Implementation Brief: Real-Time Mesoscale Analysis (RTMA)

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NCEP

Where the Nation's climate and weather services begin

T O P I C S

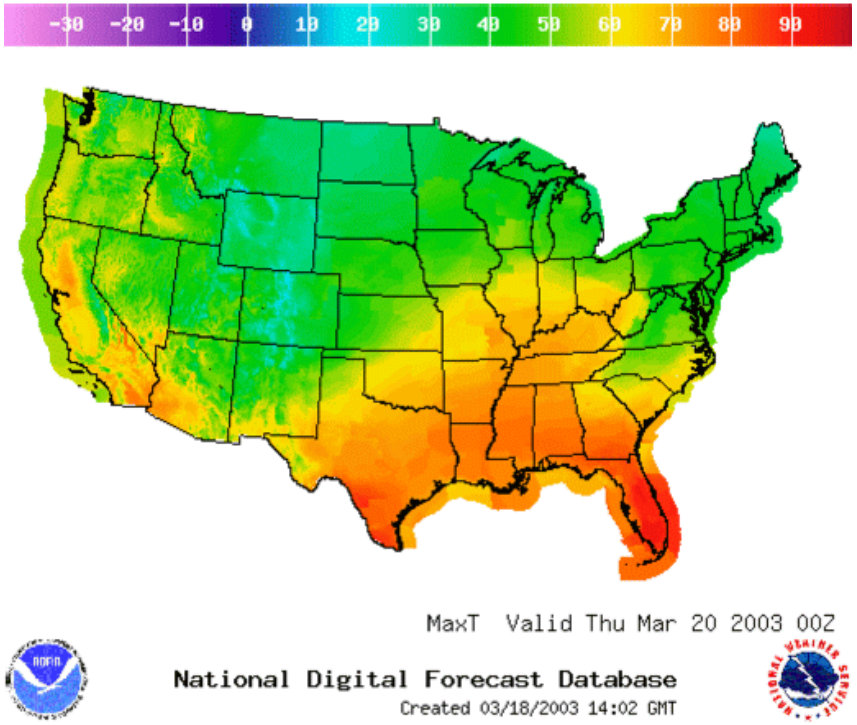
- Backgroud and Expectations
- Precipitation RTMA
- RUC Downscaling
- 2D-VAR RTMA
- OSIP
- Parallel Testing

Background

- WR SOO/DOH IFPS White Paper provided recommendations:
  - **Develop a national real-time, gridded verification system**
  - Provide full-resolution NCEP model grids
  - **Produce objective, bias-corrected model grids for WFO use**
  - Implement methods to objectively downscale forecast grids
  - **Incorporate climatology grids into the GFE process**
  - Deliver short and medium-range ensemble grids
  - **Produce NDFD-matching gridded MOS**
  - Modify the GFE software to ingest real-time data
  - Optimize ways to tap forecaster expertise

Glahn-Livesey Verification Meeting: Need to Verify NDFD – Grid vs Analysis

- **Insufficient density of obs for grid vs point verification of NDFD alone**
- **No 00 hr analysis in NDFD**
- **Need centrally produced "analysis of record" (DiMego's application of a term used in FGGE)**
- **No funds available**



National Digital Forecast Database (NDFD)

- A national database of digital weather forecast information
- Designed to meet the basic weather information needs of industry, media, commercial weather services, academia, and the public
- 3 hour to 7 day lead time

First Steps Toward an AOR

- **A Community Meeting on Real-time and Retrospective Mesoscale Objective Analysis**
  - **Convened by NWS' Seattle SOO Brad Colman and University of Utah's John Horel**
  - **June 2004 in Boulder**
- **AOR program should develop and implement suite of consistent sensible weather analysis products using current and future technologies.**
- **Mesoscale Analysis Committee (MAC) established August 2004 by Jack Hayes Director, NWS Office of Science and Technology**

Mesoscale Analysis Committee (MAC)

- Robert Aune, NOAA/NESDIS University of Wisconsin Space Sciences & Engineering Center
- Stanley Benjamin, Forecast Systems Laboratory
- Craig Bishop, Naval Research Laboratory
- Keith A. Brewster, Center for Analysis and Prediction of Storms The University of Oklahoma
- Brad Colman (Committee Co-chair), NOAA/National Weather Service -- Seattle
- Christopher Daly, Spatial Climate Analysis Climate Service Oregon State University
- Geoff DiMego, NOAA/NWS National Centers for Environmental Prediction
- Joshua P. Hacker, National Center for Atmospheric Research
- John Horel (Committee Co-chair), Department of Meteorology, University of Utah
- Dongsoo Kim, National Climatic Data Center
- Steven Koch, Forecast Systems Laboratory
- Steven Lazarus, Florida Institute of Technology
- Jennifer Mahoney, Aviation Division Forecast Systems Laboratory
- Tim Owen, National Climatic Data Center
- John Roads, Scripps Institution of Oceanography
- David Sharp, NOAA/National Weather Service -- Melbourne

Ex Officio:

- Andy Edman, Science & Technology Committee representative
- LeRoy Spayd, Meteorological Services Division representative
- Gary Carter, Office of Hydrology representative
- Kenneth Crawford, COOP/ISOS representative

Steps Toward an AOR Strategy

- MAC Committee meeting in Silver Spring in October 2004 to define needs and development strategy for AOR
- Distinct requirements become clear:
  - Real-time for forecasters – hourly within ~30 min
  - Best analysis for verification – time is no object
  - Long-term history for local climatology

Three Phase Strategy for AOR

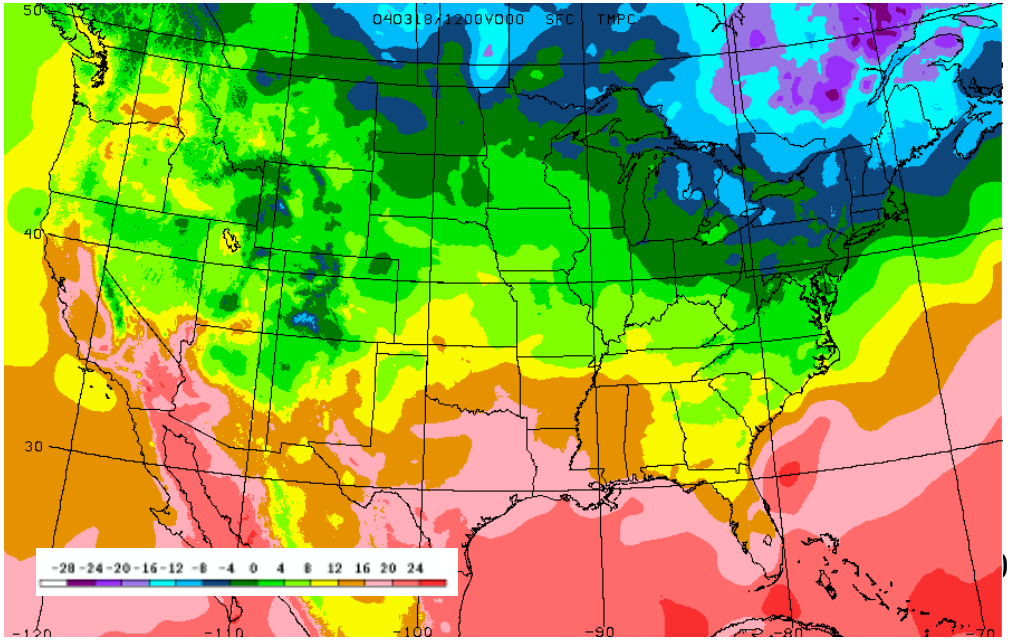
- Phase I – Real-time Mesoscale Analysis
  - Hourly within ~30 minutes
  - Prototype for AOR
  - NCEP/EMC and GSD volunteer to build first phase:
    - NCEP/EMC's Stage II National Precipitation Analysis
    - NCEP/EMC 2D-Var of 2m Temperature, 2m Dew Point and 10 m wind plus analysis uncertainty
    - GSD provide downscaled (RUC 13 – NDFD 5) first guess
    - NESDIS provide GOES-based Equivalent Cloud Amount
- Phase II – Analysis of Record
  - Best analysis possible
  - Time is no object
- Phase III – Reanalysis
  - Apply mature AOR retrospectively
  - 30 year time history of AORs

NWS' Integrated Work Team (IWT)

- Lee Anderson (co-chair), OST PMB
- Brad Colman (co-chair), WFO SEA
- Fred Branski, OCIO
- Geoff DiMego, NCEP EMC
- Brian Gockel, OST MDL
- Dave Kitzmiller, OHD
- Chuck Kluepfel, OCWWS Performance Branch
- Art Thomas, OCWWS
- Al Wissman, OOS

Analysis of Record

A comprehensive set of the best possible analyses of the atmosphere at high spatial and temporal resolution with particular attention placed on weather and climate conditions near the surface



Expectation

- In OCWWS – SREC poll of NWS Forecast Offices, AOR is top ranked priority two-years running
- In 2005, RTMA was accepted for inclusion in AWIPS build OB7.2 scheduled for deployment in Fall 2006

Phase I: The Real-Time Mesoscale Analysis (RTMA)

RTMA Procedure

- Temperature & dew point at 2 m & wind at 10 m
  - RUC forecast/analysis (13 km) is downscaled by GSD to 5 km NDFD grid
  - Downscaled RUC used as first-guess in NCEP's 2DVar analysis of ALL surface observations
  - Estimate of analysis error/uncertainty
- Precipitation – NCEP Stage II analysis
- Sky cover – NESDIS GOES sounder effective cloud amount

RTMA Logistics

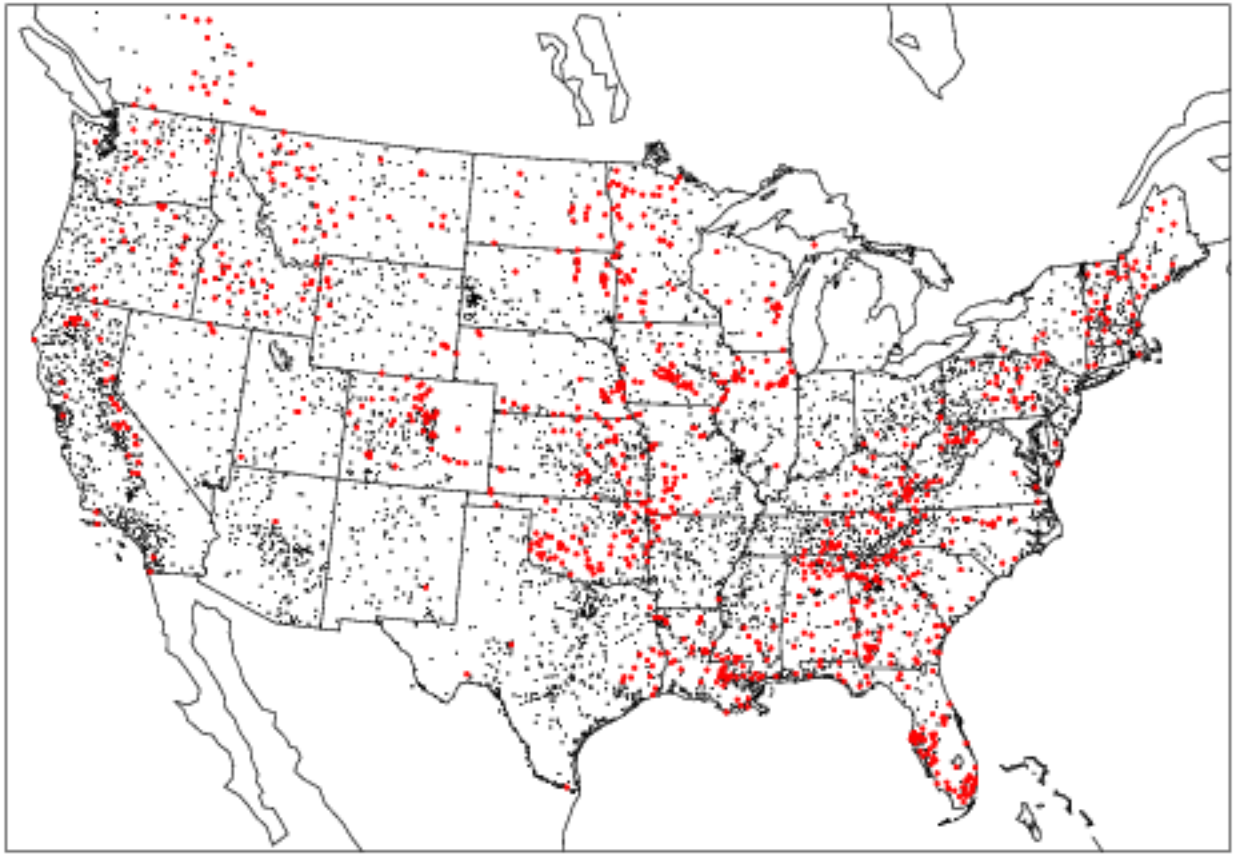
- Hourly within ~30 minutes
- 5 km NDFD grid in GRIB2
- Operational at NCEP Q3 FY2006
- Distribution of analyses and estimate of analysis error/uncertainty via AWIPS SBN as part of OB7.2 upgrade – end of CY2006
- Archived at NCDC

Precipitation RTMA

- Ying Lin's existing Stage 2 National Precipitation Analysis hourly product
  - Timely ~35min after each hour
  - High resolution ~4 km HRAP grid
- Interpolate Stage 2 product to 5 km NDFD grid to create the RTMA Precipitation analysis product
- Since April 19, 2005 http://wwwt.emc.ncep.noaa.gov/mmb/ylin/pcpanl/precip_rtma_aor.html
- Became operational 13Z 28 June 2006

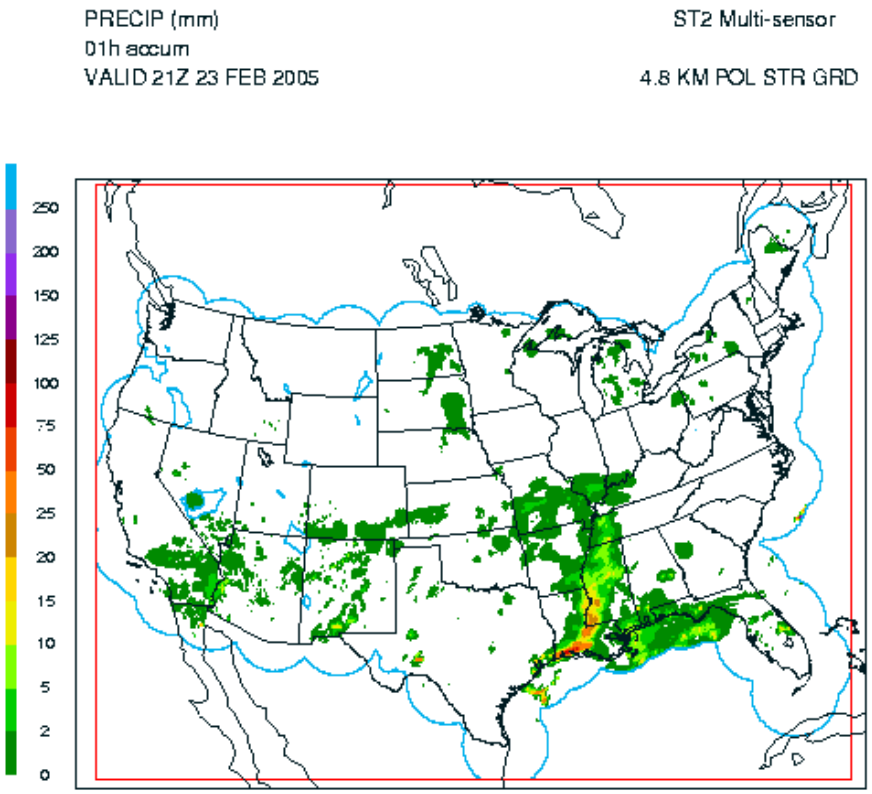
Hourly Gages Available for Stage II Precipitation Analysis

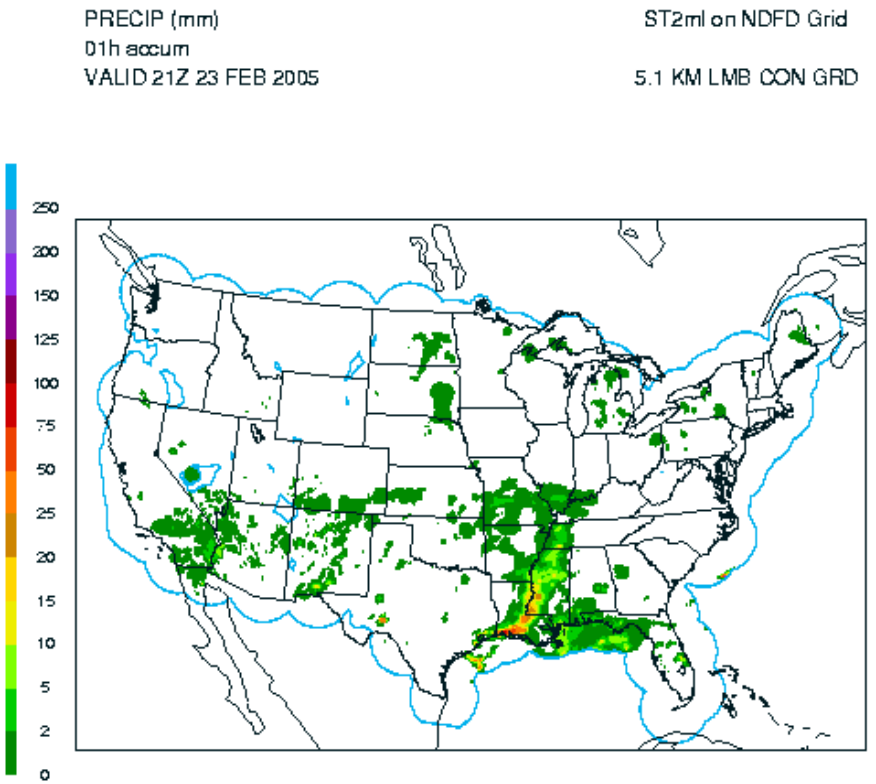
Hourly Gauges (Red: Flagged) 24h Ending 12Z 20050704



Precipitation Analysis

HRAP grid versus NDFD grid

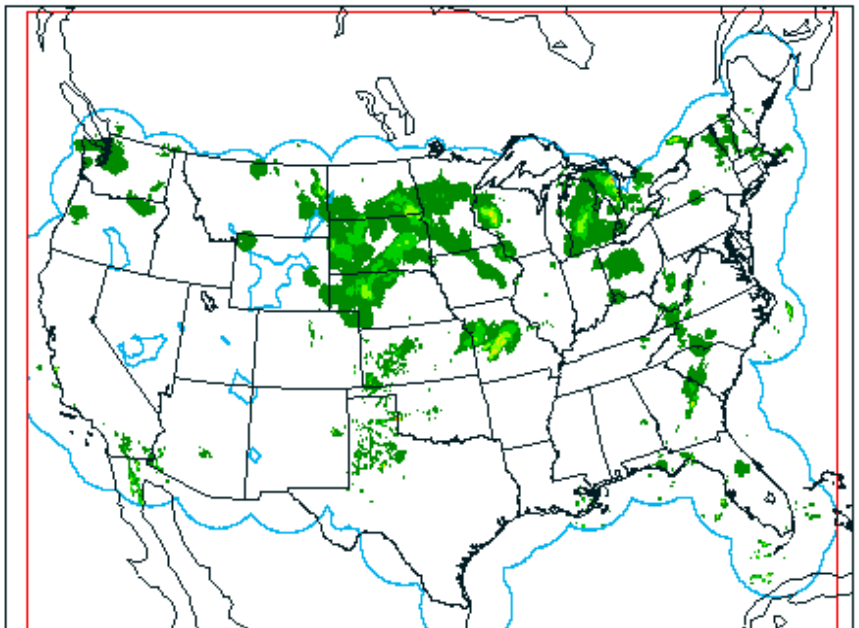




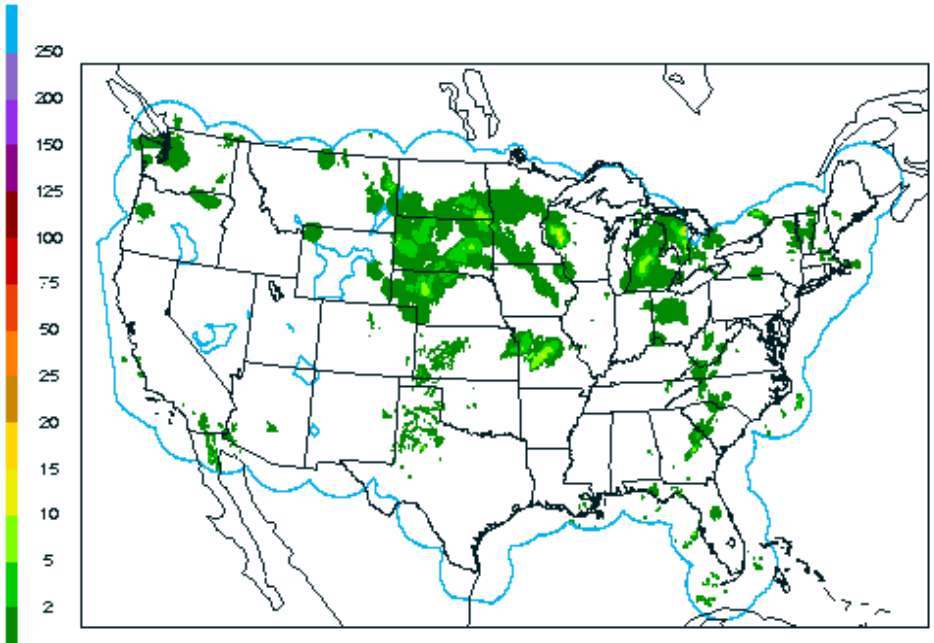
NCEP RTMA Precipitation Analysis

- NCEP Stage II (real-time) and Stage IV (delayed) precipitation analyses are produced on the 4-km Hydrologic Rainfall Analysis Project grid
- The existing multi-sensor (gauge and radar) Stage II precipitation analysis available 35 minutes past the hour
- RTMA is mapped to the 5 km NDFD grid and converted to GRIB2
- Upgrade plan including OHD analysis + improved gauge QC from GSD
- Primary contact: Ying Lin, NCEP/EMC
- **http://wwwt.emc.ncep.noaa.gov/mmb/ylin/pcpanl/**

ORIGINAL

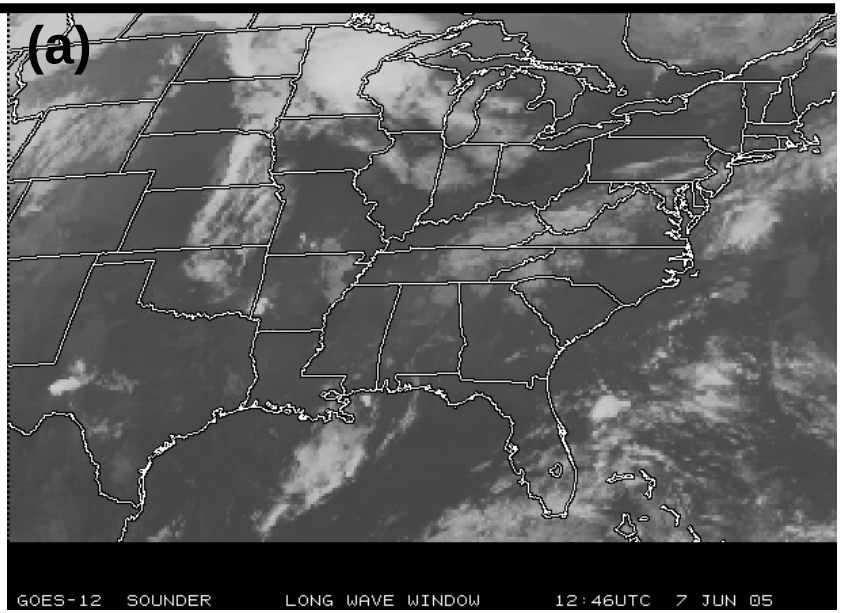


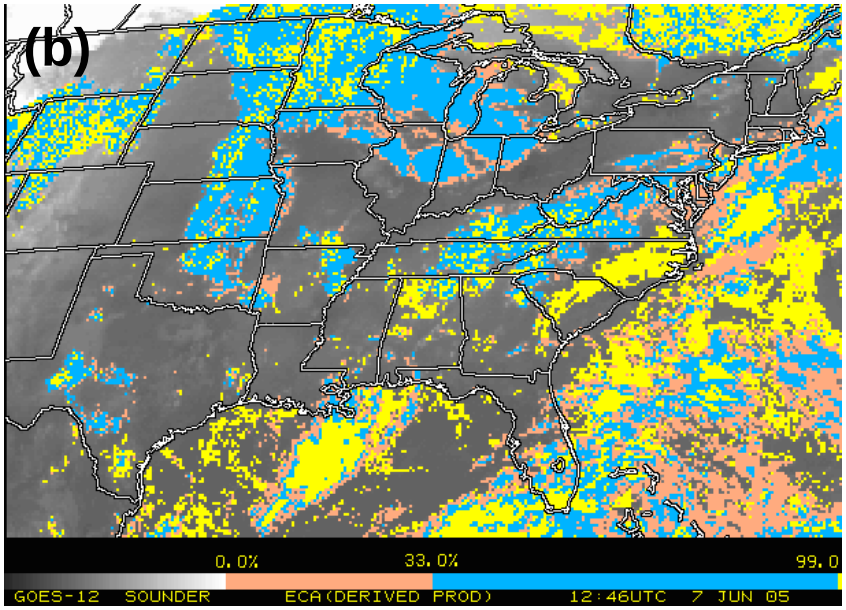
NDFD GRIB2



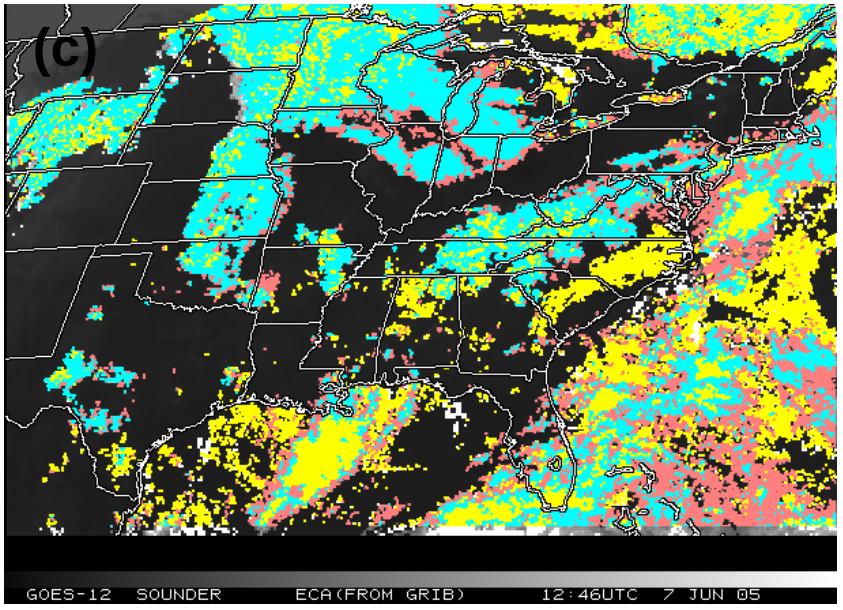
NESDIS' GOES Effective Cloud Amount

- Effective Cloud Amount (ECA, %)
- Derived from GOES sounder
- Mapped onto 5-km NDFD grid
- Converted to GRIB2 for NDGD
- Contacts: Jaime Daniels NESDIS





Derived ECA from GOES-12



ECA from GRIB2 file – 5km grid

RTMA-RUC downscaling

NOAA-ESRL-GSD
Stan Benjamin
John Brown

NCEP-EMC
Geoff Manikin

- Original code – 28 June 2005 – part of 13-km RUC package
- Revised code – 11 July 2006 – part of 2006 RUC package
  - Review of RTMA-RUC downscaled grids in winter/spring 2006 by NWS, EMC, GSD
  - New topo, roughness length grids now used, improved code for extrapolation vs. interpolation, coastlines

Why RUC for First Guess

- **Hourly update frequency**

- **Characteristics of RUC grids appropriate for RTMA/AoR**
  - Hourly mesoscale analysis (digital filter essential)
  - Designed to fit observations (within expected error)
    (incl. Sfc 2m temp (as θ), dewpoint, altimeter, wind)
  - Consistent with full-physics 1-h forecast
    (most important in physics – PBL, land-surface)
  - Accounting for local PBL depth in assimilation of surface data
  - Accounting of land-water contrast
  - Assimilation of METAR cloud, vis, current wx
  - Assimilation of full mesonet obs (except winds)
  - Assimilation of GPS PW, PBL profiler
  - QC criteria for mesonet different than METARs
  - Assimilation of GOES cloud-top data into initial fields of 3-d hydrometeors (5 types)

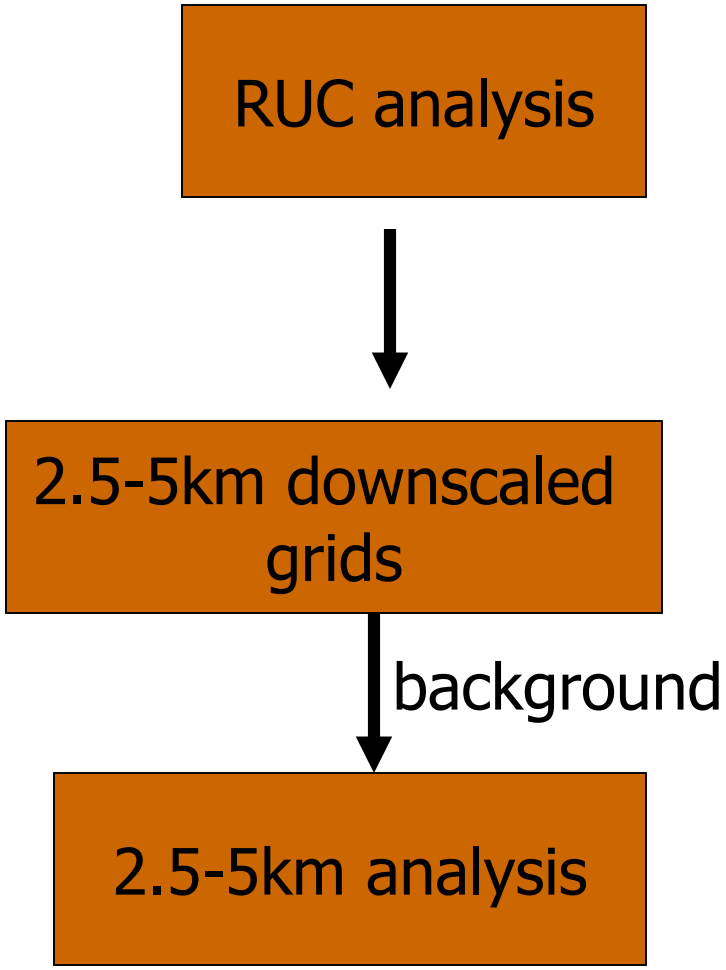
Outline of original EMC/GSD (then FSL) proposal

Combined approach

- Step 1. Full model-based 1-h (or less) assimilation cycle at coarser resolution (e.g., current 13km RUC $\rightarrow$ 13-km RR)

- Step 2. Non-model downscaling using ~2.5-5km topography, land-use, roughness length, land/water

- Step 3. Analysis w/ high-resolution observations – Mesonet/METAR inc. cloud/vis.., radar, satellite



RUC downscaling to RTMA background

- Runs as extra module at end of RUC post-processing code for both 0-h and 1-h data, 1-h RUC is currently used for RTMA background
  - All diagnostics ready on 13km grid

- Horizontal and vertical interpolation components for downscaling to 5-km

  - Use of 5-km RTMA high-resolution terrain

  - Use of 5-km roughness-length on RTMA grid (from WRF Standard Initialization program) to more sharply define land-water contrast on 5-km RTMA grid

- Variables – p, z, 2-m T/Td/q, u/v, wind gust, ceiling, visibility

RTMA-RUC downscaling

1. Step 1 - Horizontal component

    a. Bilinearly interpolate RUC grids to RTMA 5-km

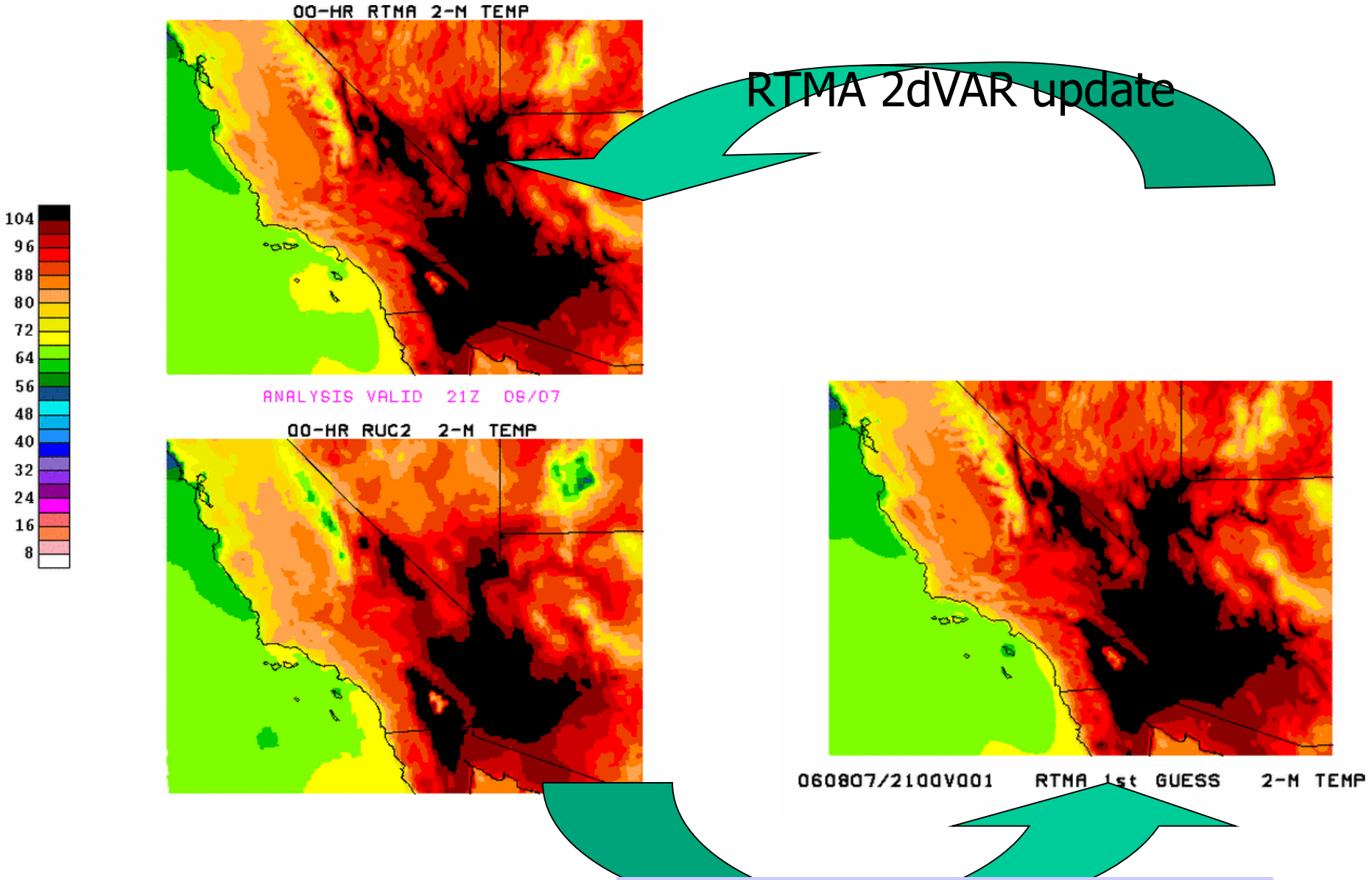
    b. Variables – p, z, 2-m T/Td/q, u/v, wind gust, ceiling, visibility

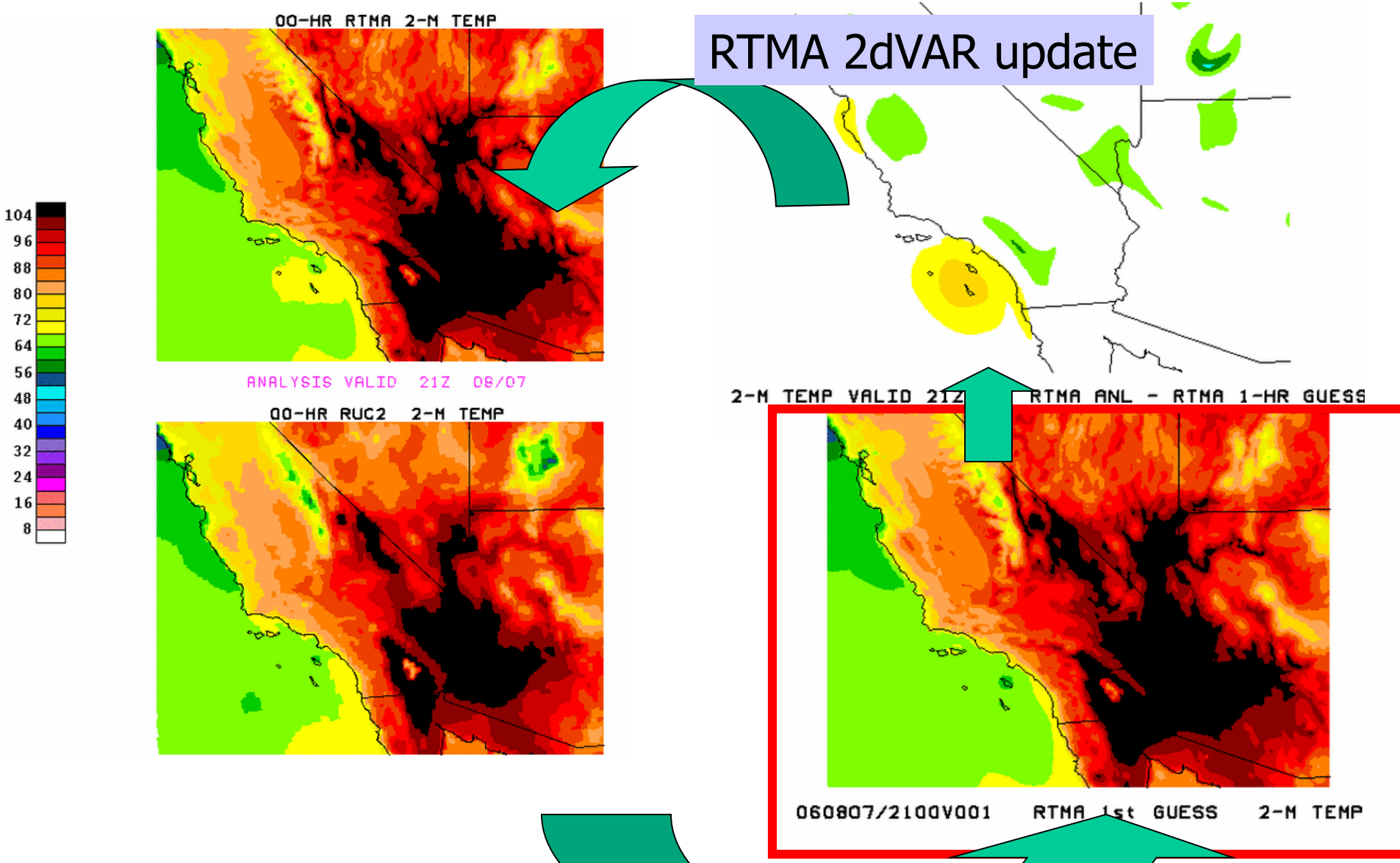
    c. Use 5-km roughness length to estimate RTMA water point values (2mT/Td, u/v) from nearby RUC water points – maintain appropriate coastal gradients using high-res RTMA land-water

RTMA-RUC downscaling

2. Step 2 – Vertical component
   a. 2-m temp (most critical part of RTMA downscaling)
      1) If z-RUC > z-RTMA
         a) Use local lapse rate from native RUC lowest 25 mb, constrained between dry adiabatic and isothermal
      2) If z-RUC < z-RTMA
         a) Interpolate from native RUC levels, but maintain inversion such that 2mT-RTMA does exceed 2mT-RUC in this condition
   b. 2-m dewpoint, wind, wind gust
      1) Use similar techniques dependent on z-RUC/z-RTMA, with different constraints for each

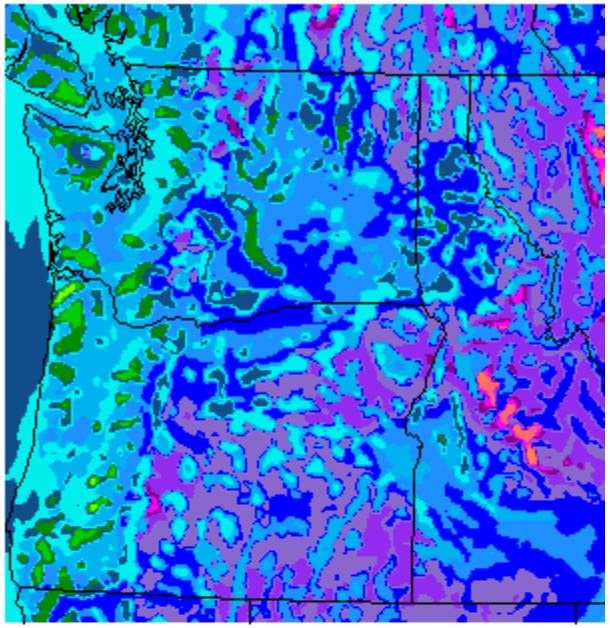
(More discussed at AMS on RUC-RTMA downscaling)


00-HR RTMA 2-M TEMP
104
96
88
80
72
64
56
48
40
32
24
16
8
ANALYSIS VALID 21Z 08/07
00-HR RUC2 2-M TEMP
060807/2100V001 RTMA 1st GUESS 2-M TEMP
RTMA 2dVAR update
RUC-RTMA downscaling
to detailed RTMA background

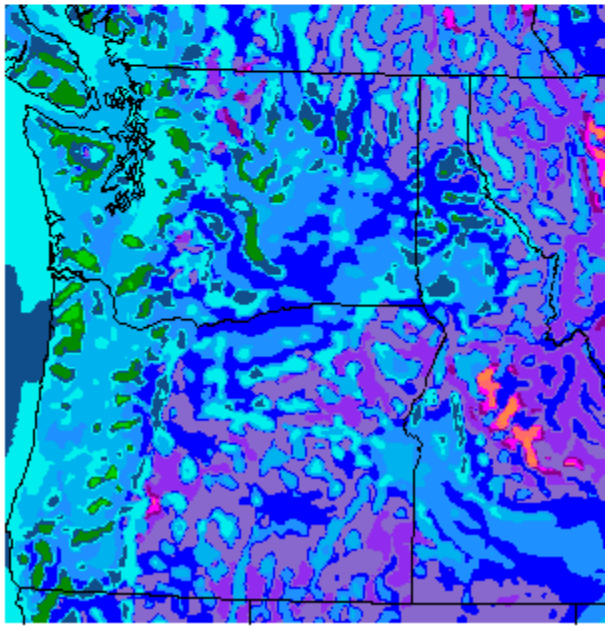


RTMA 2dVAR update

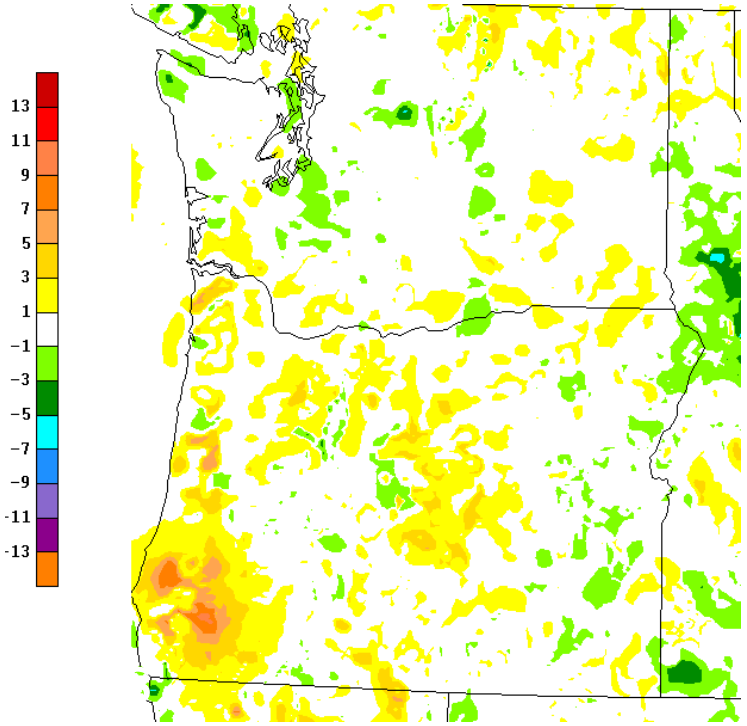
RUC-RTMA downscaling to detailed RTMA background



00V001 OPS RTMA 1st GUESS



00V001 NEW RTMA 1st GUESS



Example of revision in RTMA-RUC downscaling based on 2006 review

Revised code to generate downscaled NDFD 1st guess constrains the upward extrapolation that previously led to too warm 2-m temps over high terrain during early morning inversions

Why 2DVar solution?

- 2DVar is subset of NCEP's more general 3DVar Grid-point Statistical Interpolation (GSI)
- Connected to state-of-the-art unified GSI development at NCEP / JCSDA
- 2DVar is already running in NAM (low risk)
- Anisotropy built into 2DVar provides way to restrict influence of obs based on
  - Elevation (terrain height – NAM & ADAS in WR)
  - Future use of potential temperature
- 2DVar is fast enough to run overtop of hourly RUC in tight NCEP Production suite
- Can provide estimate of analysis uncertainty
- Can assess analysis "accuracy" via built-in cross-validation

The RTMA 2D-Var is a special application of NCEP's Gridpoint Statistical Interpolation (GSI)

http://wwwt.emc.ncep.noaa.gov/gmb/treadon/gsi/documents/presentations/1st_gsi_orientation/

1st GSI User Orientation 4-5 January 2005

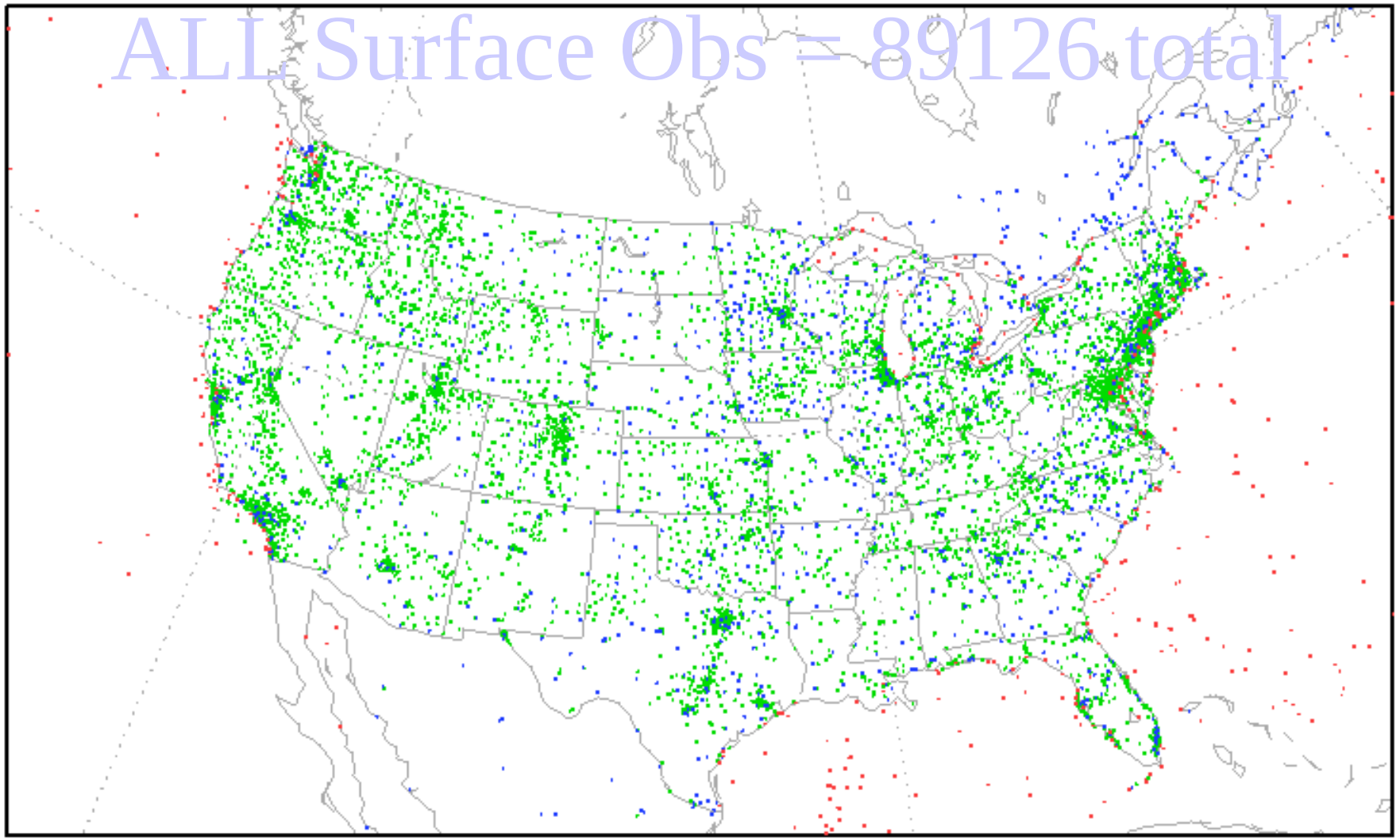
Presentation	Speaker(s)
High-level Overview of GSI systems	John Derber
Observations, PrepBUFR, and the interface to PrepBUFR	Dennis Keyser
Observation error: estimation & qc (conventional & satellite retrievals)	Wan-Shu Wu
Satellite radiance treatments	John Derber
Reflectivity and wind radar data treatment and gross quality control (Marshall, Parrish)	Curtis Marshall, Dave Parrish
Nonlinear quality control within GSI	Dave Parrish
Minimization and pre-conditioning, inner and outer loops	John Derber
Recursive filter primer	Jim Purser
Background errors and their estimation (Parrish, Wu)	Dave Parrish, Wan-Shu Wu
Anisotropic capabilities (Parrish, Pondeca)	Dave Parrish, Manuel Pondeca
WRF connections	Dave Parrish
The GSI code	Russ Treadon
Analysis Input/Output	Russ Treadon
Cycling issues – How NCEP is going to do it	Wan-Shu Wu
GSI Compilation, Coding, & Updates	Russ Treadon

Cross-Validation

NCEP obtains full complement of observations

- Conventional through TOC
- Mesonets through MADIS (FSL)
- MesoWest will be critical alternate path to MADIS during AOR due to their ability to store and forward “old” data transmitted in bursts from some sites/networks (may have better QC as well)

2005092600 NAM Surface Data Dump Distribution over CONUS



SFCSHP (red) + ADPSFC (blue) + MSONET (green)

DOC/NOAA/NWS/NCEP/EMC/MMB

REPORT COUNT: 89126

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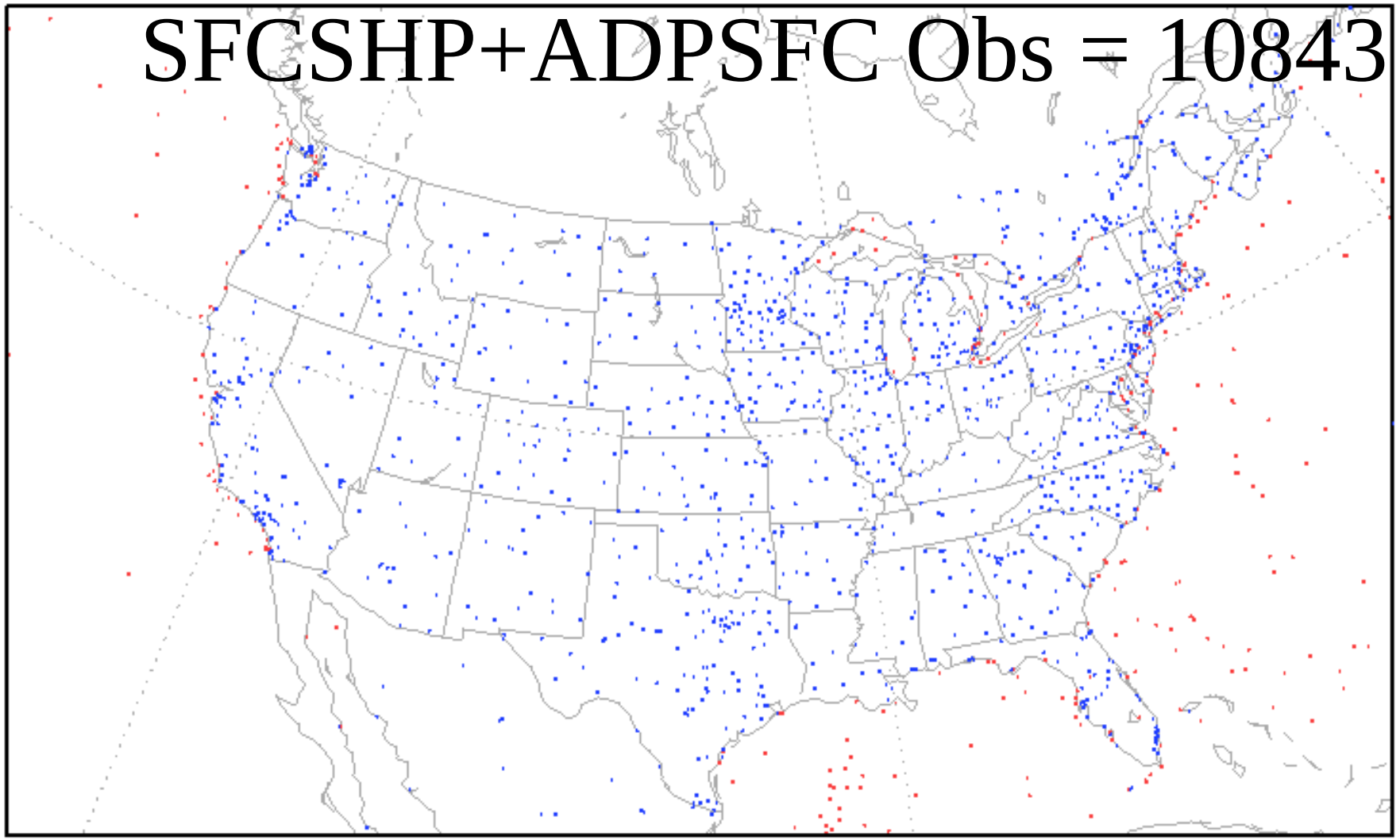

(all SFCSHP (red) + ADPSFC (blue) data)

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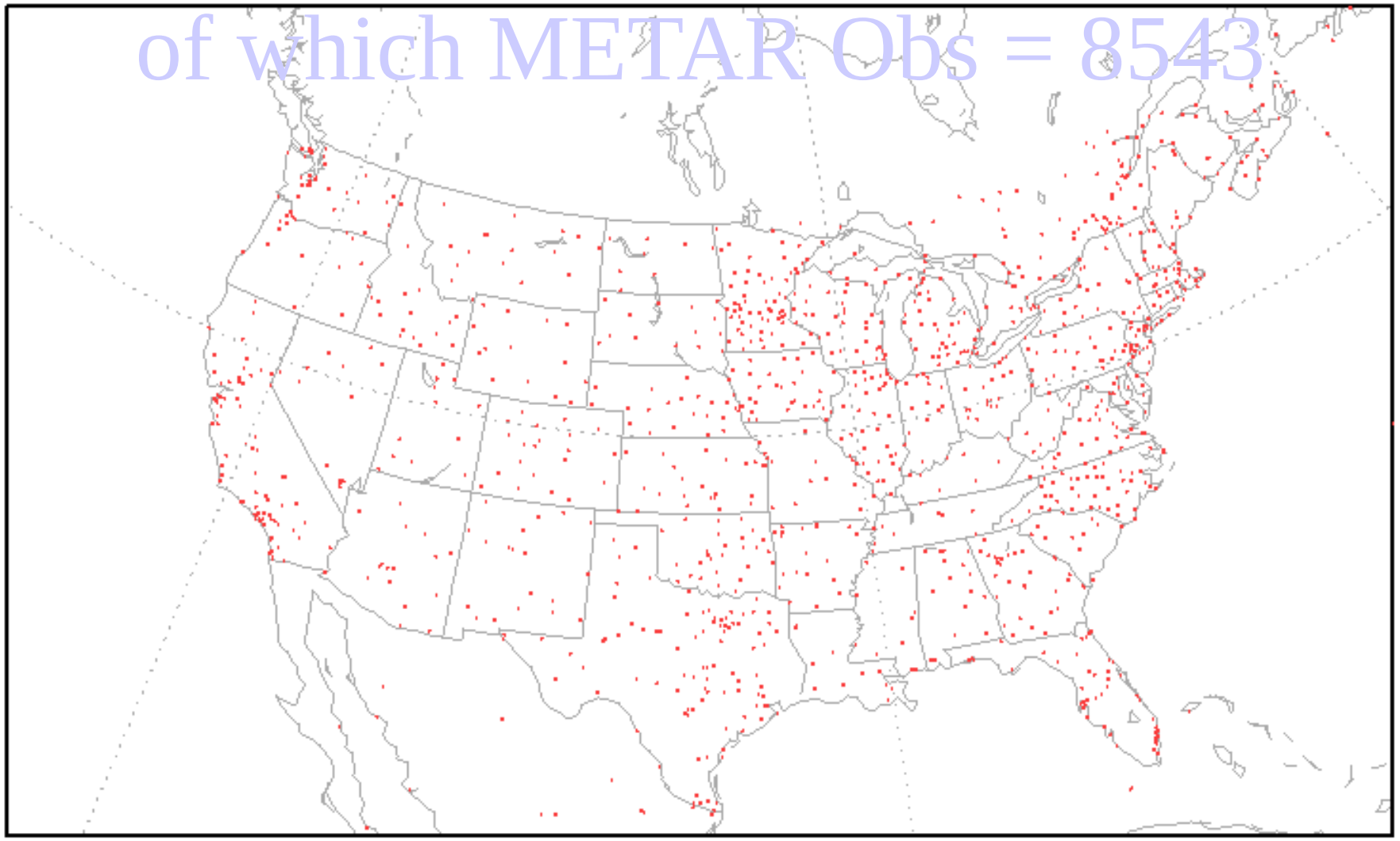

(METAR only)

DOC/NOAA/NWS/NCEP/EMC/MMB

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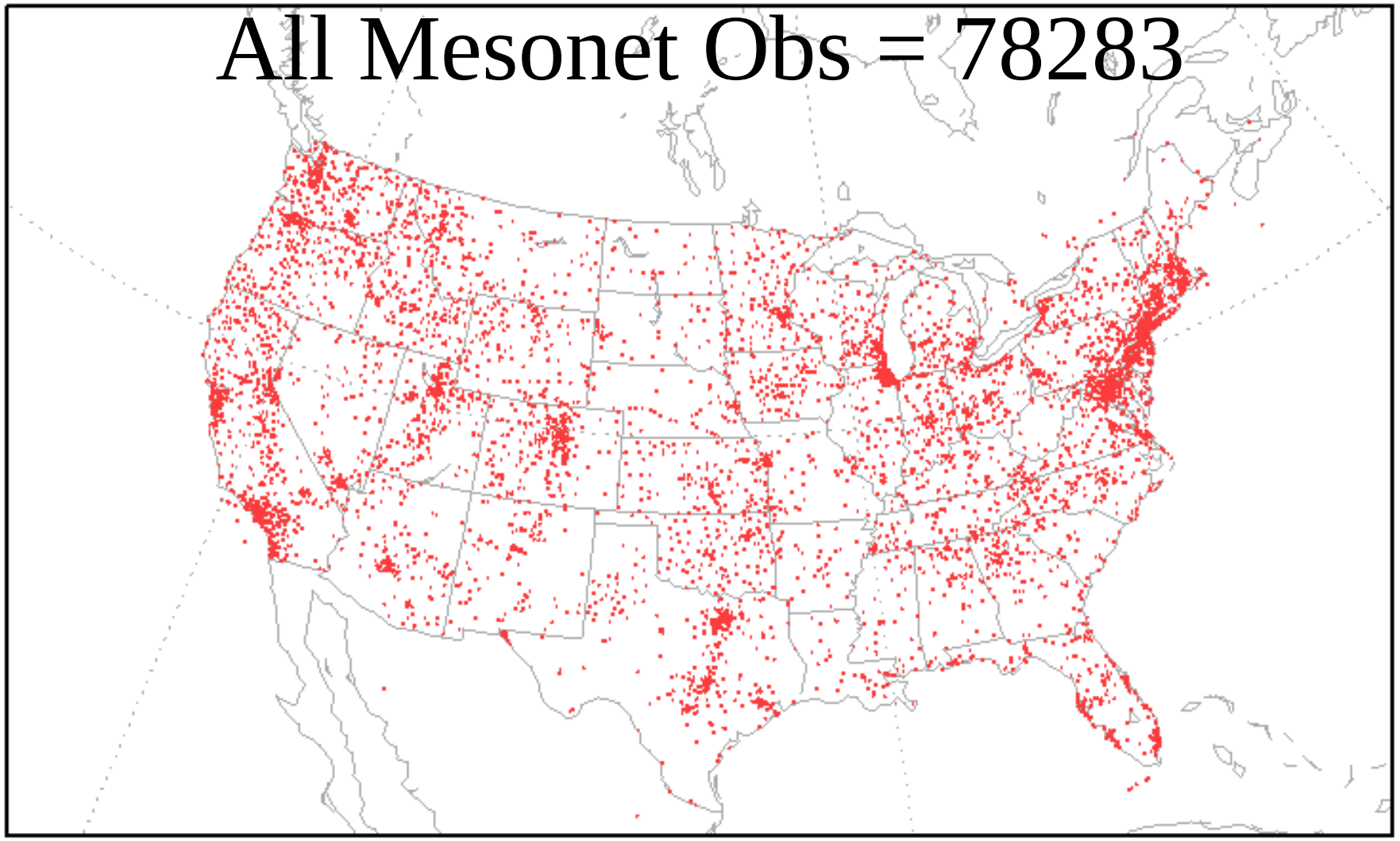

(all Mesonet data, including AWS)

DOC/NOAA/NWS/NCEP/EMC/MMB

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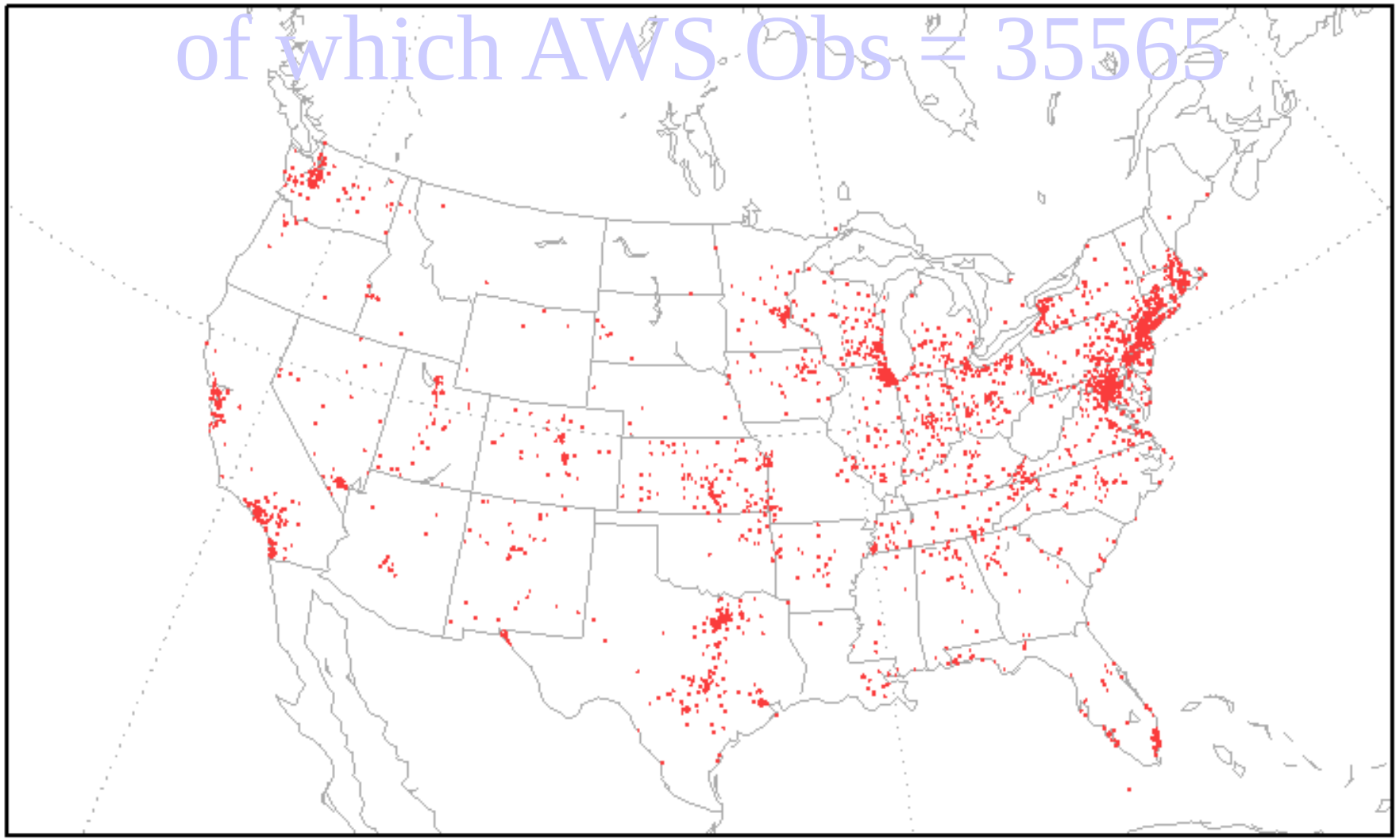

(AWS only)

DOC/NOAA/NWS/NCEP/EMC/MMB

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Mesonet Issues

- Mesonets comprise majority of obs but they are not as good as other conventional sfc ob sources
  - No mesonet winds not used in current RUC (or NAM) due to slow wind bias
  - GSD has constructed a "Uselist" of acceptable networks based on overall siting strategies etc.
  - GSD Uselist is applied in the RTMA
  - Continuing need for scrutiny of mesonet quality
- Data volumes arriving at NCEP from MADIS are deficient to run analysis in time for targetted 30 minute delivery
- Temporarily moved ob dump to H+30 to get sufficient obs – leads to delivery at H+42

GSI: Nonlinear Quality Control

- Next to be tried will be the GSI's nonlinear QC procedure

$$J = J_b + J_o$$

$$J_b = \frac{(a - b)^2}{\sigma_b^2} \qquad \text{(background penalty)}$$

$$J_o = \frac{(o - a)^2}{\sigma_o^2} \qquad \text{(standard observation penalty)}$$

$$J_o^{QC} = -\ln[\exp(-J_o) + \alpha] \qquad \text{(nonlinear qc observation penalty)}$$

$\alpha << 1$ related to probability of gross error

$\alpha = 0,$ then $J_o^{QC} = J_o$

for large J_o (observation far from analysis), J_o^{QC} independent of J_o

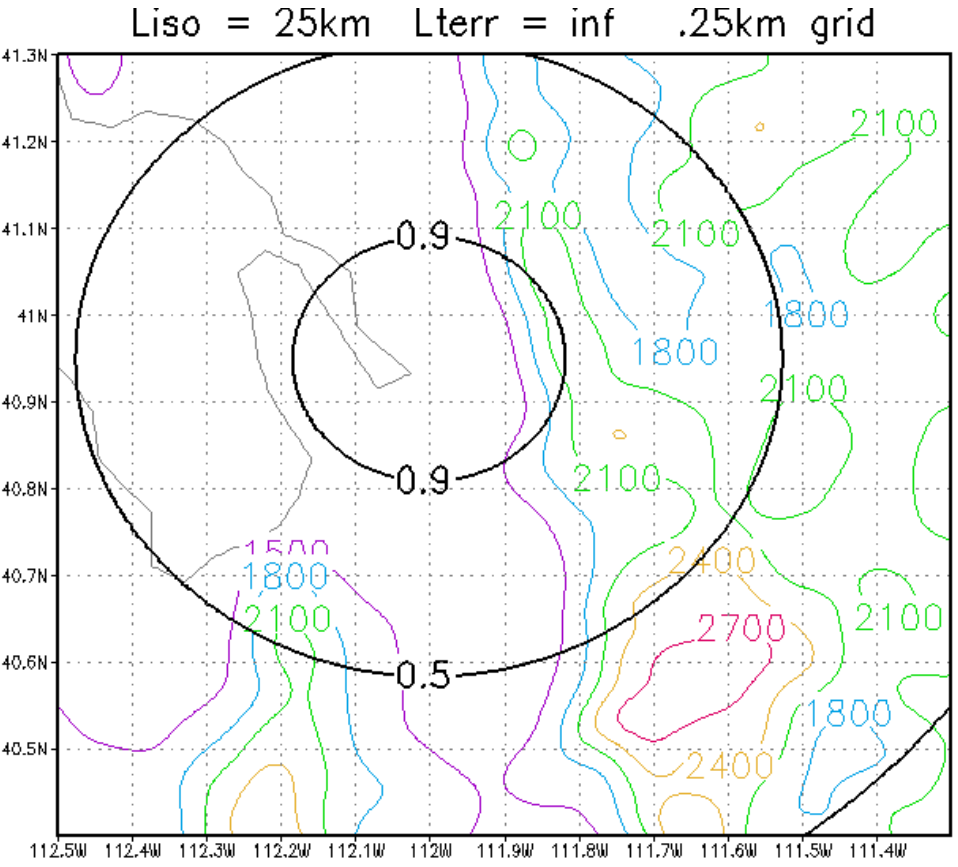
(observation tossed)

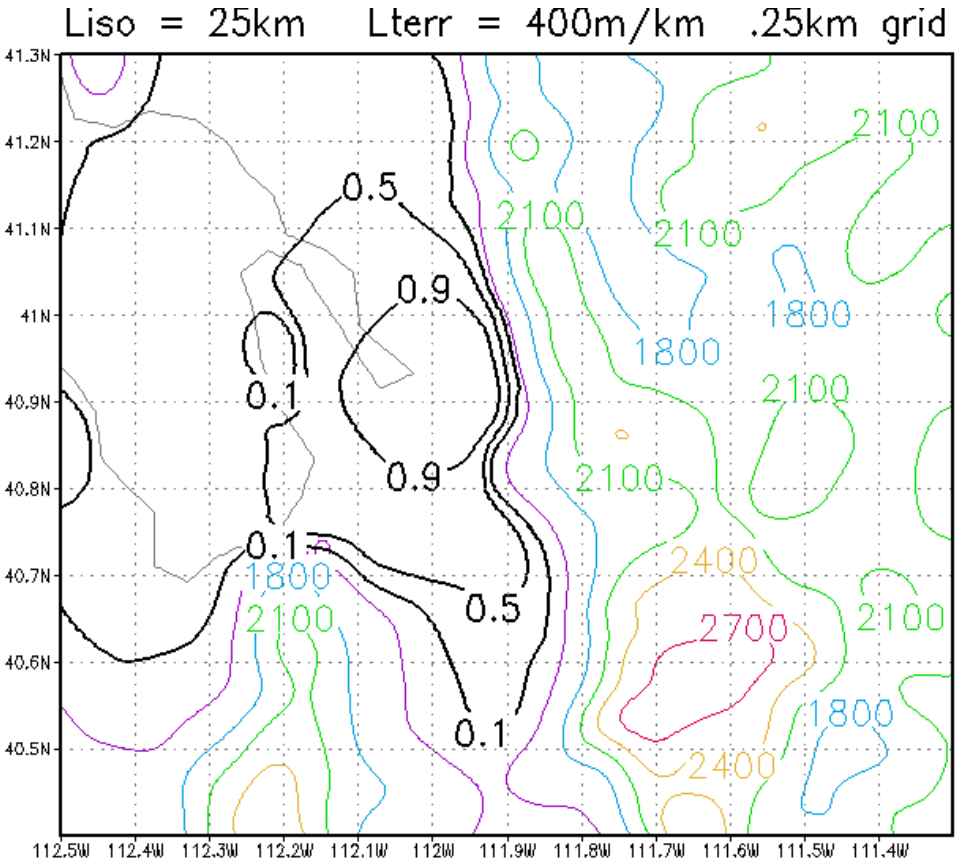
α tuned for each observation type by examining observed - background statistics and estimating probability of gross error.

Error Correlations for Valley Ob (SLC) Location Plotted Over Utah Topography

Isotropic Correlation:
obs' influence extends up mountain slope

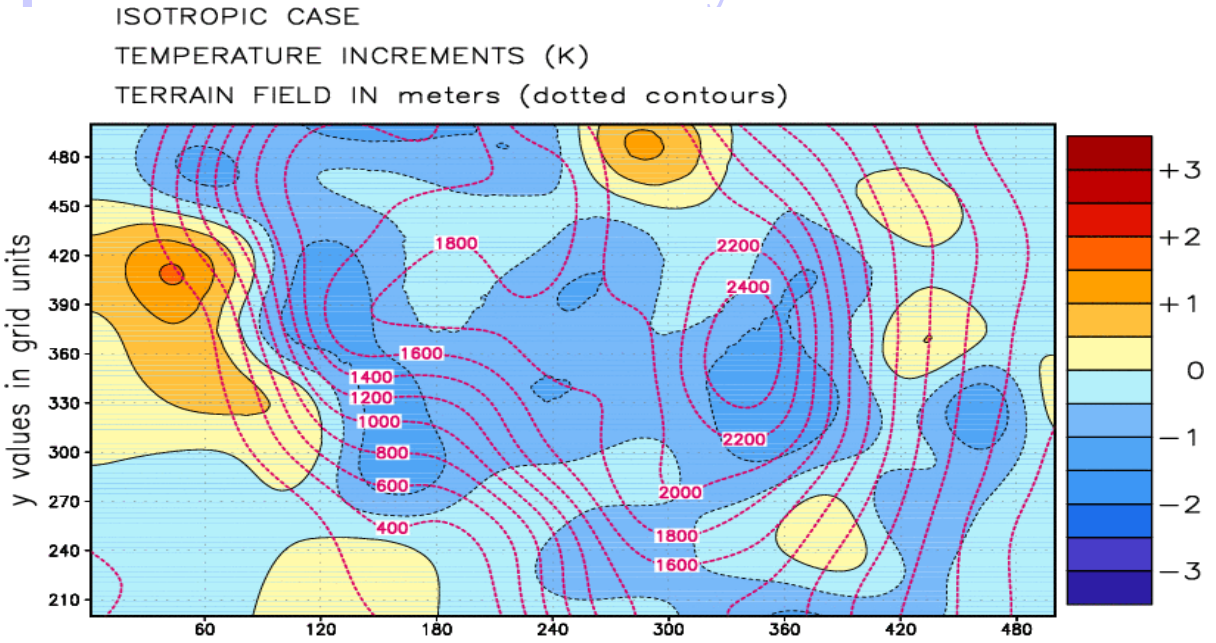
Anisotropic Correlation:
obs' influence restricted to areas of similar elevation



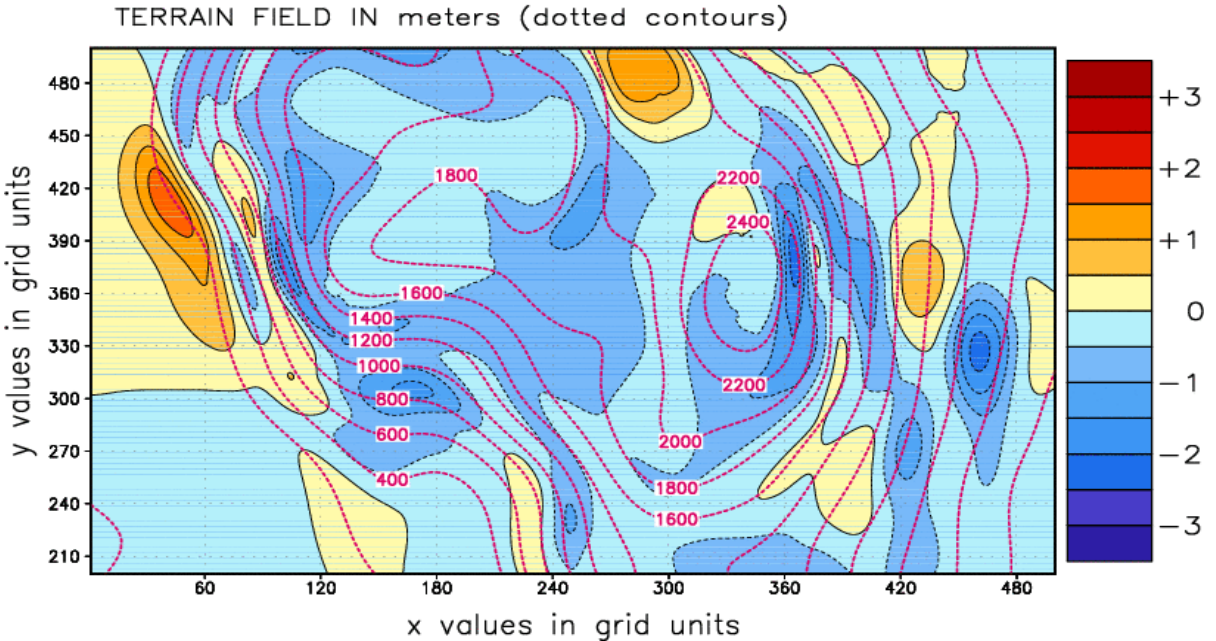


Example of 2DVar/RTMA analysis increment for temp

Isotropic



Anisotropic



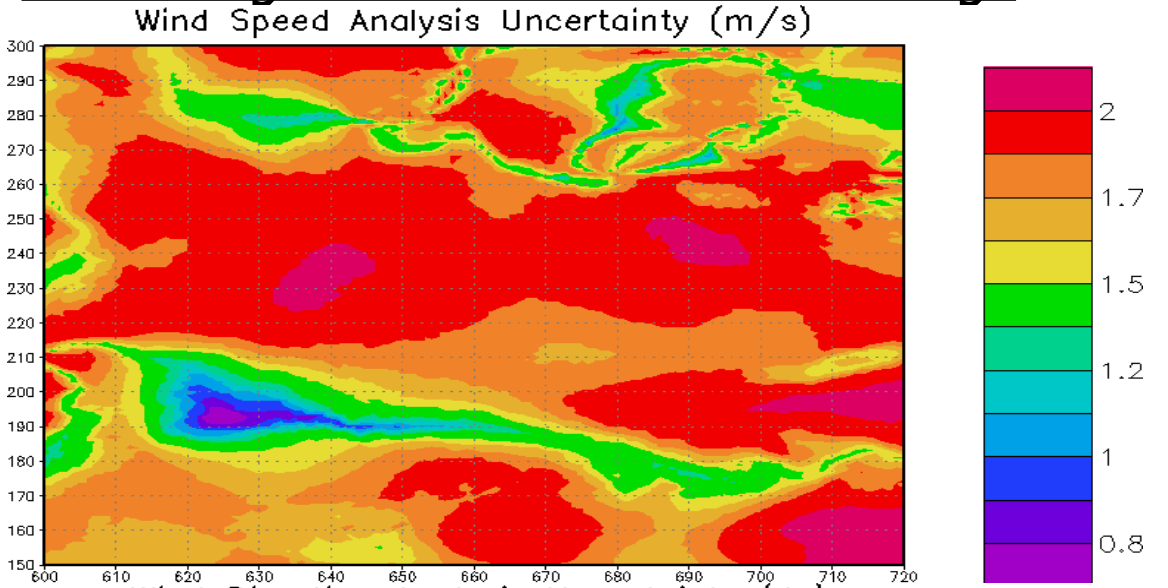
Estimates of RTMA Analysis Error / Uncertainty

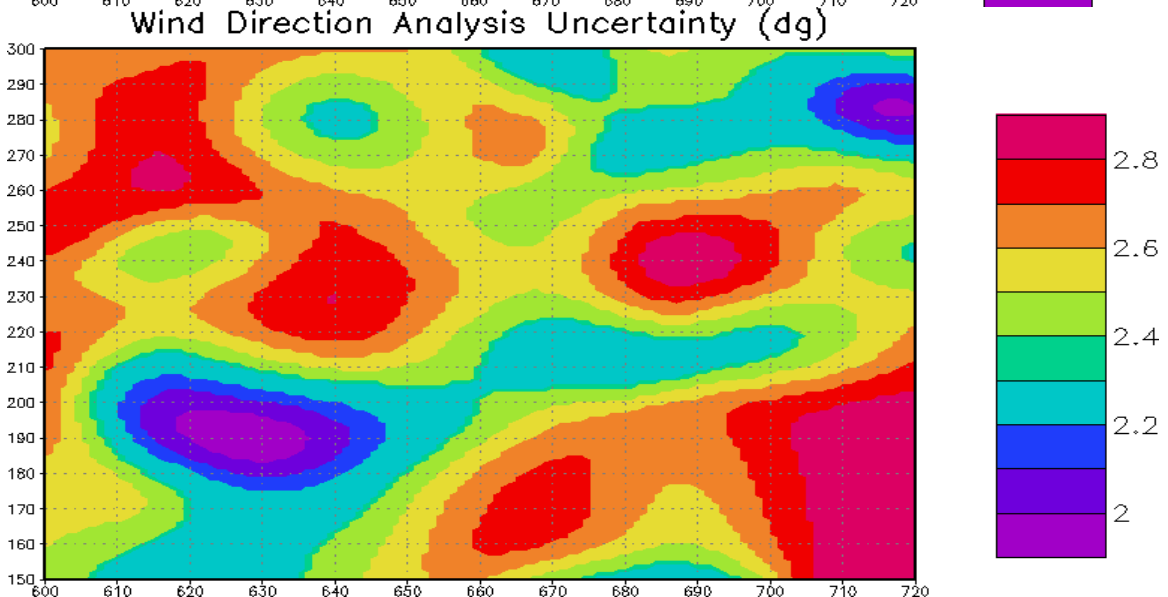
- Reflect Obs density, Obs quality and Background quality
- Not direct from GSI but it will be possible to estimate it:
  - Analysis error = (Hessian of cost function)$^{-1}$
    see Rabier and Courtier 1992; Fisher and Courtier 1995
  - Hessian of a simplified cost function: $\nabla^2 J = \frac{1}{B} + \frac{1}{O}$
  - Analysis error: $A = \frac{1}{1/B + 1/O} = \frac{xO}{y}$

    since

    $\frac{\partial J}{\partial x} = 0 \Rightarrow x(\frac{1}{B} + \frac{1}{O}) = \frac{y}{O}$

Wind Direction and Wind Speed Analysis Uncertainty





Cross-Validation in GSI and the RTMA's 2D-VAR

- Cross-validation
  - Withhold small percentage of obs from analysis
  - Validate analysis at those withheld obs
  - Only way to verify analysis for analysis sake
- Now built into GSI
  - Can withhold and internally compare analysis
  - Baseline CV also computed internally based on a simple single-pass Cressman scheme
  - Future performance metrics will be based on improvement over this Baseline

OSIP Process / Progress

- IWT Team led by OS&T's Lee Anderson
- Three Phase Analysis of Record (AOR)
  - Need Identification Document (NID)
    03/14/2005
  - Statement of Need (SON)
    05/04/2005
  - CONOPS/ORD
    12/16/2005
  - Project Plan (PP)
    07/10/2006

OSIP Process / Progress

- Real Time Mesoscale Analysis (RTMA = Phase 1 of AOR)
  - Statement of Need (SON)
    05/24/2006
  - Project Plan (PP)
    07/10/2006
  - CONOPS/ORD
    05/24/2006
  - Business Case (BUS)
    05/25/2006
  - Requirement Specification (REQ)
    05/08/2006

RTMA Testing

- Manuel Pondeca built RTMA 2D-Var system and Dennis Keyser built special obs dumps
- Started running hourly in real-time in December 2005
- Output grids in GRIB2 format on NCEP's ftp server
- Test files picked up by field evaluators and by TOC and SOC for testing for OB7.2

RTMA Evaluation Website

- http://www.emc.ncep.noaa.gov/mmb/rtma/
- Established 24 Jan. 2006 by Geoff Manikin
- 7 geographical sub-regions displayed:
  NE, DC, FL, MW, TX, NW and SW
- 3 analysis field displays: 2 m Temperature,
  2 m Dew Point and 10 m Wind
- 4 analysis increment displays: 2 m Temp,
  2 m Dew Point, 10 m Wind Speed and
  10 m Vector Wind

RTMA Webpage - Legend

2-M Temperaure

NE	DC	FL	MW
TX	NW	SW	

2-M Dew Point

NE	DC	FL	MW
TX	NW	SW	

10-M Wind

NE	DC	FL	MW
TX	NW	SW	

2-M Temp Increments

NE	DC	FL	MW
TX	NW	SW	

2-M Dew Pt Increments

NE	DC	FL	MW
TX	NW	SW	

10-M Wind Speed Increments

NE	DC	FL	MW
TX	NW	SW	

10-M Wind Vector Increments

NE	DC	FL	MW
TX	NW	SW	

RTMA Graphics

The current forecast cycle is **06Z 09 Aug** with graphics finished at 03:08:43 EDT Wed Aug 9 2006

This page displays the RTMA analysis and compares it to the RUC, Surface RUC, NAM, observations, and the first guess. When any forecast hour button on the left is activated, the following maps will be displayed:

Top:	RTMA	RTMA-RUC	SFC RUC
Bottom:	RUC	OBS	NAM

For the plots in any section featuring INCREMENTS, the following format is used:(GES indicates a 1-hour forecast used as a 1st guess)

Top:	RTMA ANL-GES	RTMA GES
Bottom:	RUC ANL-GES	OBS

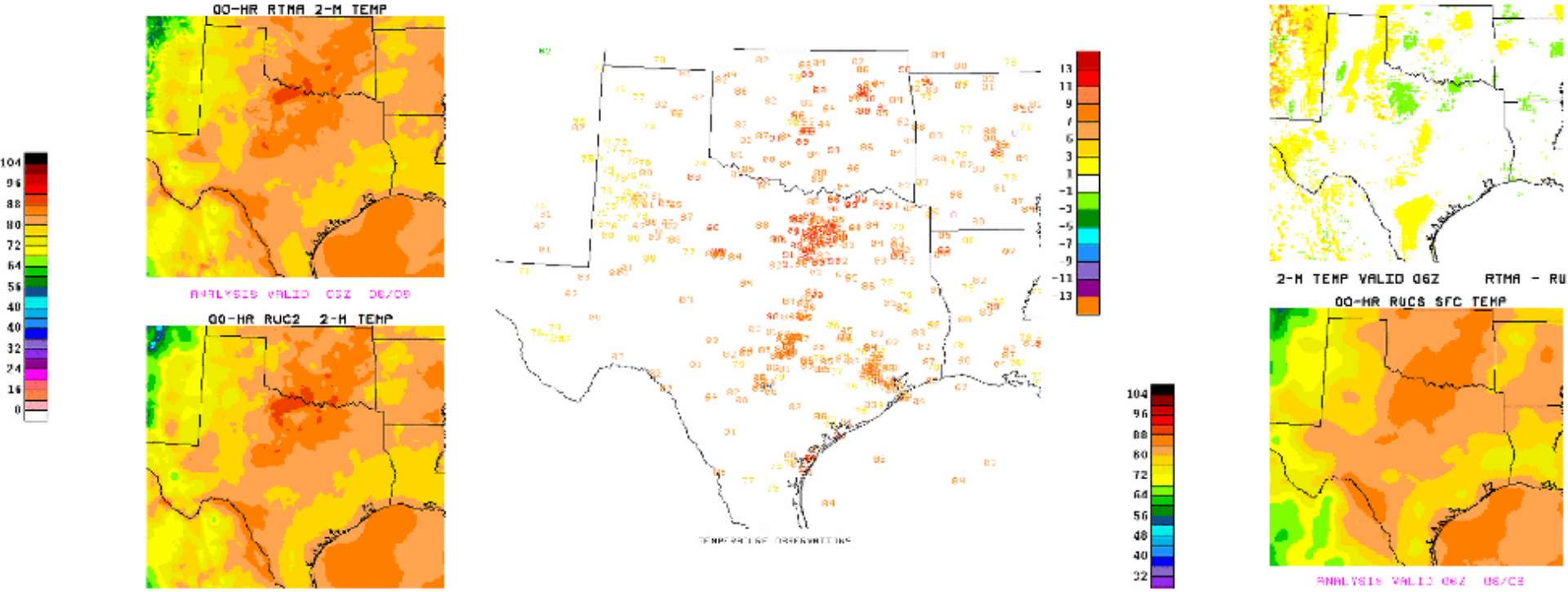
NOTE: The AWIPS grid #227 (5 km Lambert Conformal) is used for all plots.

NOTE: A NAM analysis is only available every 3 hours.

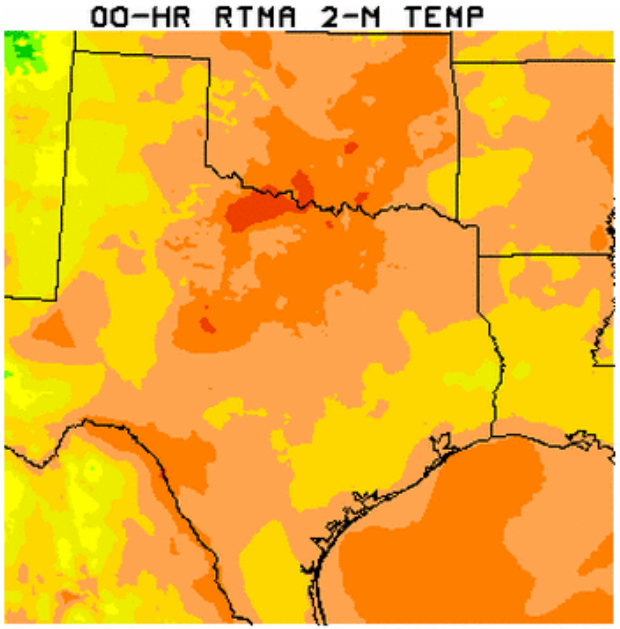
NOTE: All displayed winds are in knots.

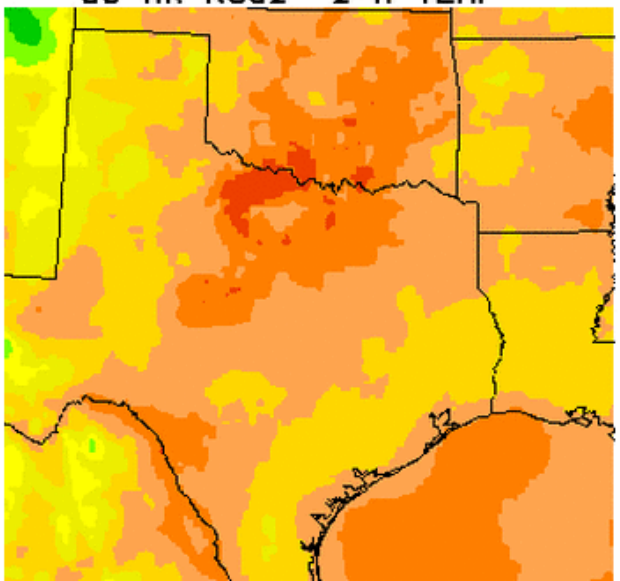
Disclaimer

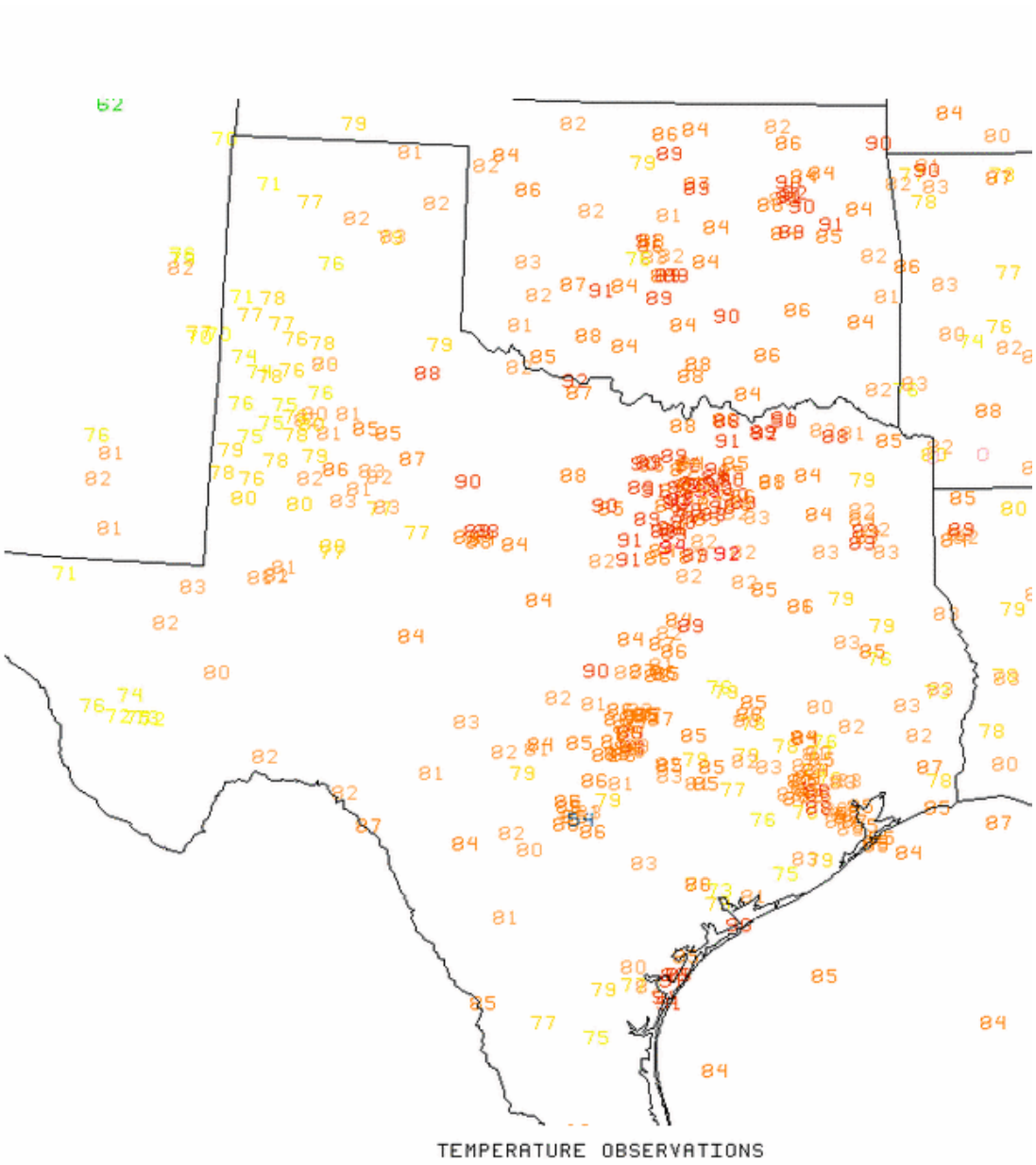
TX 2 m Temperature Analysis



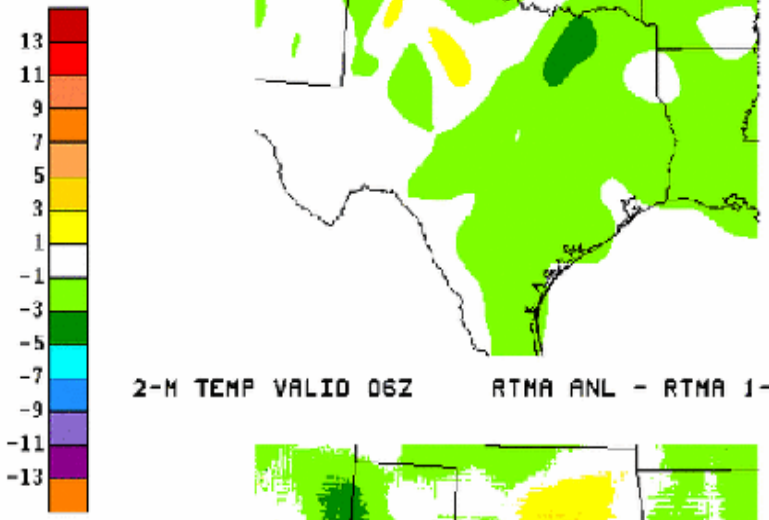
TX 2 m Temperature Analysis



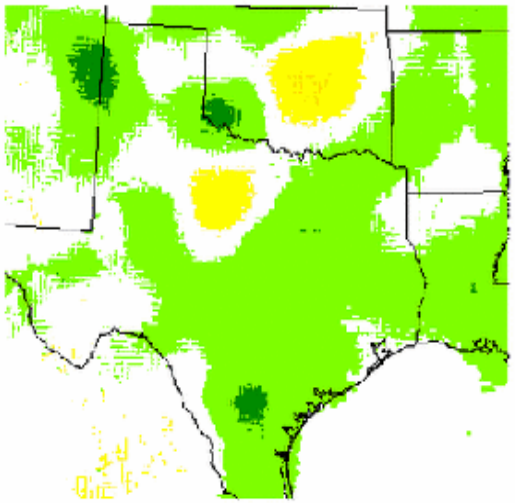




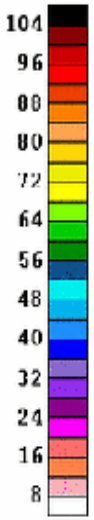
TX 2 m Temperature Increment

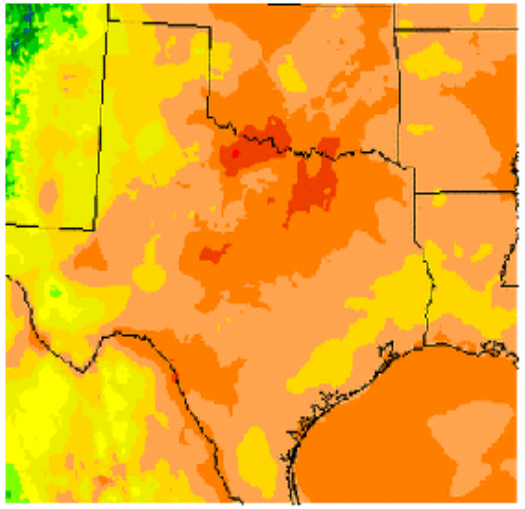


2-M TEMP VALID 06Z RTMA ANL - RTMA 1-HR GUESS

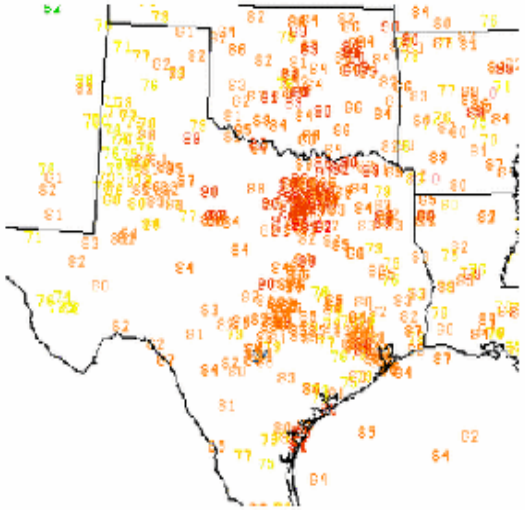


2-M TEMP VALID 06Z RUC ANL - RUC 1-HR GUESS





060809/0600V001 RTMA 1st GUESS 2-M TEMP



060809/0600 OBSERVED TEMPERATURES

RTMA Field Evaluation

- The IFPS Science Steering Team (ISST) has coordinated the distribution of the parallel datasets to the field
  - WR SSD took the lead on providing installation materials
  - WR is retrieving, parsing and distributing the datasets to the other CONUS regions
  - Each region distributes the datasets to the WFOs via LDM
  - Data is displayable in AWIPS/D2D and GFE
- ISST is conducting a field evaluation similar to that of the DGEX implementation
  - Web based response form
  - Evaluation has been focused data quality issues with T, Td, and Wind and will expand to QPE
  - Data delivery has not been a focus to this point

Multiple Stage Evaluation

- Field evaluation is still ongoing
  - Initial stage (April – August)
    - ISST members (2 per region), 4 select sites, and Regions
    - Evaluate overall dataset quality
  - Second stage (August –)
    - Expand the number of field sites
    - Continued quality evaluation
    - Evaluate the delivery and daily usability of the datasets

Initial Evaluation

- Direct feedback to the developers from the ISST, regions and other evaluators has resulted in substantial improvements to the dataset quality
  - Smaller scale quality issues are still being addressed
- Currently, use in operations is limited due to the current delivery schedule
  - Evaluation has been limited to the SOOs

Next Phase

- The complete evaluation of the RTMA goes beyond the quality of the dataset
- Consistent/Reliable delivery of the RTMA to the field is vital to its continued improvement
- Transfer of the RTMA to operational status will greatly increase the daily usage in operations and is the next important step in the RTMA evolution