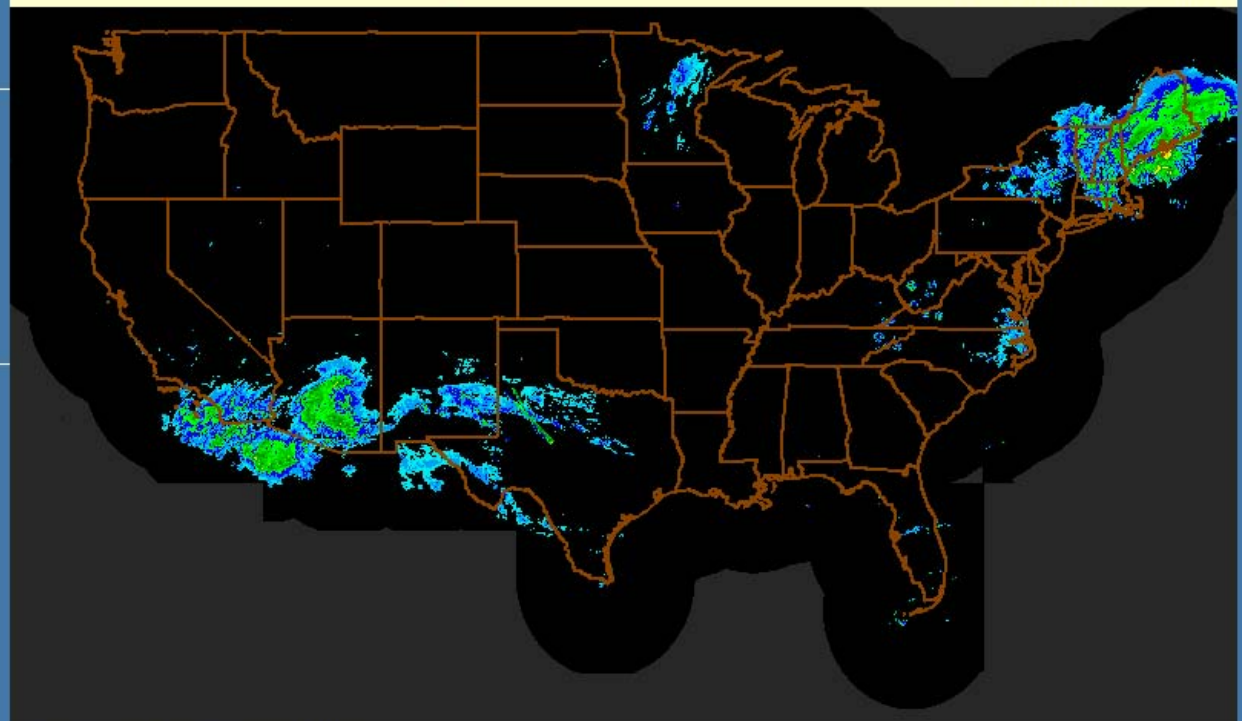
Differences

QC-Raw | SM-QC | QC-HSR

Mosaic 2d - CREF QC

02/10/2005 2200Z

Lat: 50.00N - 20.00N
Long: 128.00W - 65.00W



Composite Reflectivity [dBz]

5 10 15 20 25 30 35 40 45 50 55 60 65 No Data

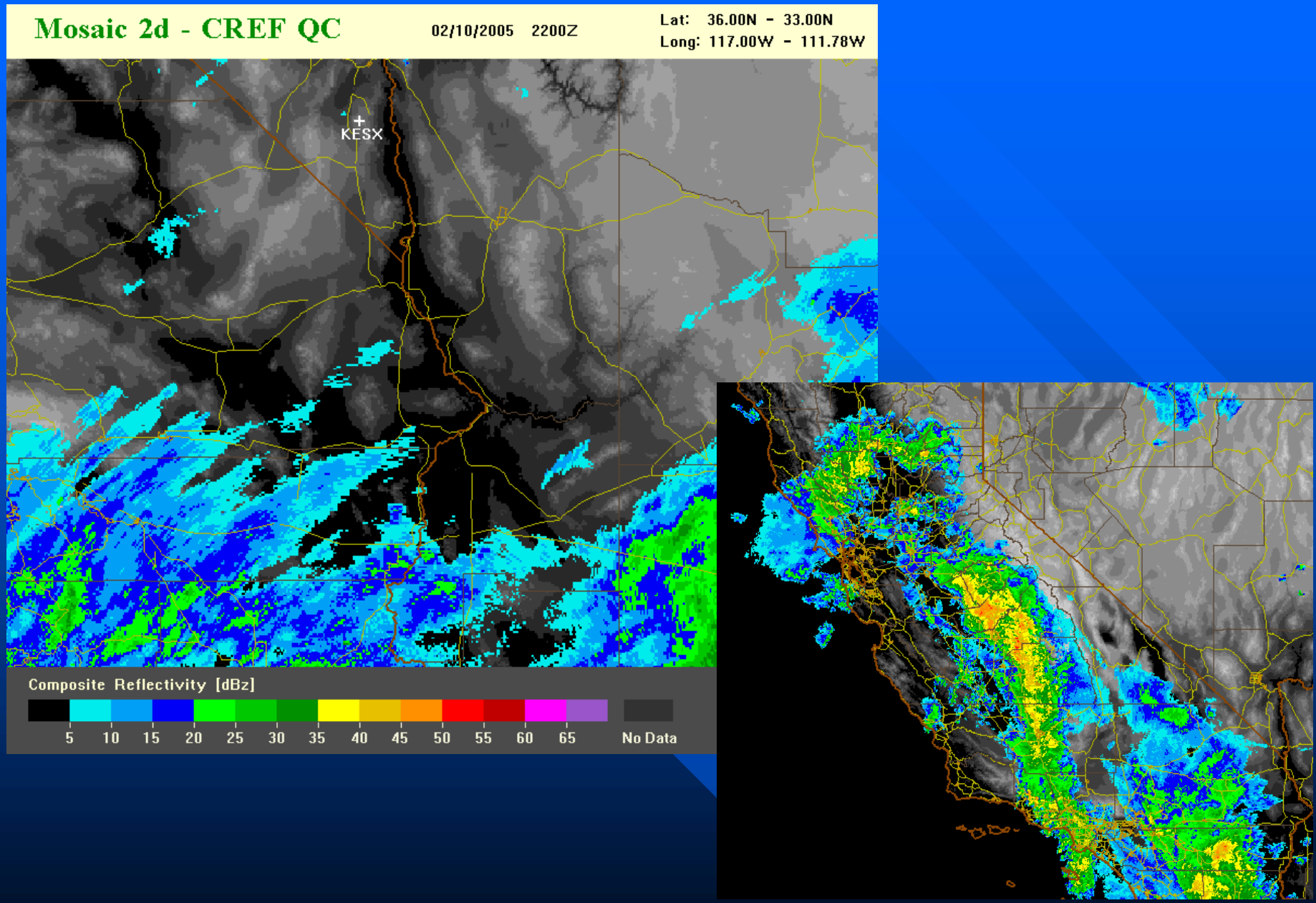
Page Loaded
02/10/2005 23:00 Z

Overlays

- State Borders ☑
- County Borders ☐
- Terrain ☐
- Roads ☐
- Lat/Long Grid ☐

Time Jump

-5 min | +5 min
-1 hr | +1 hr
-1 dy | +1 dy


Mosaic 2d - CREF QC
02/10/2005 2200Z
Lat: 36.00N - 33.00N
Long: 117.00W - 111.78W
KESX
Composite Reflectivity [dBz]
5 10 15 20 25 30 35 40 45 50 55 60 65
No Data

NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time Period

24 hr beginning 0Z

On Date

Month: 10

Day: 18

Year: 2004

-1 dy | +1 dy

Options

Region: CONUS

- tile | + tile

Select/Refresh

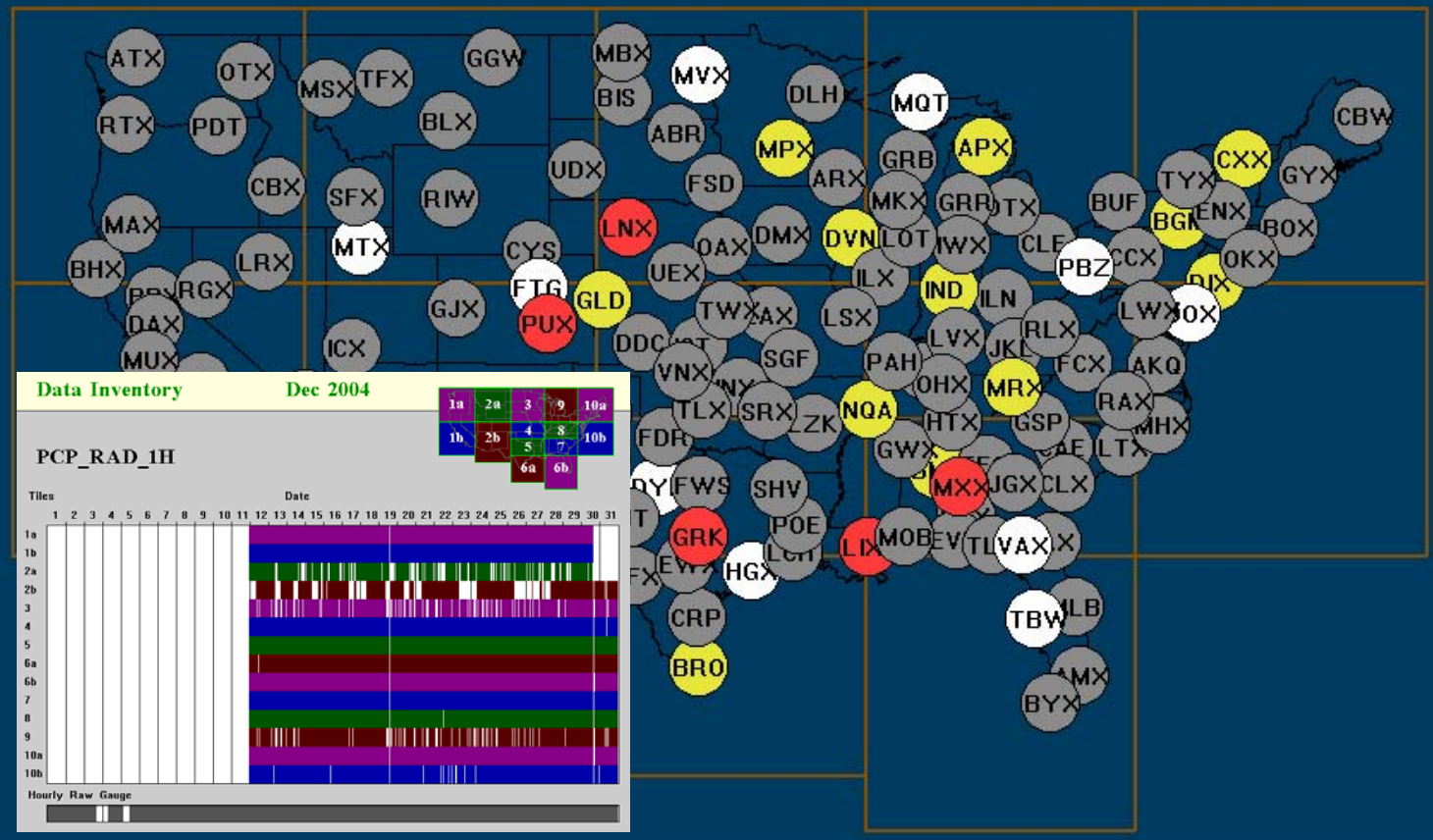
Mosaic File Generation Monitoring

Polar File/Radar Ingest Monitoring

National Radar Status

10/18/2004 00Z - 10/19/2004 00Z
Image Generated: 10/18/2004 21:34Z

Lat: 19N - 51N
Long: 129W - 64W



Data Inventory Dec 2004

PCP_RAD_1H

Tiles Date

Hourly Raw Gauge

Longest Data Gap : < 20 min SHV | 20 min - 1 hr BUF | 1 hr - 6 hr GRK | > 6hr VAX

NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

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NMQ Verification Page

Meteorological Data System Monitoring Radar Comparison

Time

Hour: 20 Z

Minute: 40

On Date

Month: 10

Day: 18

Year: 2004

-5 min +5 min

-1 hr +1 hr

-1 dy +1 dy

Options

Units: English

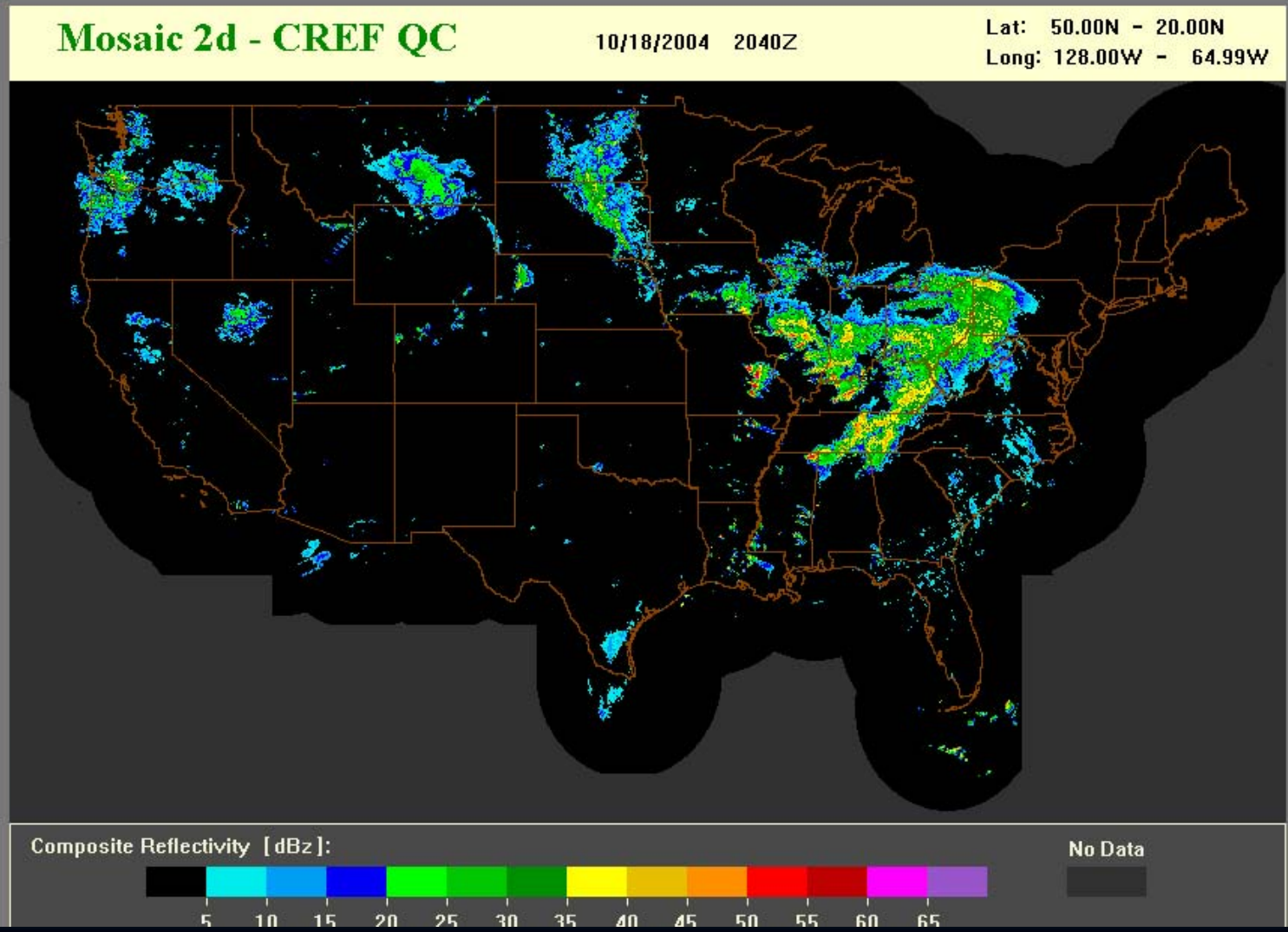
Draw Terrain

Product

CREF_QC

Submit/Refresh

To Accumulating Data



NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time
Hour: 20 Z
Minute: 40

On Date
Month: 10
Day: 18
Year: 2004

-5min +5min
-1 hr +1 hr
-1 dy +1 dy

Lat/Long

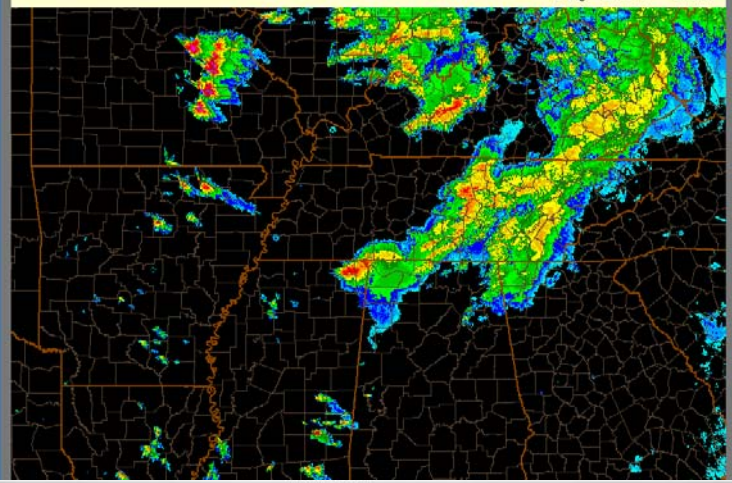
Options
Units: English
Draw Terrain

Product
CREF_QC

Mosaic 2d - CREF QC

10/18/2004 2040Z

Lat: 39.00N - 31.00N
Long: 95.00W - 81.17W



NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time
Hour: 20 Z
Minute: 40

On Date
Month: 10
Day: 18
Year: 2004

-5min +5min
-1 hr +1 hr
-1 dy +1 dy

Lat/Long

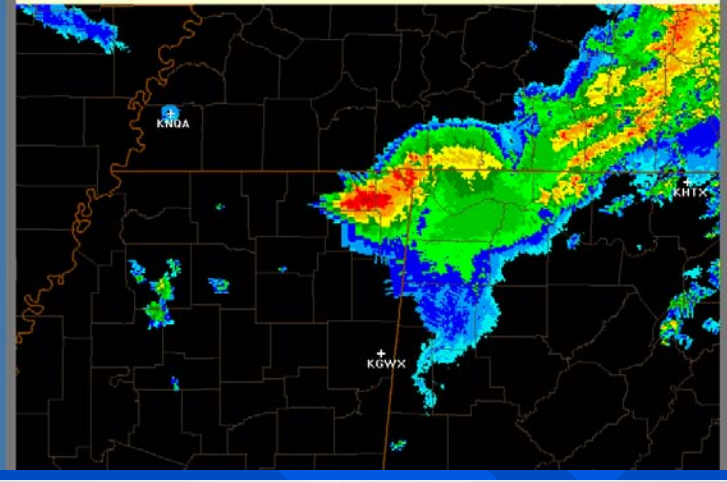
Options
Units: English
Draw Terrain

Product
CREF_QC

Mosaic 2d - CREF QC

10/18/2004 2040Z

Lat: 36.00N - 33.00N
Long: 91.00W - 85.84W



NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time
Hour: 20 Z
Minute: 40

On Date
Month: 10
Day: 18
Year: 2004

-5min +5min
-1 hr +1 hr
-1 dy +1 dy

Lat/Long

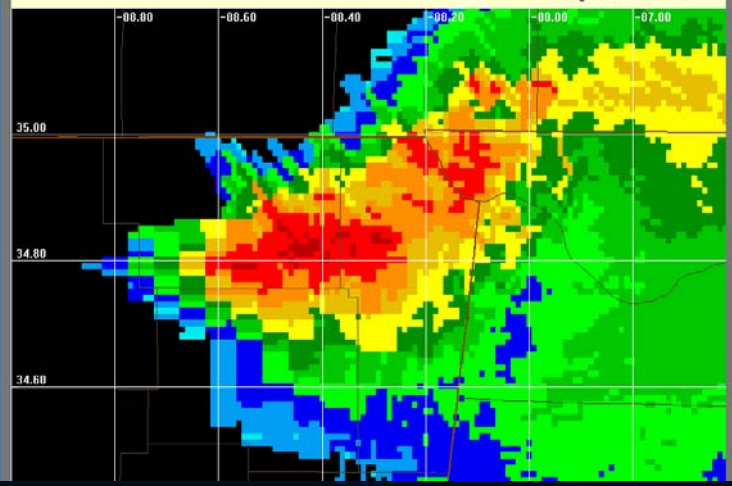
Options
Units: English
Draw Terrain

Product
CREF_QC

Mosaic 2d - CREF QC

10/18/2004 2040Z

Lat: 35.20N - 34.40N
Long: 89.00W - 87.62W



NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time
Hour: 20 Z
Minute: 40

On Date
Month: 10
Day: 18
Year: 2004

-5min +5min
-1 hr +1 hr
-1 dy +1 dy

Lat/Long

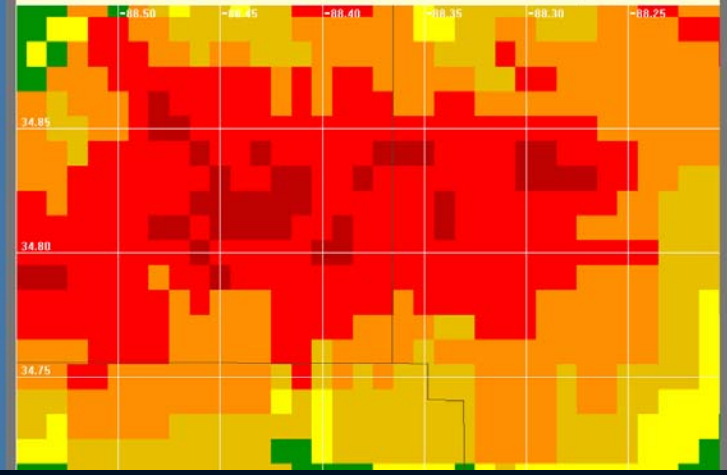
Options
Units: English
Draw Terrain

Product
CREF_QC

Mosaic 2d - CREF QC

10/18/2004 2040Z

Lat: 34.90N - 34.70N
Long: 88.55W - 88.20W



NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time Period

- 1 month ending 1st/12Z
- 24 hr ending 12Z
- 1 hr ending: 12 Z

On Date

Month: 10
Day: 18
Year: 2004

-1 dy | +1 dy

Options

Units: English

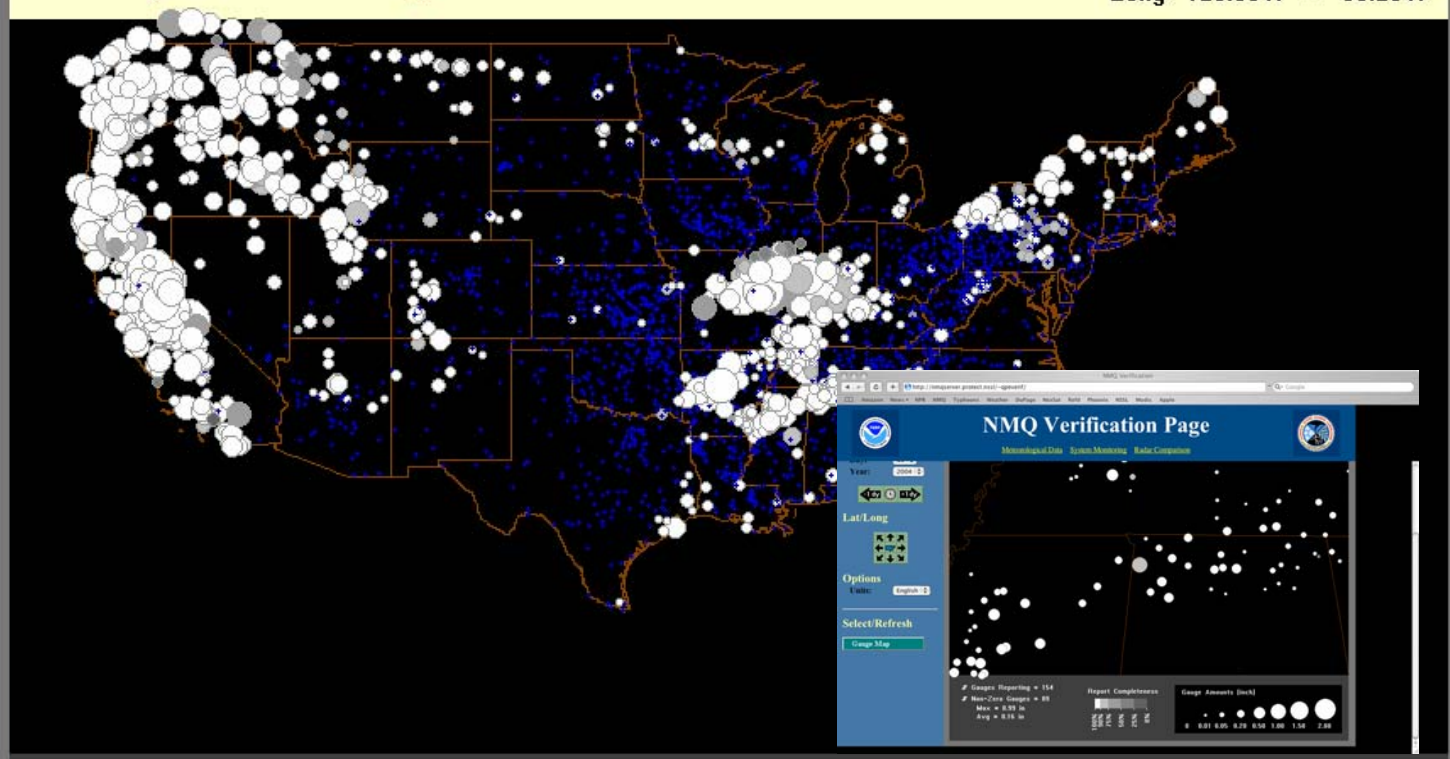
Select/Refresh

Gauge Map

Daily NCEP Gauges

10/17/2004 12Z - 10/18/2004 12Z

Lat: 50.00N - 20.00N
Long: 128.00W - 56.28W



# Gauges Reporting = 2831
# Non-Zero Gauges = 828
Max = 3.35 in
Avg = 0.27 in

Report Completeness

100% 90% 75% 50% 25% 0%

Gauge Amounts (inch)

0 0.01 0.05 0.20 0.50 1.00 1.50 2.00

NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Google

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time

Hour: 20 Z

Minute: 40

On Date

Month: 10

Day: 18

Year: 2004

-5 min | +5 min

-1 hr | +1 hr

-1 dy | +1 dy

Options

Units: English

Draw Terrain

Product

CREF_UNQC

Submit/Refresh

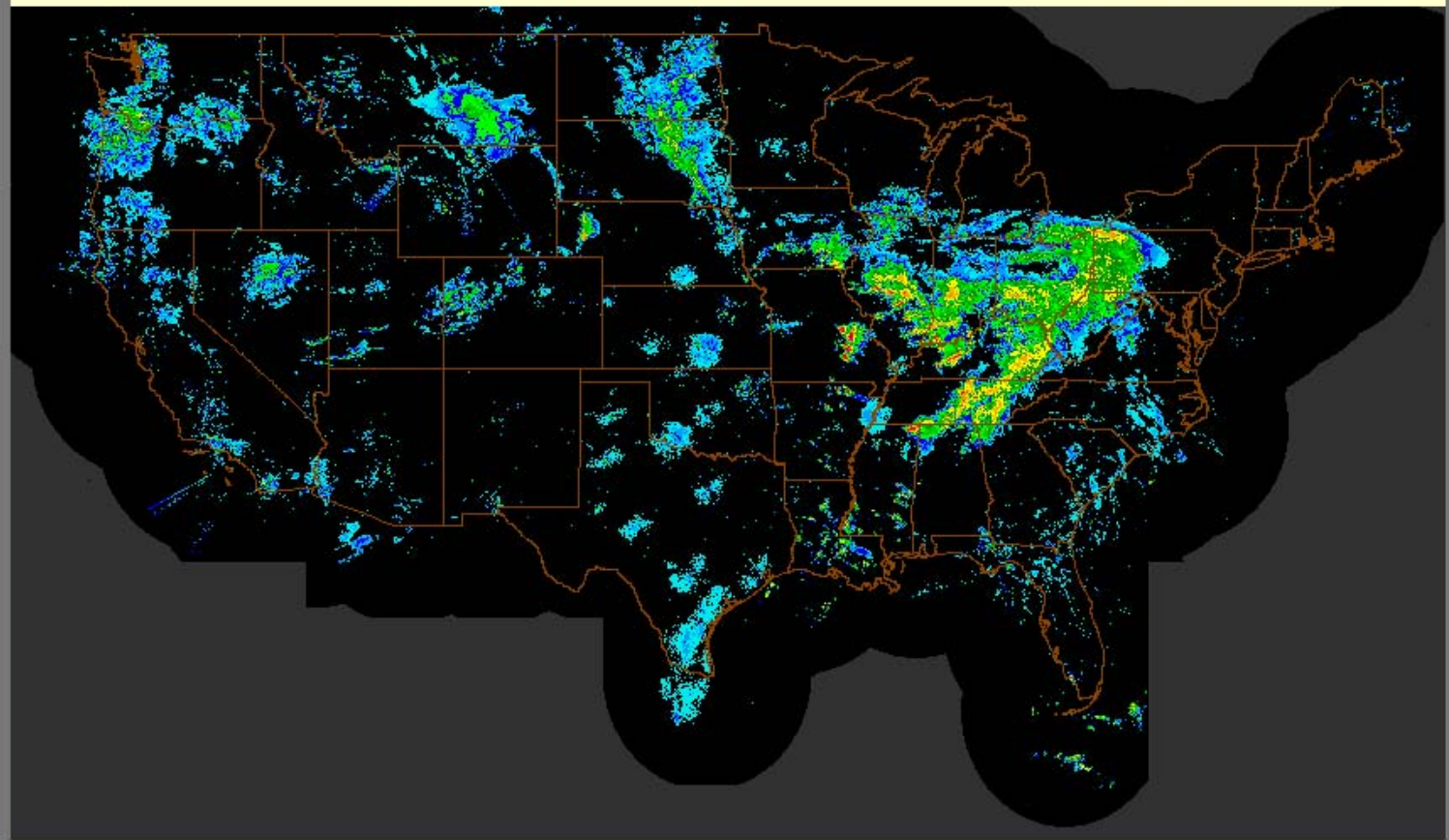
To Accumulating Data

Mosaic 2d - CREF UNQC

10/18/2004 2040Z

Lat: 50.00N - 20.00N

Long: 128.00W - 64.99W



Composite Reflectivity [dBz]:

5 10 15 20 25 30 35 40 45 50 55 60 65

No Data

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time

Hour: 20 Z
Minute: 40

On Date

Month: 10
Day: 18
Year: 2004

-5 min | +5 min
-1 hr | +1 hr
-1 dy | +1 dy

Options

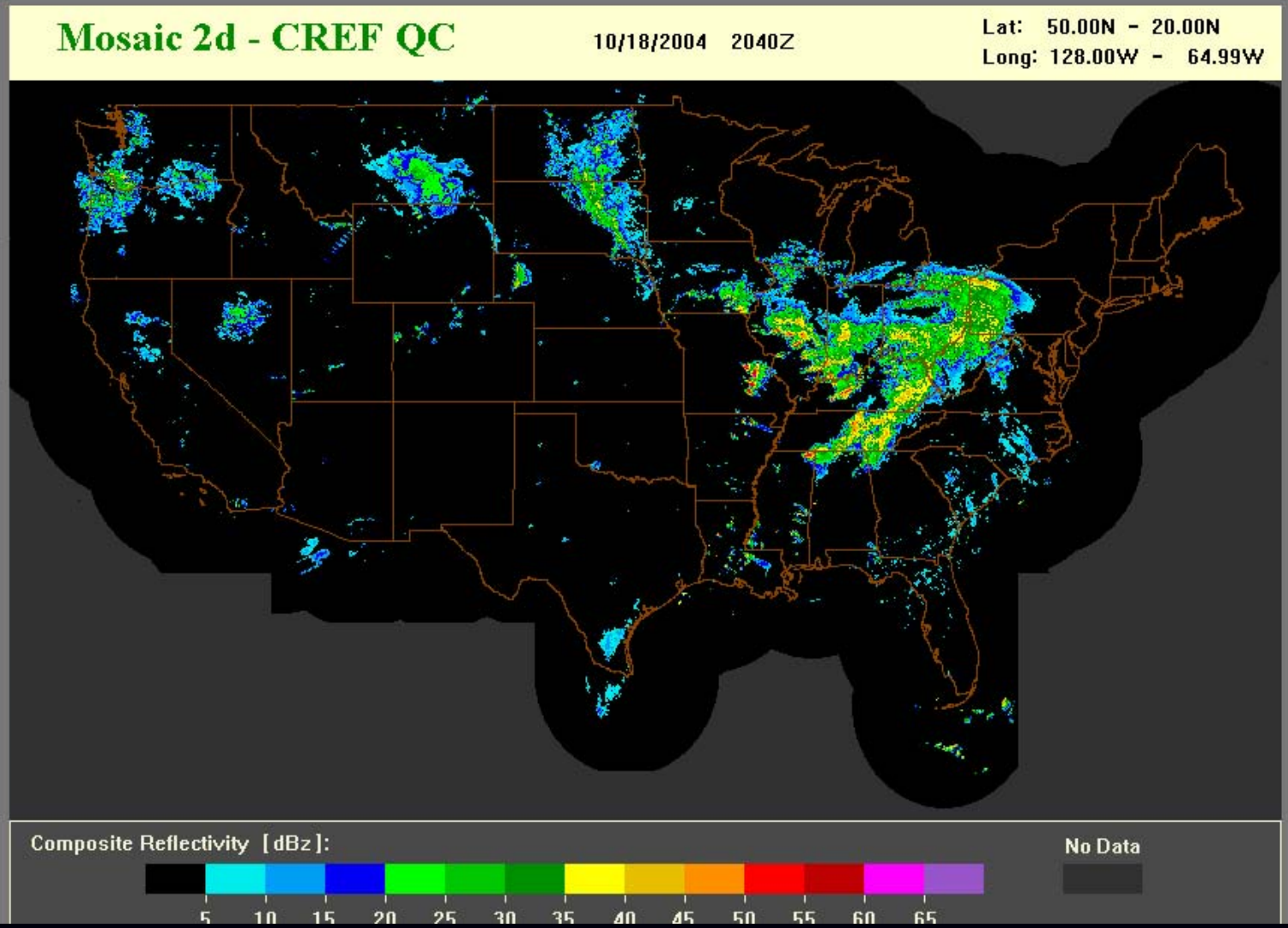
Units: English
Draw Terrain

Product

CREF_QC

Submit/Refresh

To Accumulating Data



NMQ Verification

http://nmqserver.protect.nssl/~qpeverif/

Amazon News NPR NMQ Typhoons Weather DuPage NexSat Refd Phoenix NSSL Modis Apple

NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Time

Hour: 20 Z

Minute: 40

On Date

Month: 10

Day: 18

Year: 2004

-5 min +5 min

-1 hr +1 hr

-1 dy +1 dy

Options

Units: English

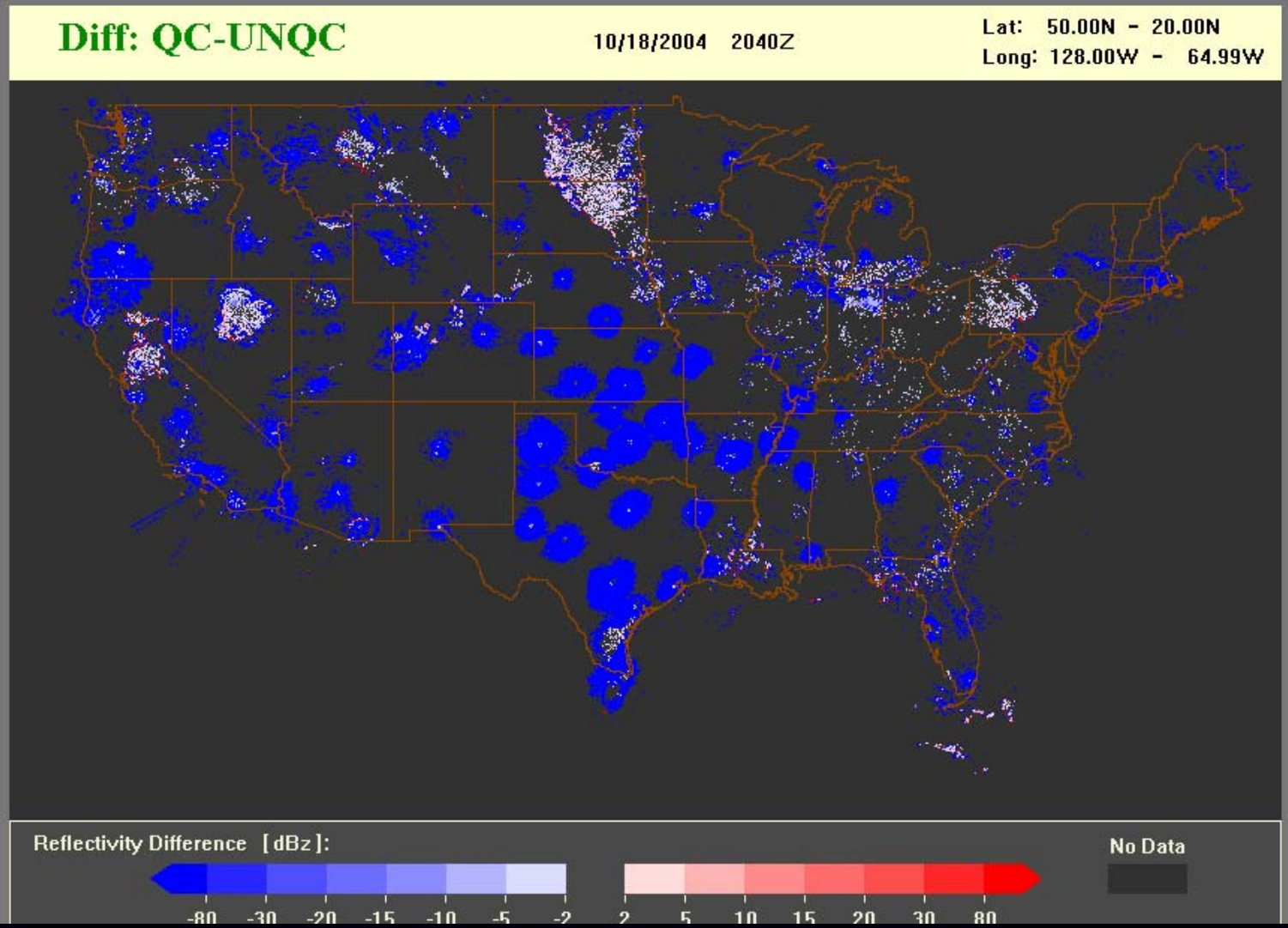
Draw Terrain

Product

DIFF:QC-UNQC

Submit/Refresh

To Accumulating Data



National Mosaic System Monitoring

Time Period

24 hr beginning 0Z

On Date

Month: 7
Day: 8
Year: 2004

-1 dy | +1 dy

Options

Region: Tile 7

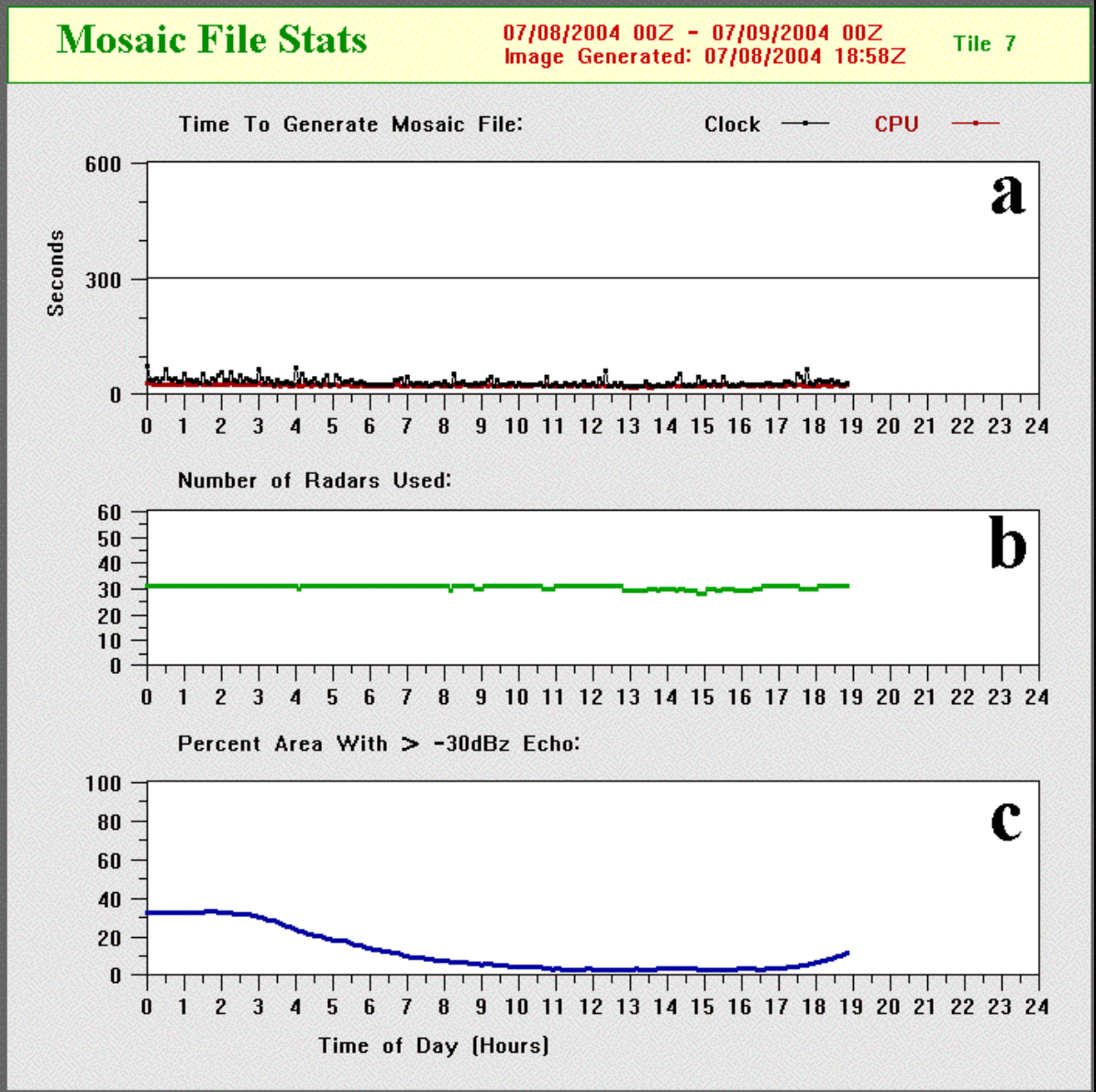
- tile | + tile

Select/Refresh

Mosaic File Generation Monitoring

Polar File/Radar Ingest Monitoring

Radar Transmit Status (from NWS)



NMQ Verification Page

Meteorological Data | System Monitoring | Radar Comparison

Previous

- 24 Hours
- 10 Days
- 30 Days
- Full Archive

Or Select Range

From:

Month: 10
Day: 28
Year: 2004
Hour: 12

To:

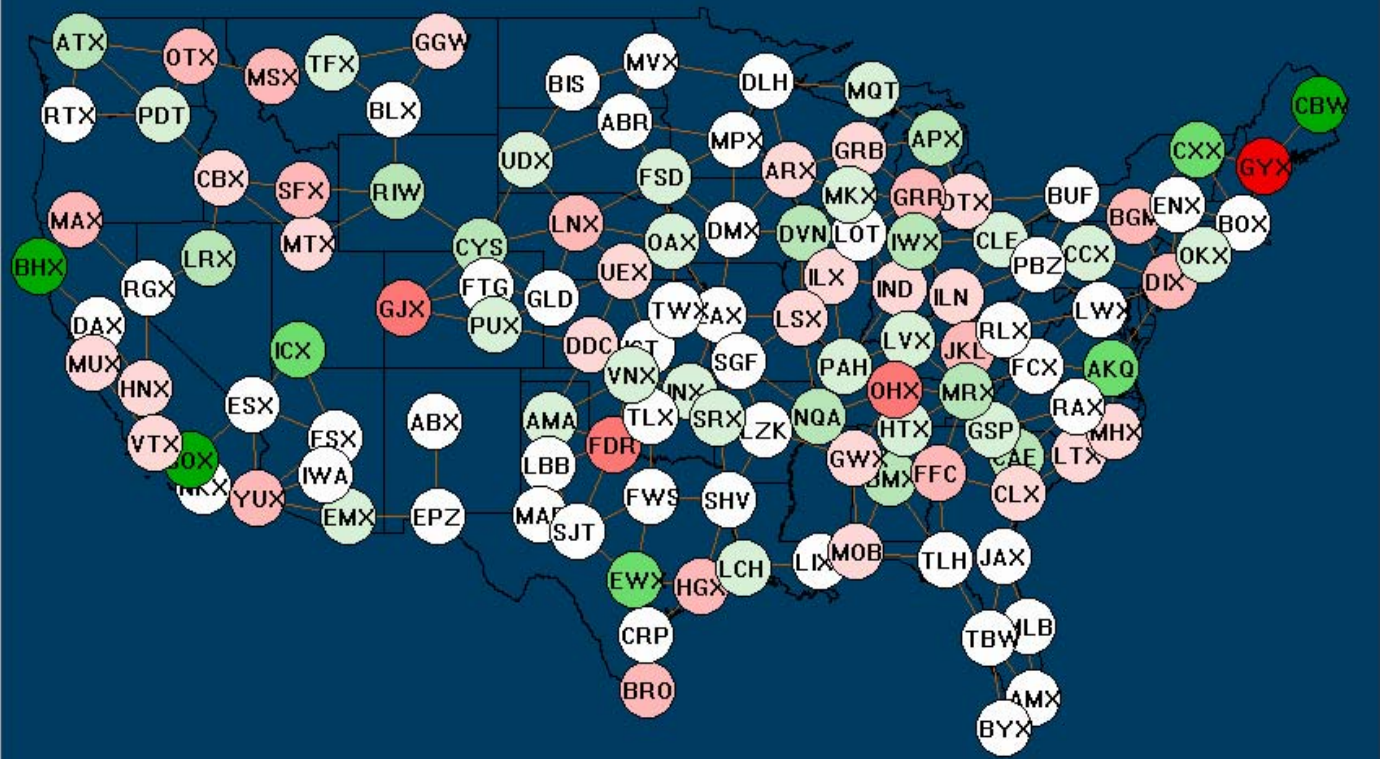
Month: 10
Day: 18
Year: 2004
Hour: 21

Submit

Radar Comparison - Map

04/28/2004 12Z - 10/18/2004 21Z

Lat: 22N - 52N
Long: 126W - 65W



Net dBz diff with nearest neighbors:

No Data

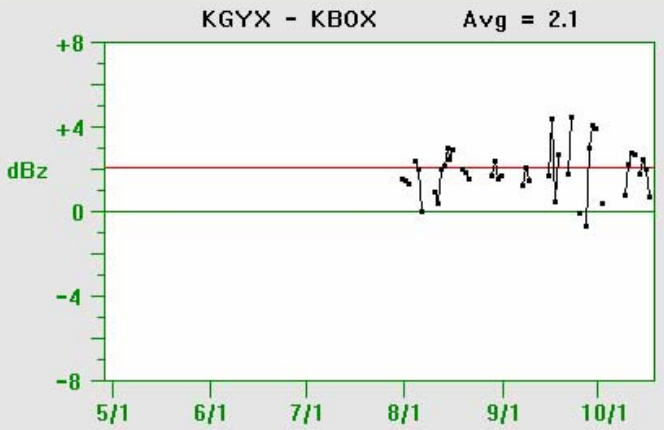
Click Map

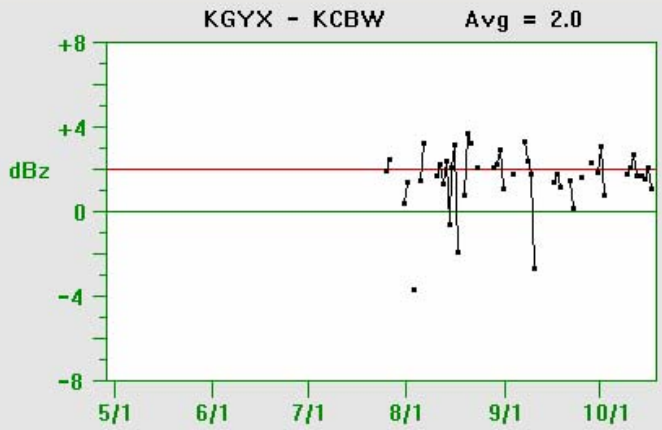
NMQ Verification Page

Meteorological Data System Monitoring Radar Comparison

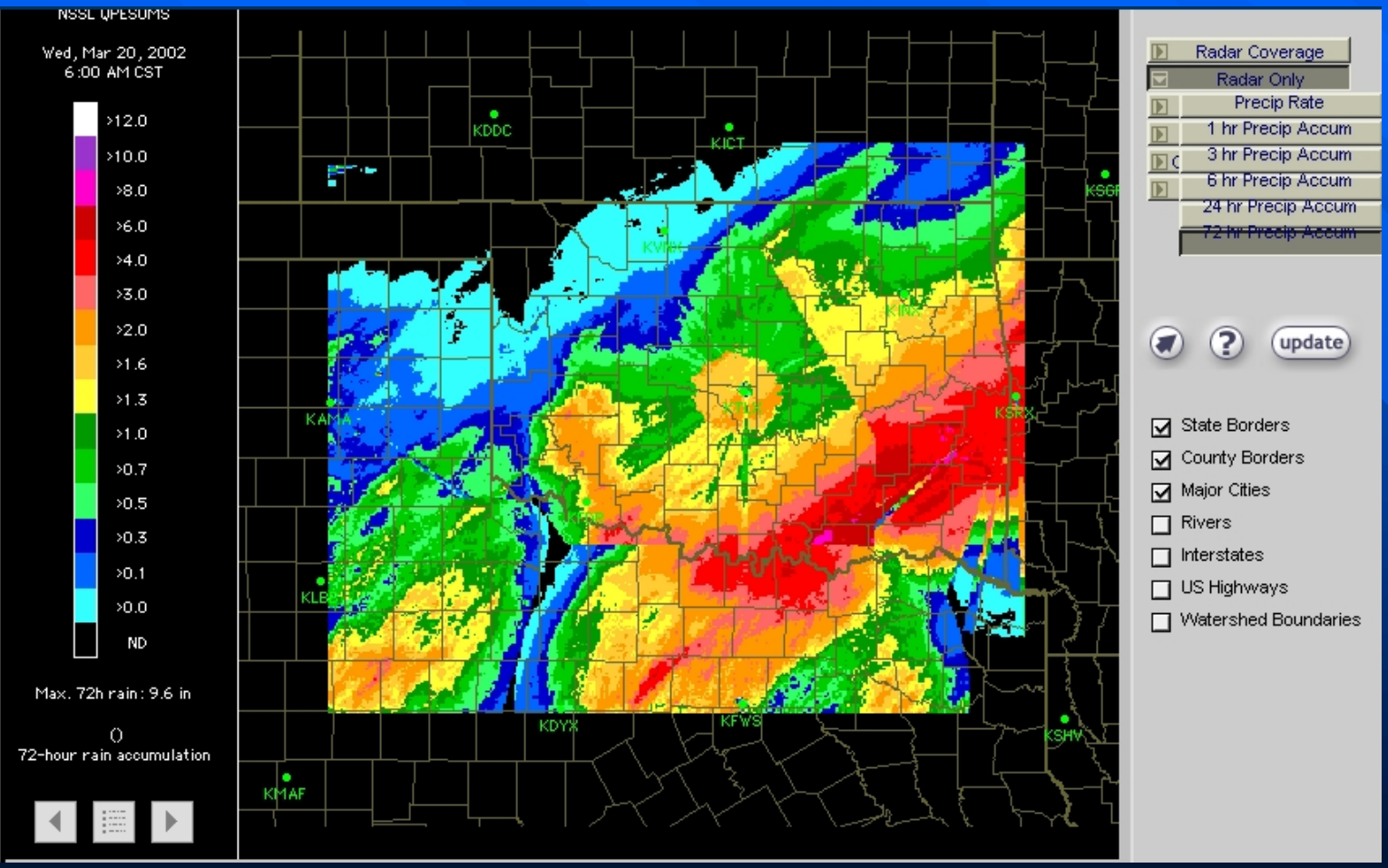
Radar Comparison - Time Series

04/28/2004 12Z - 10/18/2004 21Z





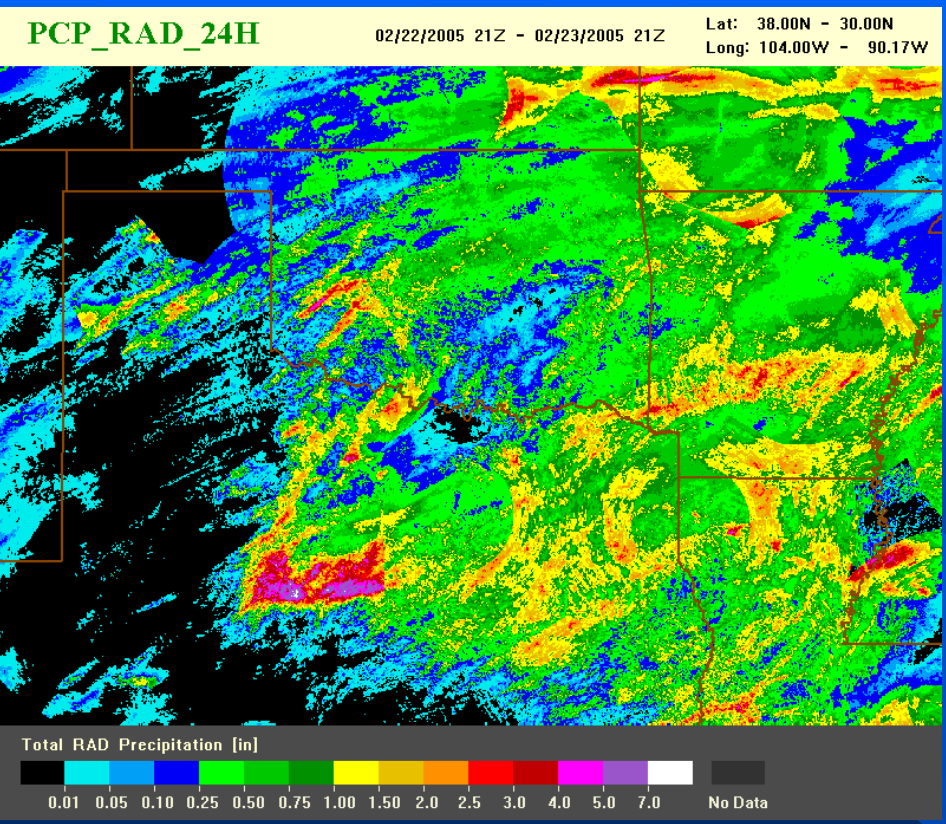
Effects of Radar Calibration Differences

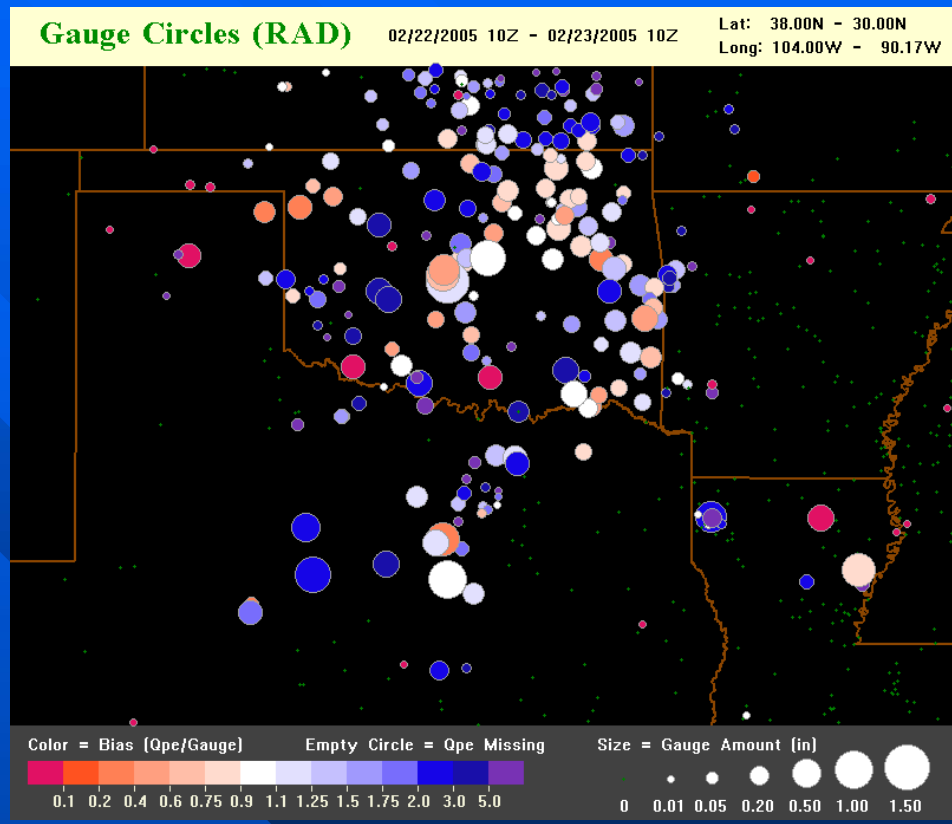


Mosaics show boundaries in QPE amounts from adjacent radars

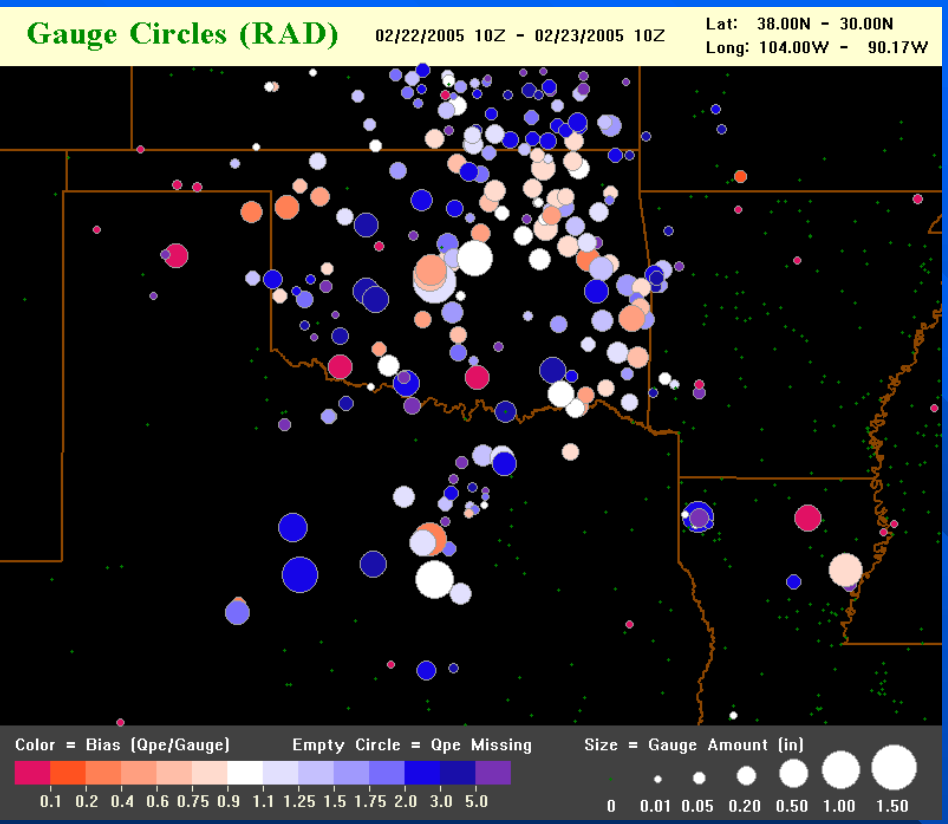
500 ft. rule also creates artifact around KTLX radar

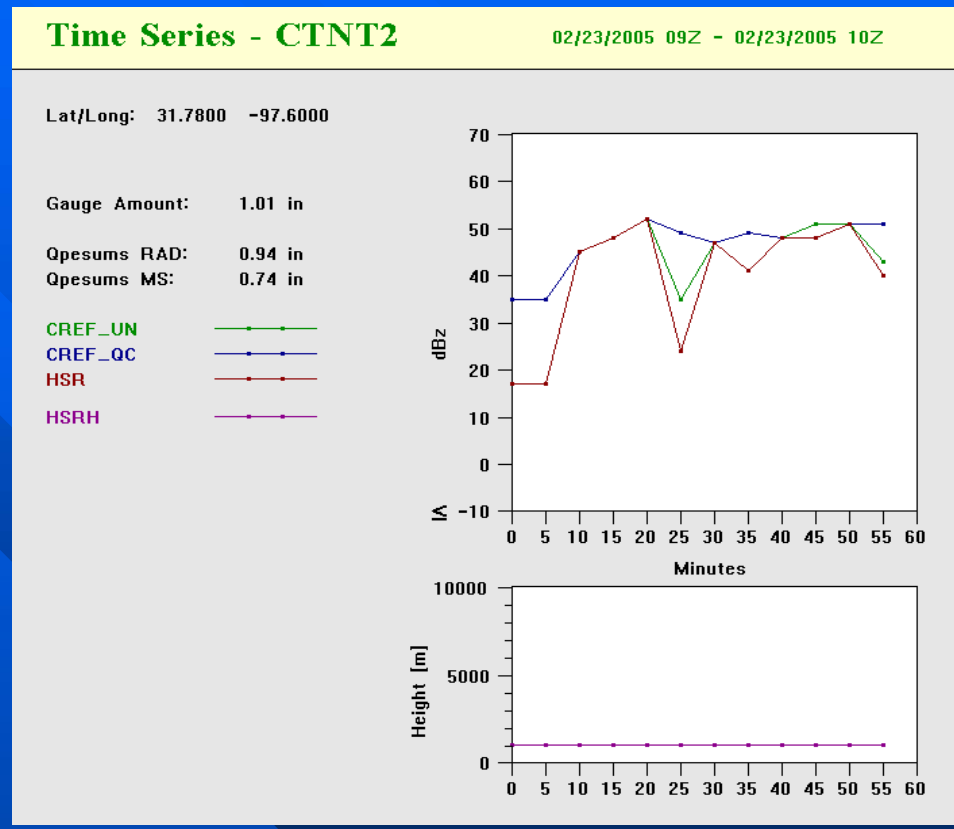
NMQ QPE Performance ‘RT’ Assessment



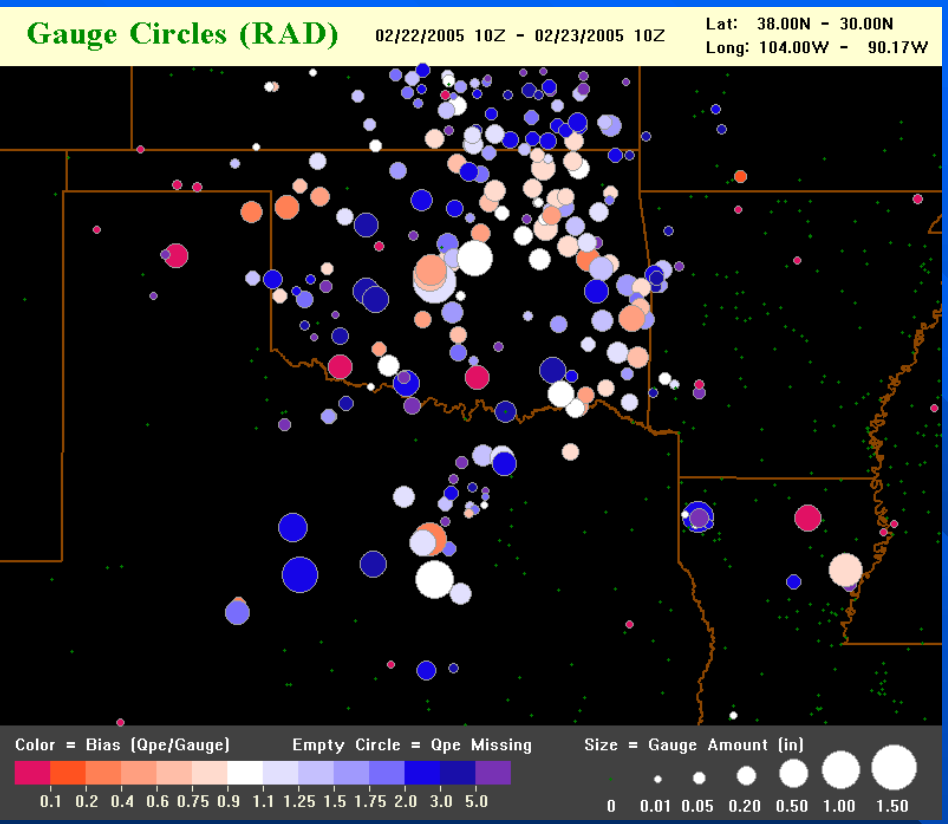


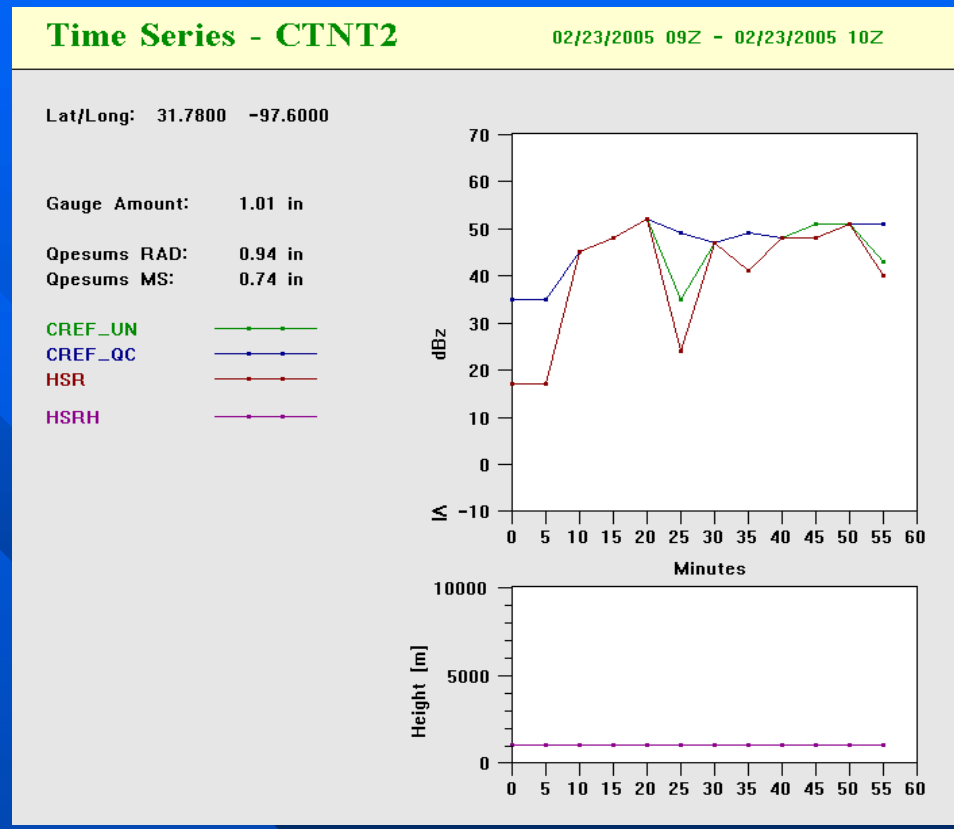
NMQ QPE Performance ‘RT’ Assessment



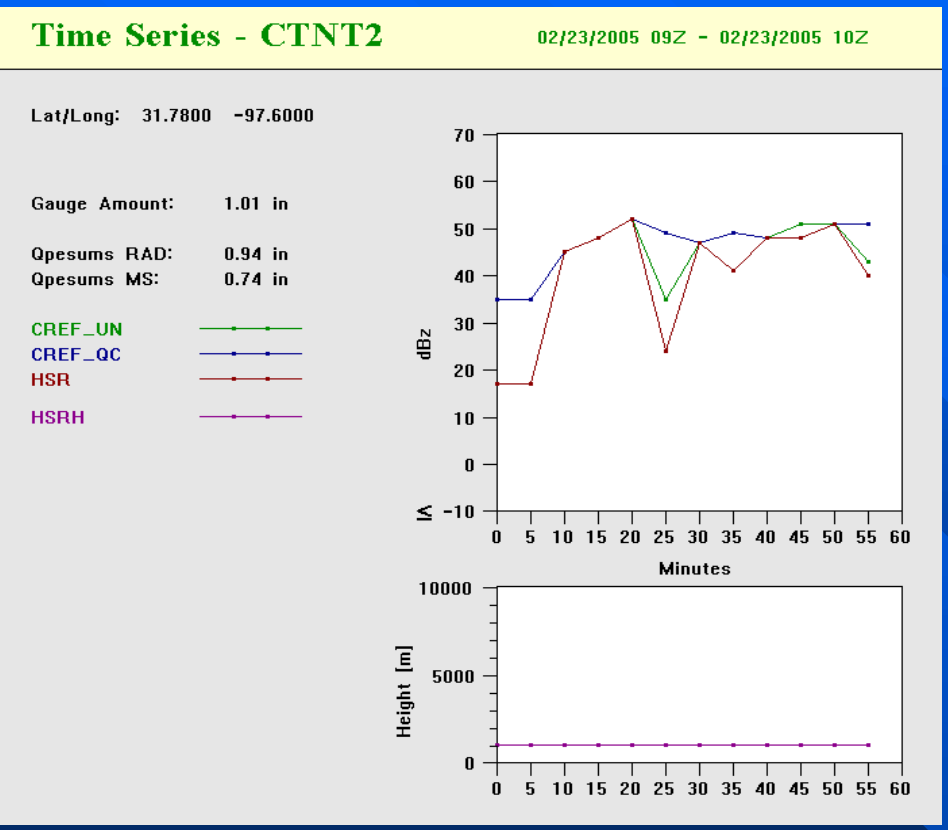


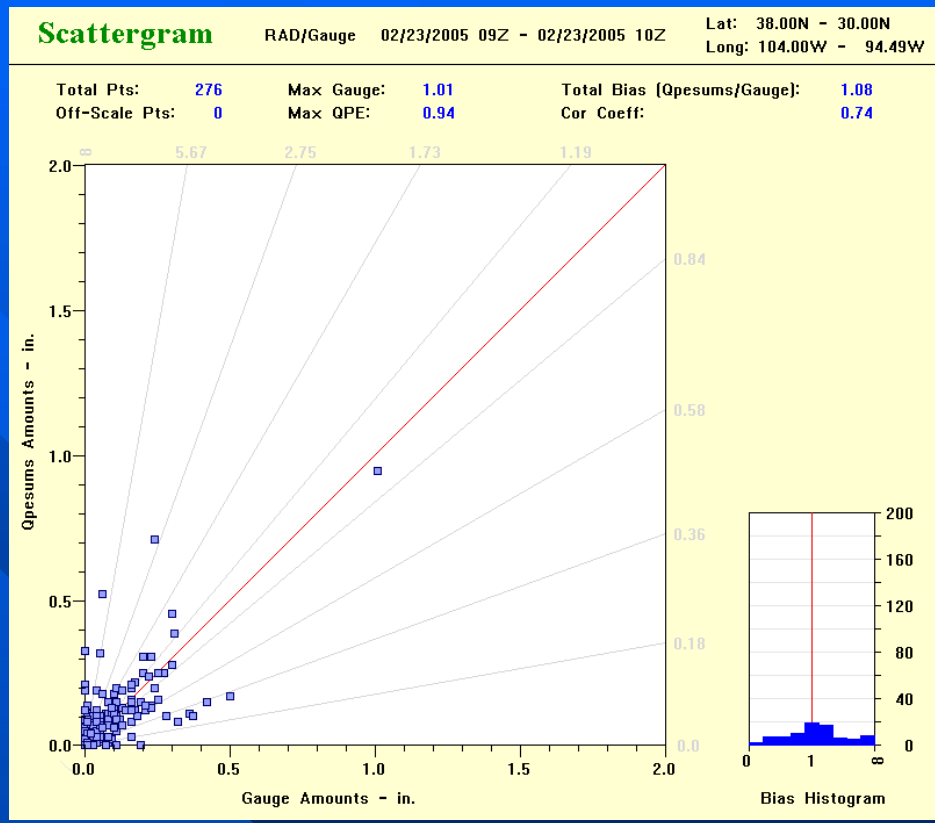
NMQ QPE Performance ‘RT’ Assessment



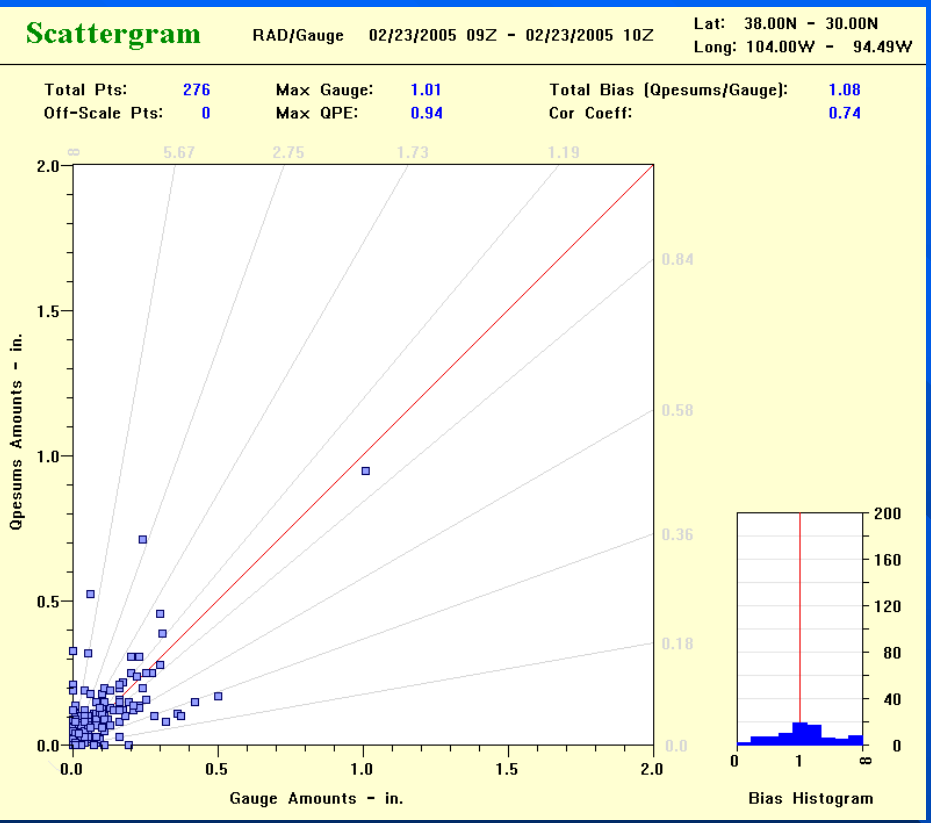


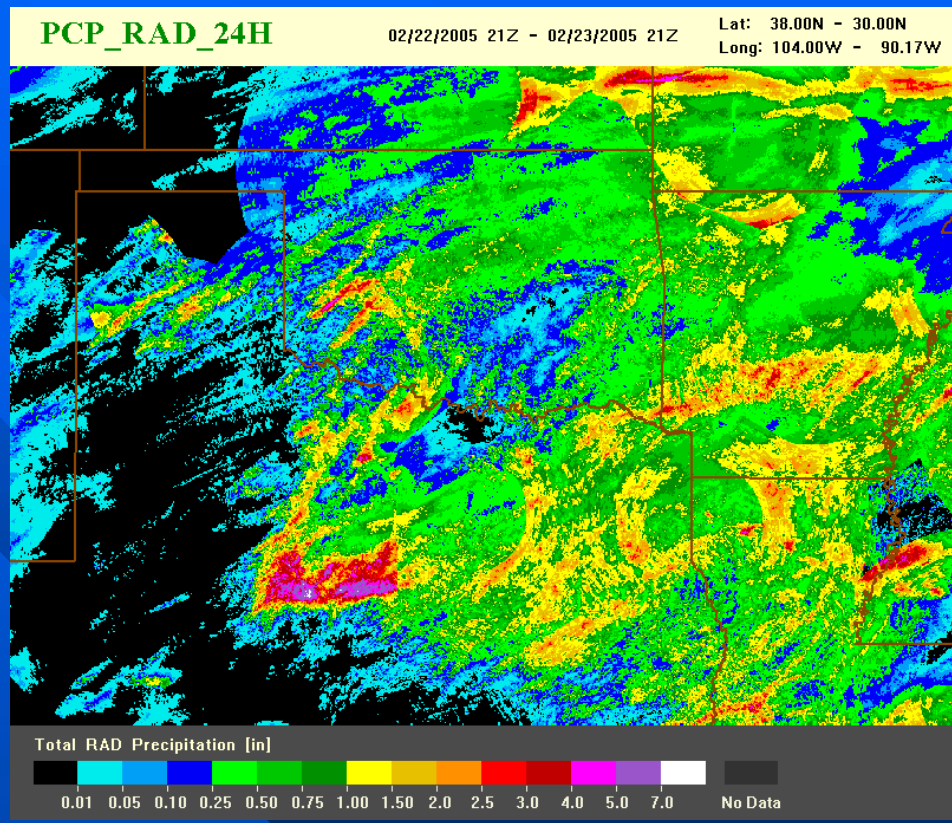
NMQ QPE Performance ‘RT’ Assessment





NMQ QPE Performance ‘RT’ Assessment





Where do we go from here?

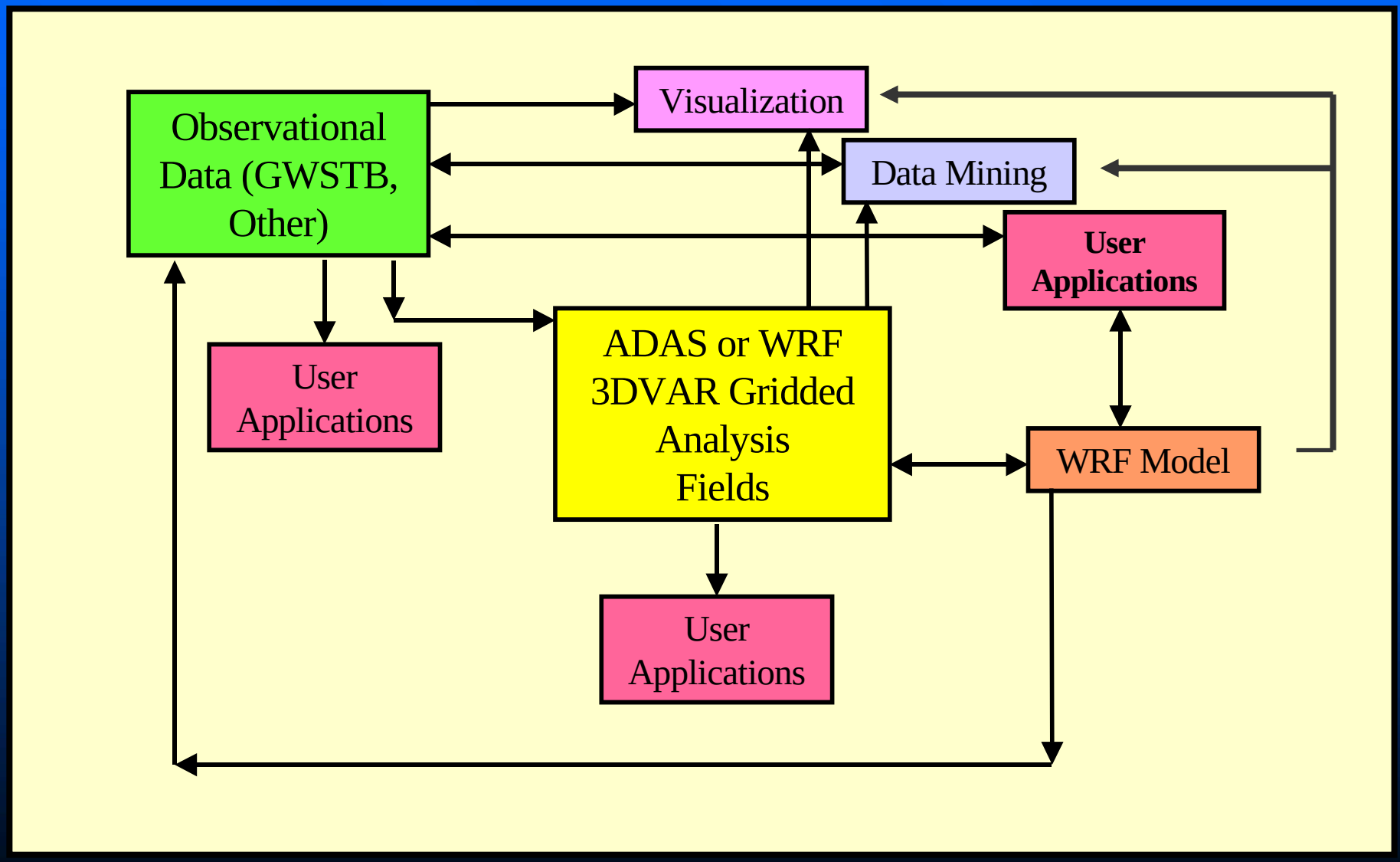
Joint Applications Development Environment (JADE)

NMQ/JADE

Joint Applications Development Environment

- Serve as national baseline for performance assessment of QPE and QPF applications
- Web-based user interface
- Real time and archival applications testing
  - Dedicated server; 10 TB RAID; DVD jukebox
- Variety of application platforms
  - GEMPAK, McIDAS, ORPG
  - Verification statistics, data viewer

Lead User Scenario: An Example

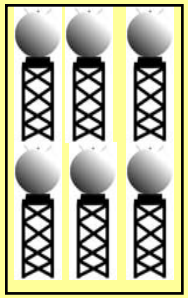


JADE components

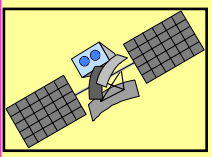
- Data access nodes
- Application I/O format
- Staging area for code testing and monitoring
- Database management
- GUI for archive playback
- Visualization tools (ArcGIS, IDV?)
- Validation tools (stats; difference fields)
- Forum (forum.nssl.noaa.gov)

NMQ JADE Goals and Science Objectives

- Develop a sustainable community hydrometeorological testbed for R&D of new QPE and short-term QPF science and technology, with particular focus on water resources applications
- Expedite RTO of new science and technology through the testbed, e.g., by facilitating testing and evaluation of QPE science for operational implementation in NEXRAD and the Advanced Weather Interactive Processing System (AWIPS)
- Gain understanding necessary to develop radar and multisensor QPE methodologies capable of producing high-resolution all-season, -region, and –terrain precipitation estimates
- Gain understanding necessary to integrate and assess new data sources from in-situ, radar, and satellite observing systems, and methodologies and techniques to improve QPE in support of hydrology and water resources and severe weather monitoring and prediction at the national scale



Radar

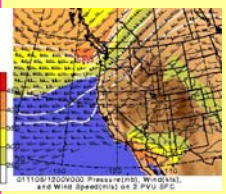


Satellite IR

Surface Obs

Upper Air Obs

Lightning



Model

JADE

INGEST Quality Control Mapping

Development Environment

Operational Infusion Pathway

Assessment and Evaluation

Operational: Applications & Systems

Real time Verification

NMQ/JADE Timetable

- NMQ/JADE Workshop June 2005
- NMQ_XRT
  - » Hardware/Server Procurement - February, 2005
  - » Configuration and Deployment - March 15, 2005
  - » System Testing - April and May 2005
  - » Initial Product Generation - June 2005
- NMQ_JADE
  - » Additional Servers - August 2005
  - » JADE Environment Configuration - Start Sept 2005

In Closing

- The NMQ project addresses high-resolution multisensor quantitative precipitation estimation (QPE) for all seasons, regions and terrains in support of hydrometeorological and hydrologic data assimilation and distributed hydrologic modeling.
- The NMQ system is being developed as a community testbed for R&D and RTO of QPE, short-range QPF and severe weather science and applications. It consists of the Research and Development Subsystem (RDS) and the Product Generation Subsystem (PGS).
- To enable joint development, testing and evaluation in an open and flexible environment, the Joint Applications Development Environment (JADE) is being developed. The JADE configuration on the NMQ system is expected to become functional in the fall of 2005.
- The many issues and complexities of quantitative estimation and short-range prediction of precipitation require a community-based approach and effort. Toward building an open and flexible community testbed for QPE and other hydrometeorological applications, we invite comments, suggestions, input, and participation of the community.

Thank you!

QuickTime™ and a
Video decompressor
are needed to see this picture.