

**N  
C  
E  
P**

# Implementation of Eta Upgrade Bundle

Geoff DiMego

[geoff.dimego@noaa.gov](mailto:geoff.dimego@noaa.gov)

301-763-8000 ext7221

18 June 2003

**Where the Nation's climate and weather services begin**

# Topics

- Recent changes in Operations for Eta-12
- Changes to be included in the postponed Fall 2002 bundle
- Changes included in Spring 2003 bundle

# Eta-12 Change Package - 27 November 2001

- Resolution increases
  - Horizontal from 22 km to 12 km
  - Vertical from 50 levels to 60 levels
- 3DVAR analysis changes
  - Improved use of radiances - AMSU-B
  - More scalable code
- New gridscale cloud+precip scheme
- Upgrades to precip assimilation scheme
- Maintains product content & timeliness

[ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/cafti12km/v3\\_document.htm](ftp://ftp.ncep.noaa.gov/pub/emc/wd20er/cafti12km/v3_document.htm)

<http://www.emc.ncep.noaa.gov/mmb/mmbpll/eta12tpb/>

# Recent Changes to Eta-12

- December 4, 2001 - A failure due to vertical CFL violation caused us to raise diffusion.
- December 18, 2001 – Crisis: Fix for vertical CFL put in and diffusion returned to normal values.
- February 26, 2002 - Improved treatment of thermal conductivity over snow (patchy & full) in response to cold bias in areas with snow cover.
- May 21, 2002 - Improved treatment of convective cloud & precip in radiation and precip assimilation schemes
- June 19, 2002 – Crisis: Reduced physics time step to mitigate too hot 2 m+skin temperature bias, fixed radiation driver for very thin clouds & fixed land-surface physics to preclude negative soil moisture availability

# Changes Planned for Fall 2002

- Gridscale cloud & precipitation: begin proper cycling of total condensate plus improved microphysics and cloud - radiation interaction;
- 3DVAR analysis: begin direct use of 88D radial velocities and begin use of more overland radiance channels made possible by improved surface emissivity in NESDIS' OPTRANS code;
- **POSTPONED** due to T-254 delays & imminent acceptance testing of new CCS was expected to be completed in early 2003
- Parallel runs available for viewing at

<http://wwwt.emc.ncep.noaa.gov/mmb/mmbpll/etapllsup12.etax/>

# Planned Changes to Eta-12

- Gridscale cloud & precipitation (Ferrier)
  - Begin proper cycling of total condensate (Rogers)
  - Upgrade microphysics and improve cloud - radiation interaction
- 3DVAR analysis (Parrish)
  - Add direct analysis of WSR-88D radial velocity from NWS Multicast
  - Upgrade radiance processing – begin use of NOAA-17
- Precipitation assimilation (Ying Lin)
  - Assimilation of GOES cloud top pressures
  - Assimilate Stage IV instead of Stage II hourly precip
- Extend off-time (06z & 18z) runs to 84 hours
- Increased output in both frequency and content

<http://wwwt.emc.ncep.noaa.gov/mmb/tpb.spring03/tpb.htm>

# Planned Changes to Eta-12 (Ferrier)

- Total condensate fields properly cycled in EDAS – major task whenever the size & content of restart file changes
- Gridscale cloud & precipitation microphysics:
  - Set the lower limit for all forms of condensate to a mixing ratio of  $1.e-12 \text{ kg kg}^{-1}$  throughout the model
  - Tunable parameters based on grid resolution (e.g. threshold relative humidity for onset of condensation, and threshold cloud mixing ratio for autoconversion to rain) are assumed to vary linearly as a function of grid resolution
  - Corrected probabilistic freezing of rain as a function of temperature to remove an underflow error
  - Corrected an error representing the number concentration of nucleated ice crystals between  $-5\text{C}$  and  $-10\text{C}$ .

# Planned Changes to Eta-12 (Ferrier)

- Gridscale cloud & precip interaction with radiation:
  - Convective precip rates properly modified in the precip assimilation
  - Convective cloud fraction (a function of precipitation rate), was increased by 20% to allow an assumed cloud fraction of 10% for shallow, nonprecipitating convective clouds.
  - Grid-scale cloud fraction is now parameterized as a function of RH and the mixing ratio of cloud water and ice (ignoring contribution of rain).
  - Radiative effects of clouds in the lowest 100 mb above the surface and above the tropopause are now included (removed legacy code that set the cloud fractions to zero at these levels, except when low-level clouds were forecast to occur below an inversion). This will have some impact on lowering forecast daytime temperatures when clouds are predicted to occur at lower levels in the absence of stable layers (e.g., frontal systems, orographic clouds, etc.).
  - Cloud fraction calculations were streamlined to allow for the future incorporation of a new radiation package into the model.



# Planned Changes to Eta-12 (Ferrier)

- Gridscale cloud & precip interaction with radiation:
  - Absorption coefficients for convective clouds: now assumed to be 0.16 at temperatures below -10C (assumes ice as the dominant phase as in the grid-scale microphysics), and 0.08 at warmer temperatures (assumes water as the dominant phase).
  - Absorption coefficients for grid-scale clouds: the absorption coefficients for cloud water are  $0.08 * \min(1., Q_w/Q_0)$ , where  $Q_w$  is the cloud water mixing ratio and  $Q_0=0.1\text{g/kg}$  ( $10^{-4}\text{ kg/kg}$ ). The coefficients for ice in the model are equal to  $500.*Q_i$ , where  $Q_i$  is the ice mixing ratio (cloud ice and snow). The derivation of the higher absorption coefficients for ice is based on the optical properties of snow. These changes replace the simple assumption that absorption coefficients vary only as a function of temperature. They were made to decrease the high transmission of solar radiation passing through the clouds (esp. ice clouds), and to reduce high incoming shortwave radiation at the surface during cloudy conditions.

# Sample Total Cloud Cover

## Before Changes

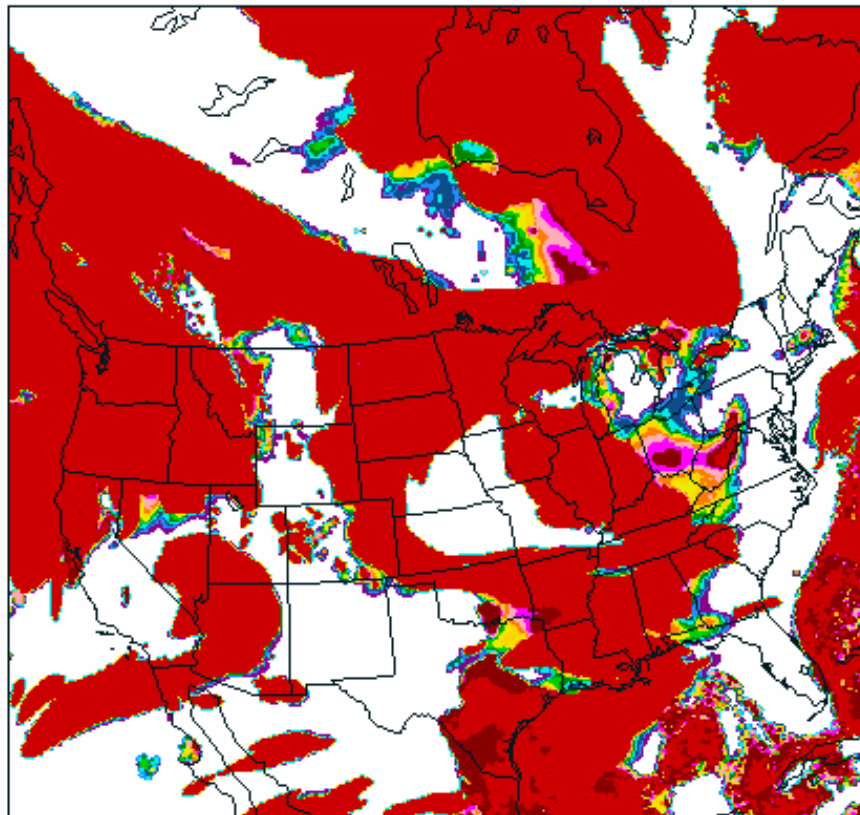
TCLD CVR ATM COLUMN

OPS run

18-H ETA FCST

VALID 06Z 25 JAN 03

12KM/60LYRS



## After 1<sup>st</sup> Changes

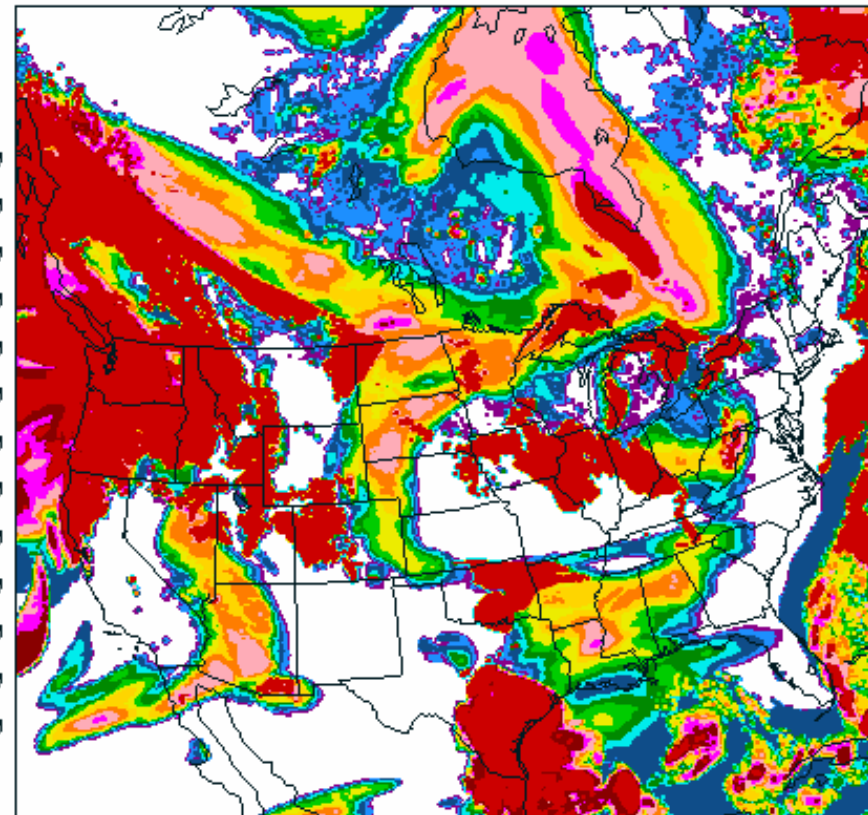
TCLD CVR ATM COLUMN

ETAX run

18-H ETA FCST

VALID 06Z 25 JAN 03

12KM/60LYRS



# Sample Total Cloud Cover

## Before Changes

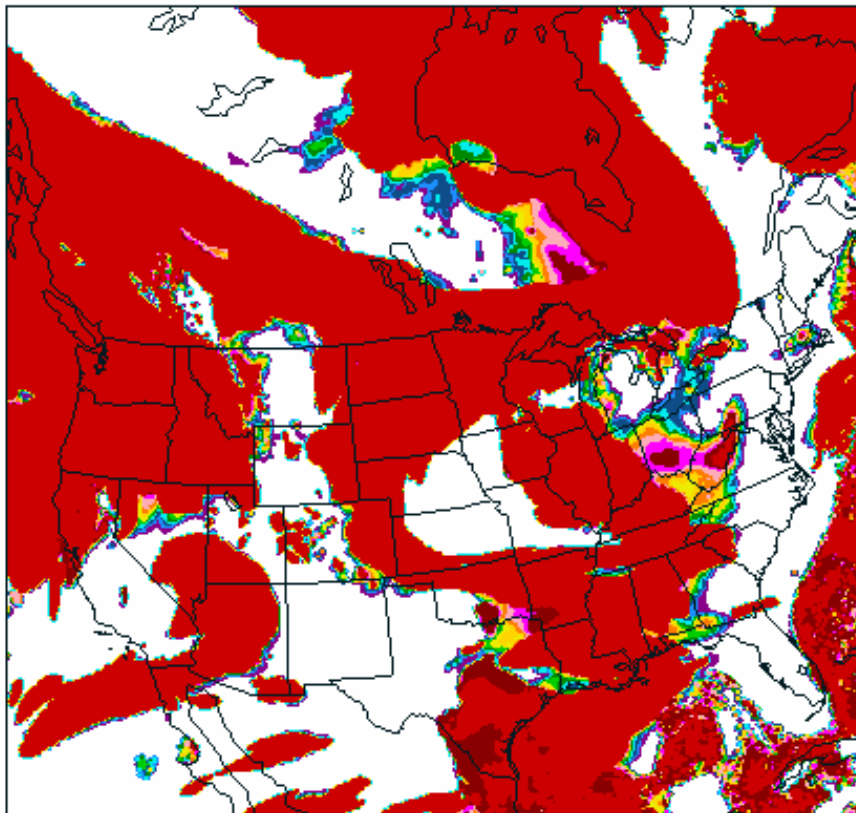
TCLD CVR ATM COLUMN

OPS run

18-H ETA FCST

VALID 06Z 25 JAN 03

12KM/60LYRS



## After 2<sup>nd</sup> Changes

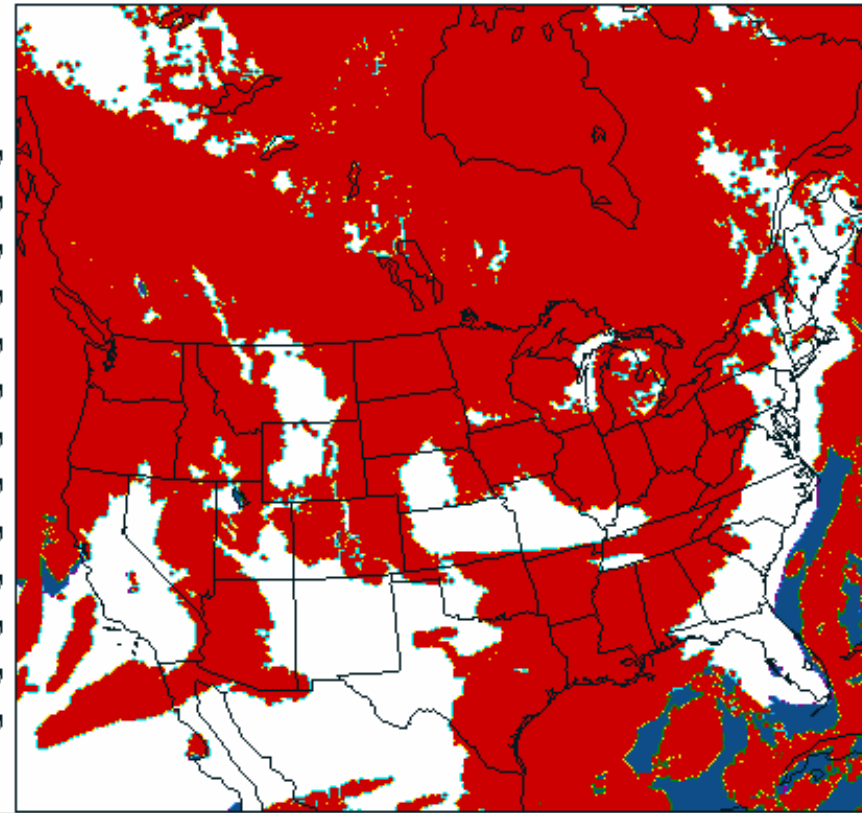
TCLD CVR ATM COLUMN

ETAX8 run

18-H ETA FCST

VALID 06Z 25 JAN 03

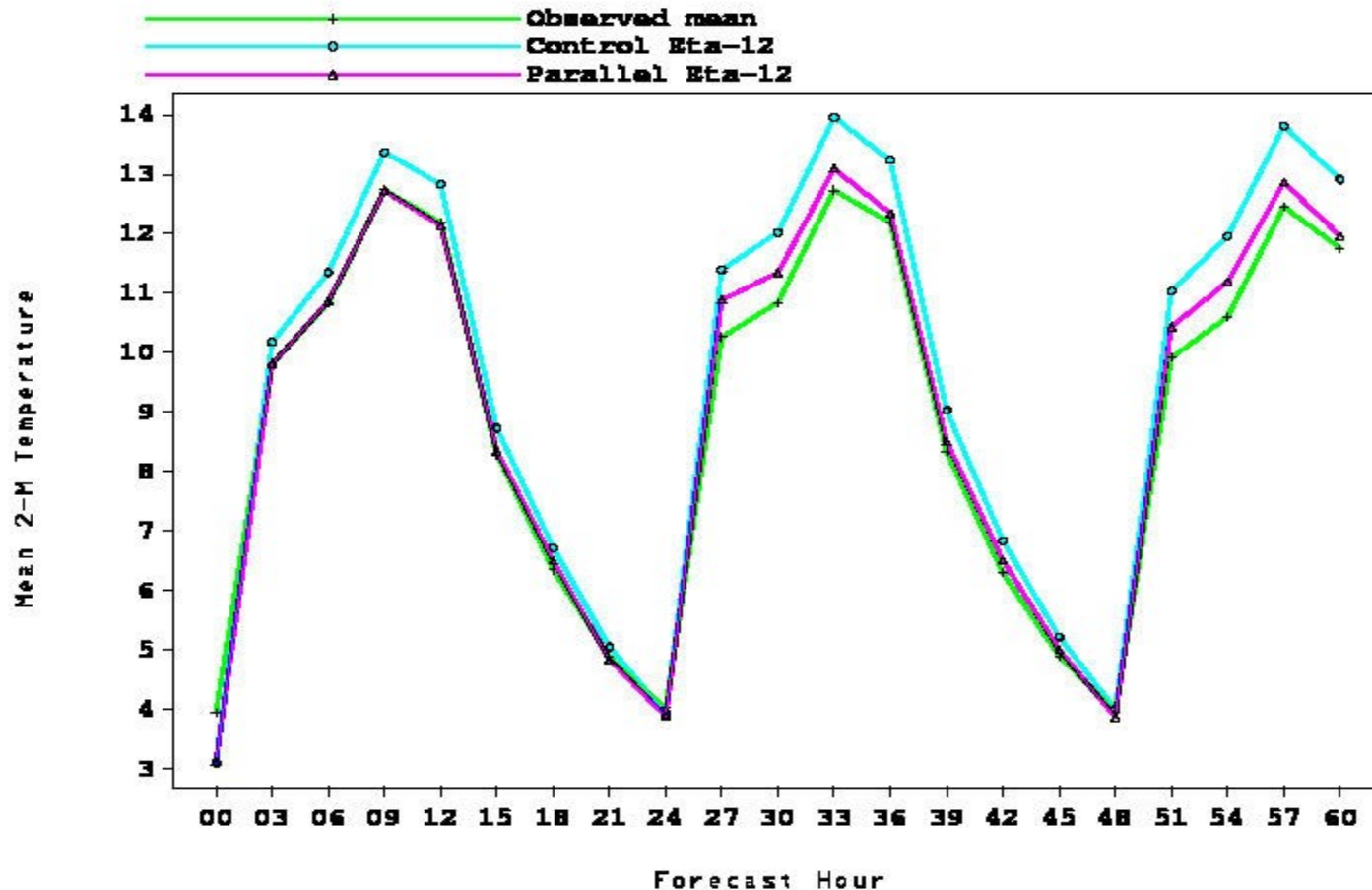
12KM/60LYRS



Better due to reduced longwave cooling

# Surface Temperature Response

Mean 2-M Temp vs. sfc obs (12Z cycle) over the Western US for ctrl Eta-12 and parallel Eta-12 (with mod cld physics, assim of NEXRAD winds and GOES cloud) forecast from 200302201200 to 200305221200



True for East and West for both 00z and 12z runs.

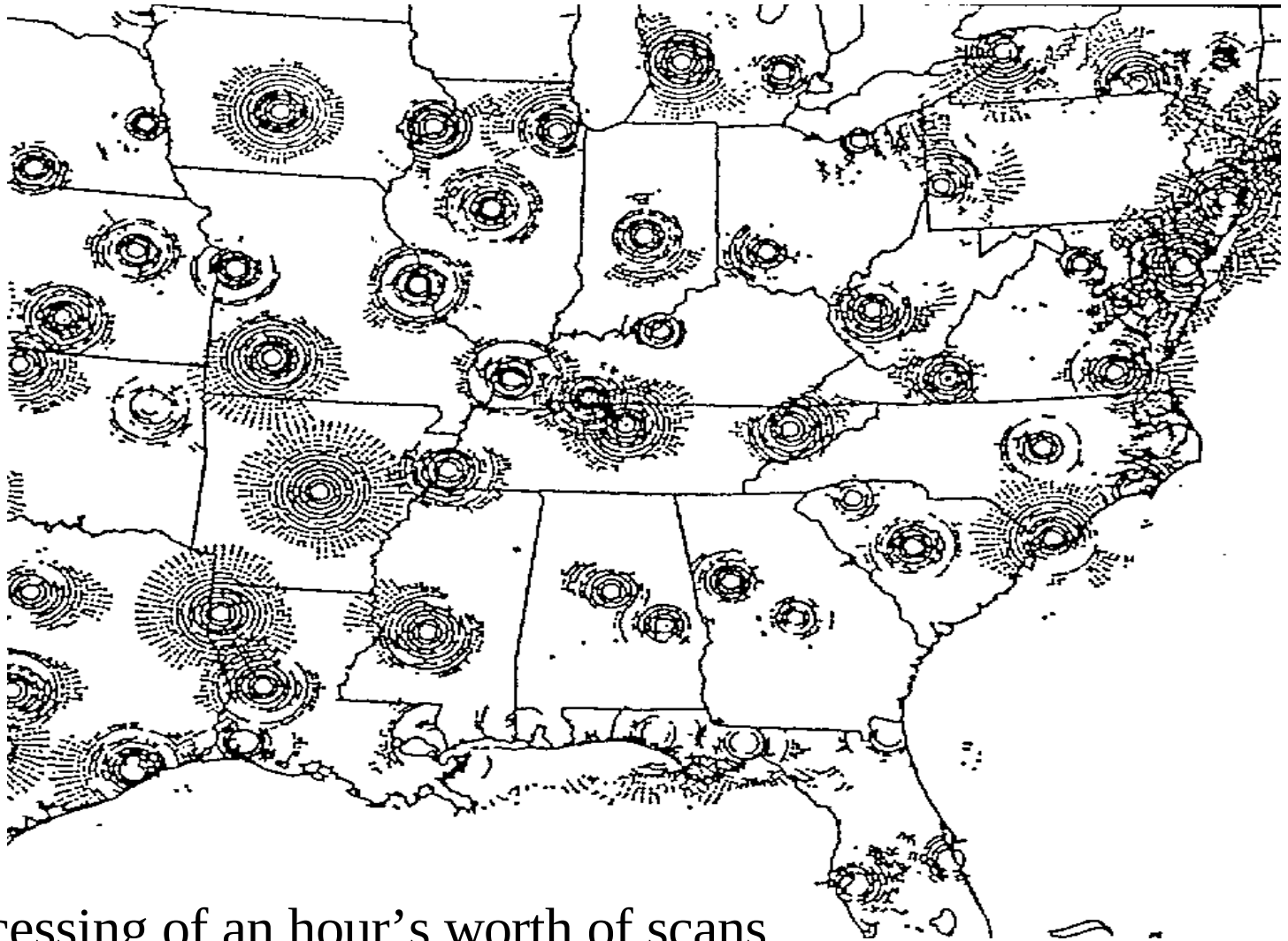
# Planned Changes to Eta-12 (Parrish)

- 3DVAR analysis of 88D radial velocities
  - NWS Multicast of the Level III products gathered from all WSR-88D doppler radar sites
  - Observations from all scans for the lowest 4 radar tilts (0.5, 1.5, 2.5 & 3.5 degrees)
  - Averaged into super-ob's covering 5km (radial) by 6 degree (azimuth) by 1 hour
  - Quality control is linked to decision made on VAD wind profile (Collins QC) which includes, among other things, checks for migrating bird contamination.

# Planned Changes to Eta-12 (Parrish)

- 3DVAR analysis of 88D radial velocities
  - To overcome large uncertainties in 88D data & to allow use of obs out to the radar's maximum range, Dave Parrish has developed a new "minimal information" technique
  - a) estimate range of model levels covered by the radar beam
  - b) obtain maximum and minimum model 'radial velocity' in the range of levels determined above
  - c) radar data are ignored when values lie within the range of model forecast wind values (i.e. no need to correct model)
  - d) non-zero increments are taken ONLY when the observed values are either smaller than the minimum or larger than the maximum model forecast wind
  - e) each non-zero increment is taken at a single location that corresponds to the level of the model forecast minimum or maximum model forecast wind.

# Sample Distribution of Processed 88D Radial Velocity Data



~ 5 km processing of an hour's worth of scans

# Planned Changes to Eta-12 (Parrish)

- 3DVAR analysis of satellite radiances
  - Update radiance processing to reflect GFS changes:
    - a) use of more overland radiance channels made possible by improved surface emissivity in NESDIS' OPTRANS code
    - b) more sophisticated quality control of microwave channel data, which allows more useable data over land and water
    - c) inclusion of NOAA-16 infrared channels (currently turned off in Eta)
    - d) ingest for polar-orbiting satellite data was switched from IEEE format to BUFR format allowing use of radiances from NOAA-17 which are available only in BUFR.
  - Dropped explicit thinning of satellite radiances in Eta 3DVAR (not done in GFS)



# Planned Changes to Eta-12 (Parrish)

- 3DVAR analysis of satellite radiances
  - Added new “quality control” procedure
    - to examine channel weighting function to sense how high in the atmosphere the influence function extends for each channel
    - if the influence function extends too far beyond the model top, then that channel's data are not used - this is especially important for the Eta Model whose model top 37 mb is much lower than GFS 0.2 mb
  - With addition of NOAA17 and no thinning, the data counts increased 20 times going from ~50000 per 3 hr cycle before the change to ~1000000 per 3 hr cycle after the change.
  - This added substantial processing to the analysis, but since the radiance processing part of the 3DVAR code is highly scalable, the run time was kept in the required window by applying additional processors to the job.
  - These changes were run in parallel for 3 weeks during the transition of the 12 km EtaX parallel run to the new CCS. The addition of all the new radiance data had a very small positive impact in upper-air fits to data of the 3 hr guess with no negative changes.

# Planned Changes to Eta-12 (Ying Lin)

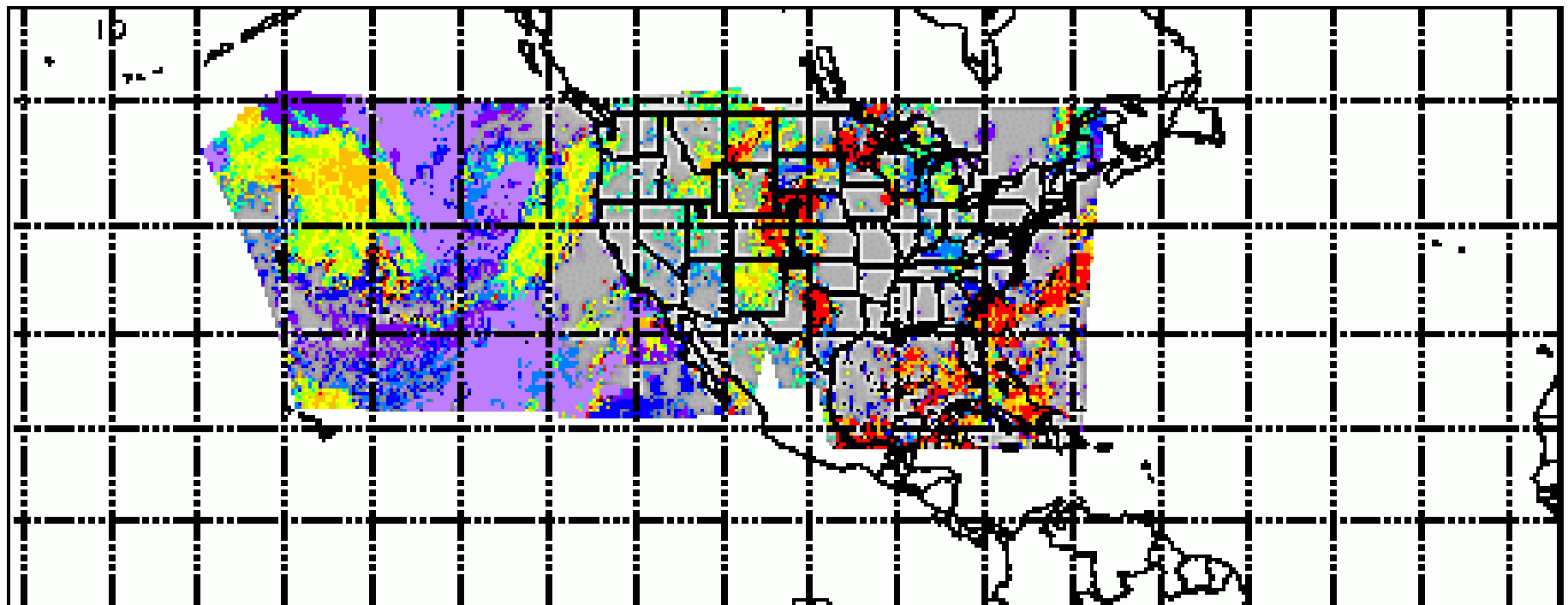
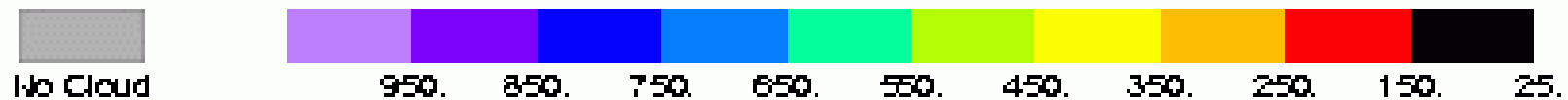
- Precipitation assimilation upgrades
  - **Assimilation of GOES Cloud Top Pressure into the Eta model**
    - Hourly SFOV (~10 km) GOES-10 and GOES-12 cloud top pressures are used to adjust cloud and moisture fields during the 12-hour data assimilation (EDAS) period, in tandem with the hourly precipitation assimilation.
    - Above the observed cloud top, model cloud water is zeroed out and moisture is brought to no more than saturation.
    - At the model level closest to the observed cloud top, the model air is moistened slightly (if it is below saturation).

# Planned Changes to Eta-12 (Ying Lin)

- Precipitation assimilation upgrades
  - **Assimilate Stage IV precipitation analysis instead of Stage II**
    - Stage IV analysis merges the regional multi-sensor precipitation analyses produced by the twelve River Forecast Centers (RFC) within CONUS.
    - Stage IV benefits from some manual quality control performed at the RFCs, and is generally considered to be of higher quality than the Stage II.
    - Stage IV product is, however, not as timely as the Stage II (produced at approximately 40 minutes after the top of the hour). Stage IV timeliness depends on the transmission of the regional analyses, which is generally delayed several hours.
    - The latest available Stage IV analyses often have only partial coverage since analyses from RFCs arrive at different times of the day.
    - Data gaps are filled in with available Stage II data. If there is no Stage IV data available at all for that hour, then Stage II alone is used. If both analyses are not available, which often occurs during the last hour of the operational EDAS, then no precipitation data is assimilated.
    - Stage II data alone is used in the NWRFC domain (using the RFC domain mask), because their Stage IV analyses often contain spurious precipitation "bulls eyes" and appear to be less reliable than the Stage II analyses.

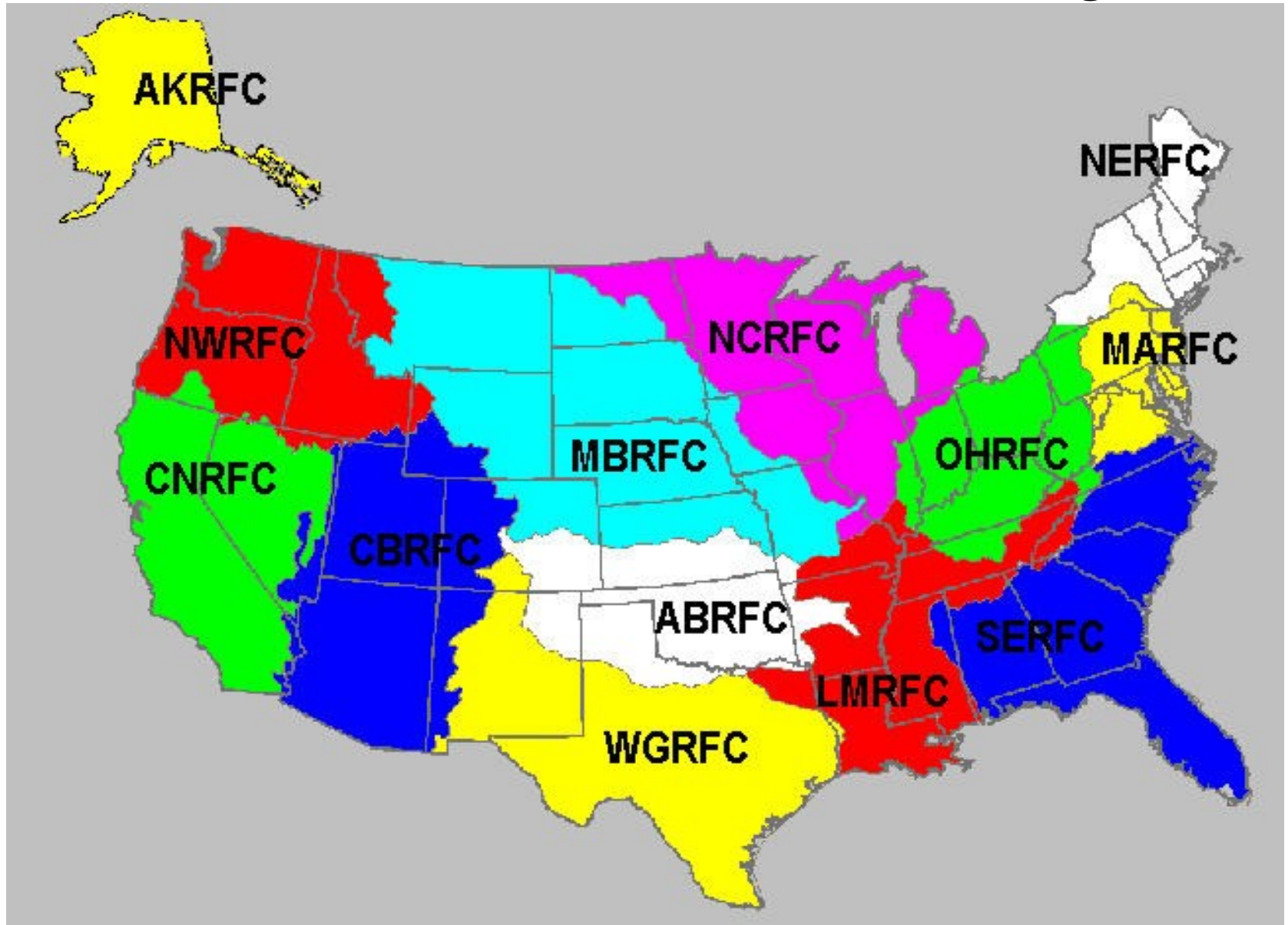
# Sample Cloud Top Pressure Field

Cloud Top Data (mb) from GOES-8, 10  
During 20020706 11:46Z - 20020706 12:24Z



# NWS RFC's

All but AKRFC & NWRFC are used in Stage IV



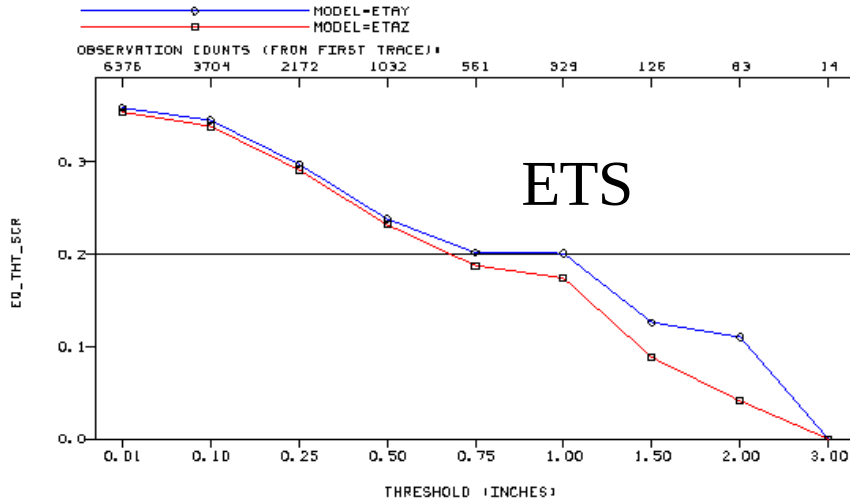
# Impact of Use of Cloud-Top on 24 hr QPF Scores

24 hour forecasts

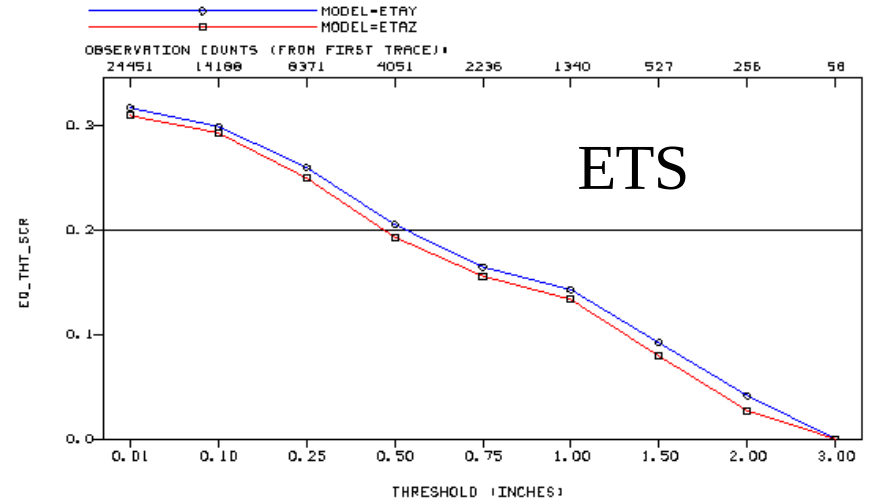
Blue: cloud top assim; Red: Control

24+36+48+60 hour forecasts

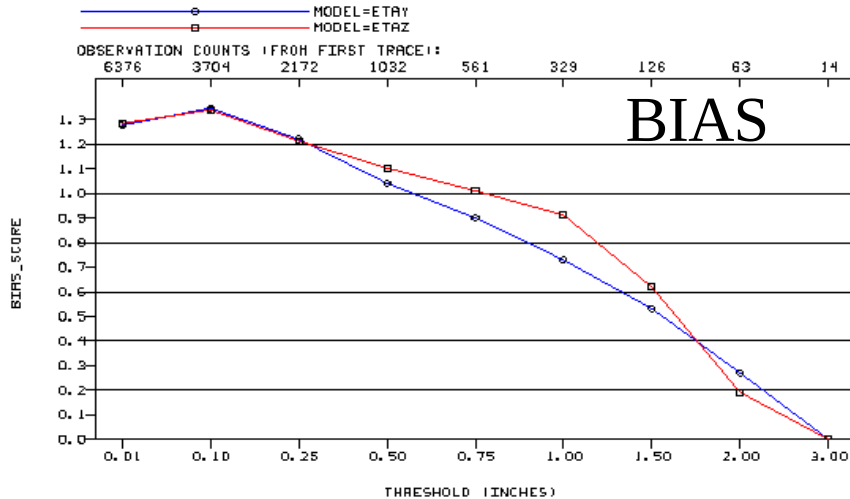
STAT=FHO PARAM=APCP/24 FHOUR=24 V\_ANL=MB\_PCP V\_RGN=6211/RFC LEVEL=SFC  
VYMDH=200206260000-200207102300



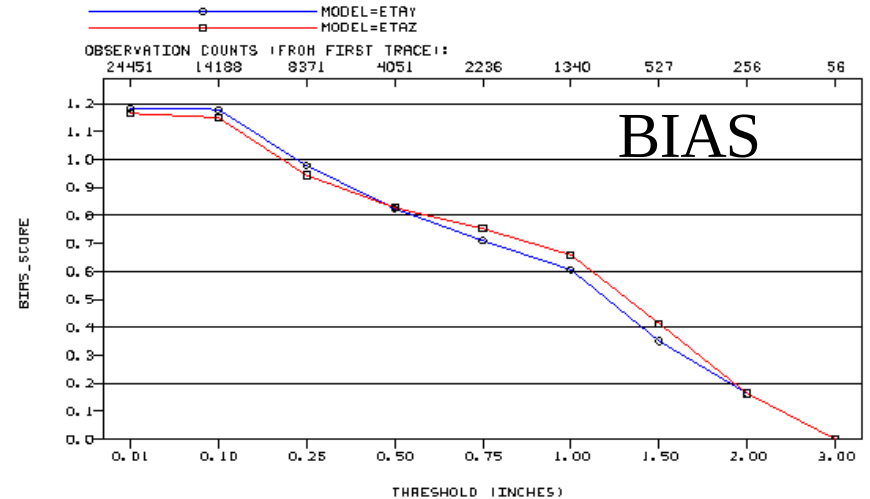
STAT=FHO PARAM=APCP/24 FHOUR=24+36+48+60 V\_ANL=MB\_PCP V\_RGN=6211/RFC  
LEVEL=SFC VYMDH=200206260000-200207112300



STAT=FHO PARAM=APCP/24 FHOUR=24 V\_ANL=MB\_PCP V\_RGN=6211/RFC LEVEL=SFC  
VYMDH=200206260000-200207102300



STAT=FHO PARAM=APCP/24 FHOUR=24+36+48+60 V\_ANL=MB\_PCP V\_RGN=6211/RFC  
LEVEL=SFC VYMDH=200206260000-200207112300



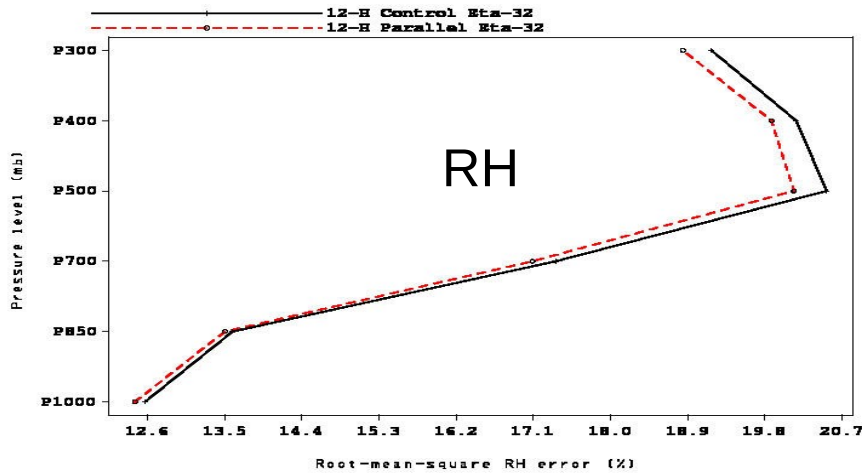
# 12 Hour Upper-air Verification: RH, T, Z & Wind

At longer-ranges, impact is smaller but still positive

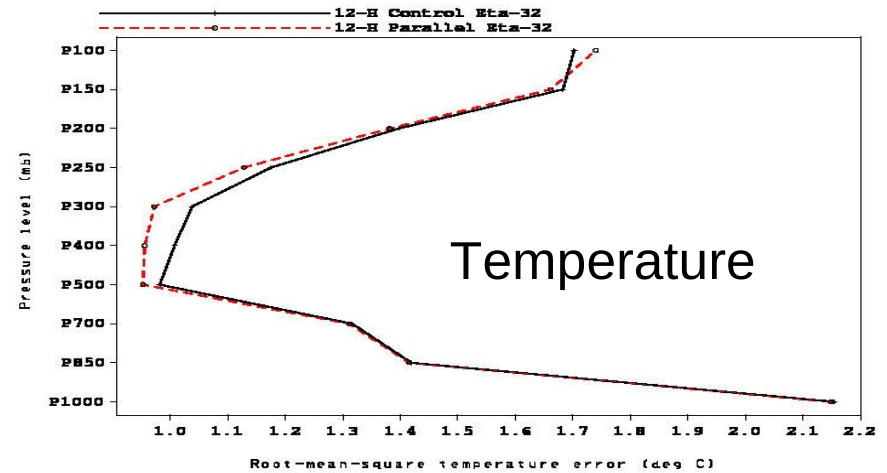
32km parallel. 25 Jun – 9 Jul 2002

Red: cloud top assim: Black: Control

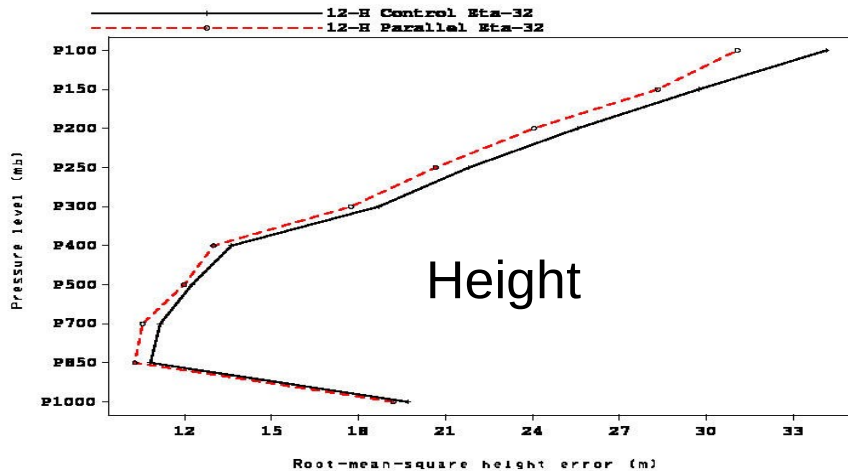
RMS relative humidity error vs. raobs over the CONUS for ctrl Eta-32 (solid) and parallel Eta-32 (with assimilation of GOES cloud top data) 12-h forecasts from 200206261200 to 200207111200



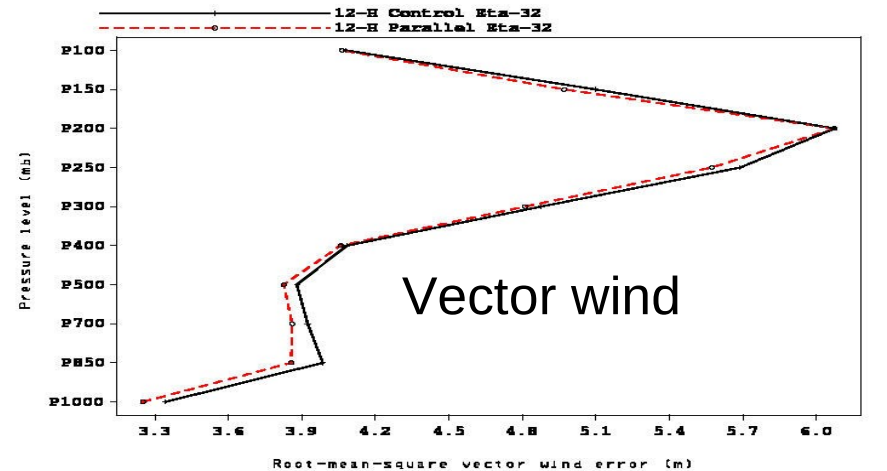
RMS temperature error vs. raobs over the CONUS for control Eta-32 (solid) and parallel Eta-32 (with assimilation of GOES cloud top data) 12-h forecast from 200206261200 to 200207111200



32 (with assimilation of GOES cloud top data) 12-h forecast from 200206261200 to 200207111200



parallel Eta-32 (with assimilation of GOES cloud top data) 12-h forecast from 200206261200 to 200207111200



# Planned Changes to Eta-12

- Response to annual EMC Production Suite Review requests from both NWS Regions and the NCEP Service Centers
  - Extend off-time (06z & 18z) runs
    - Make identical to on-time (00z & 12z) runs
    - Base run extended from 48 hours to 60 hours
    - Add extension to 84 hours
  - Extend output
    - Add cloud & hydrometeor fields made possible by Ferrier
    - Add hourly output requested by service centers
    - Add hourly fields required by Air Quality Forecast
    - Add output fields required by Land-Surface (Mitchell)



# Hourly Output to 36 hours

- 32-km Lambert conformal grid over the Northern Hemisphere (AWIPS grid #221).
- 40-km Lambert conformal grid over the CONUS (AWIPS grid #212).
- 90-km polar-stereographic grid over the Northern Hemisphere (AWIPS grid #104).
- 11.25-km polar-stereographic grid over Alaska (AWIPS grid #242).
- 12-km Lambert conformal grid over the CONUS (AWIPS grid #218).
- 1/8-degree resolution in latitude and longitude over the CONUS for the land surface products (the so-called NLDAS grid for Mitchell)

# Land-Surface Fields Added to Eta Post

<u>Parameter Name</u>	<u>GRIB No.</u>	<u>GRIB Table(s)</u>
Snow depth	066	130 (or 2)
Maximum snow albedo	159	130
Liquid volumetric soil moisture 160	130	
Snow-free albedo	170	130
Number soil layers in root zone	171	130
Canopy conductance	181	130
Minimal stomatal resistance	203	130
Wilting point (volumetric soil moisture)	219	130
Planetary boundary layer height	221	130 (or 2)
Surface slope type	222	130
Soil type	224	130
Vegetation type	225	130 (or 2)
Transpiration stress-onset (vol. soil mst.)	230	130 (or 2)
Direct evaporation cease (vol. soil moist)	231	130
Snow cover	238	130 (or 2)
Soil porosity (vol. soil moisture)	240	130
Solar parameter in canopy conductance	246	130
Temperature parameter in canopy cond.	247	130
Humidity parameter in canopy cond.	248	130
Soil moisture parameter in canopy cond.	249	130

# Air Quality Fields Required from the Eta Post

- Hourly fields on CMAQ sigma levels to 48 hours

- 3-D pressure
- 3-D temperature
- 3-D specific humidity
- 3-D u-component wind
- 3-D v-component wind
- 3-D geopotential
- 3-D vertical velocity
- 3-D TKE
- 3-D cloud water mixing ratio
- 3-D cloud ice mixing ratio
- 3-D total cloud cover
- 3-D total condensate

- Hourly fields to 48 hours

- terrain height
- 2-m temperature
- 10-m u-component wind
- 10-m v-component wind
- accumulated convective precip
- upward shortwave radiation flux
- upward longwave radiation flux
- accumulated non-convective precip
- Blackadar mixing length
- soil temperature (all four layers)
- vegetation
- land cover
- ice cover
- net latent heat flux
- net sensible heat flux
- surface roughness
- friction velocity
- drag coefficient
- surface pressure
- soil moisture (all four layers)
- latitude
- longitude
- albedo

# Air Quality Fields Required to be ADDED to the Eta Post

- canopy conductance
- evapotranspiration
- PBL height
- land-use type
- soil type
- canopy water

# Table 2&3 Fields Added to the Eta Post by Ferrier

## Table 2

- **3D rain mixing ratio on pressure (p) & eta levels**
- **3D snow mixing ratio on p and eta levels**

## Table 3

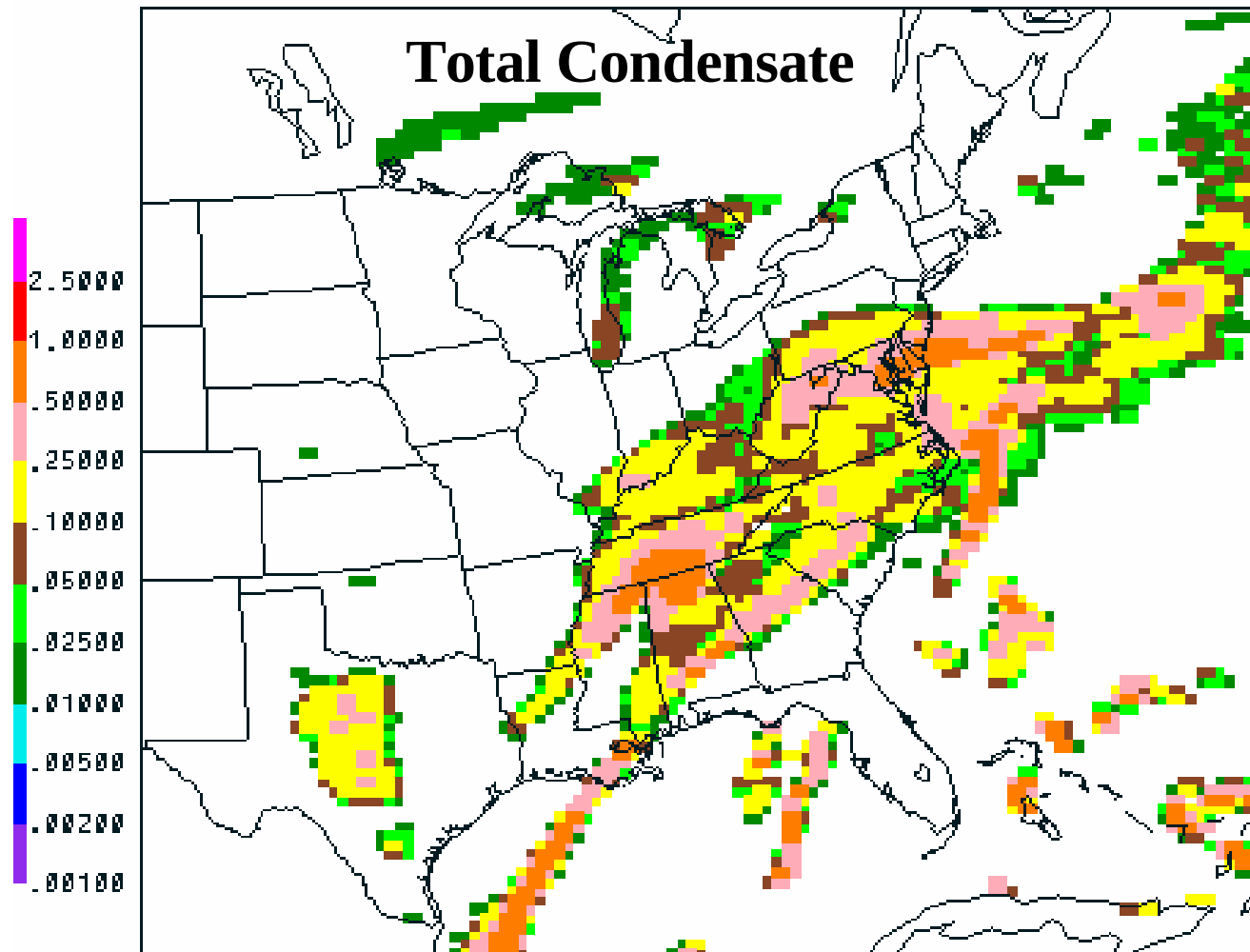
- Cloud-base pressure for (each are separate fields):
  - (1) gridscale clouds,
  - (2) convective clouds,
  - (3) deep convection, and
  - (4) shallow convection
- Cloud-top pressure for (each are separate fields):
  - (1) gridscale clouds,
  - (2) convective clouds,
  - (3) deep convection, and
  - (4) shallow convection

# Table 129 Fields Added to the Eta Post by Ferrier

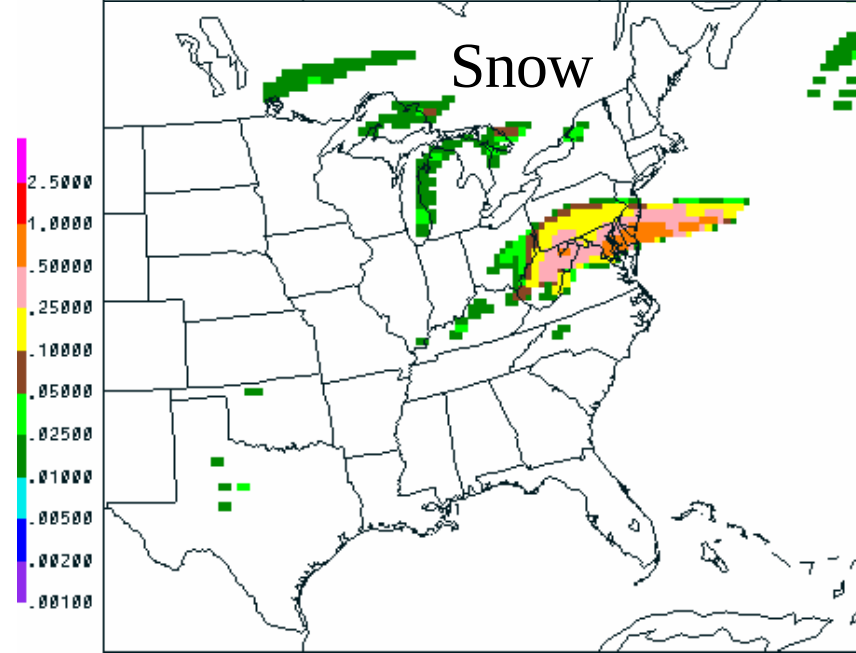
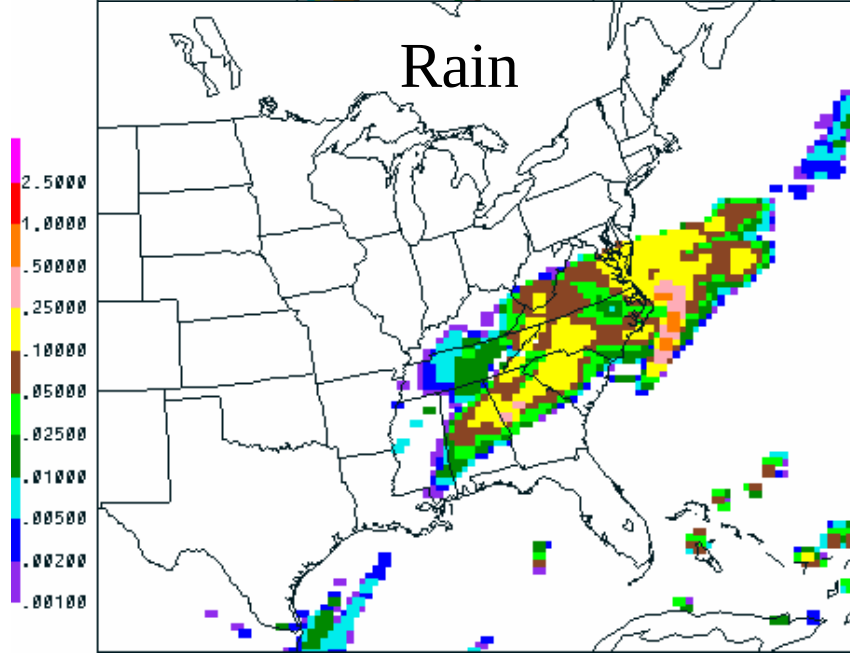
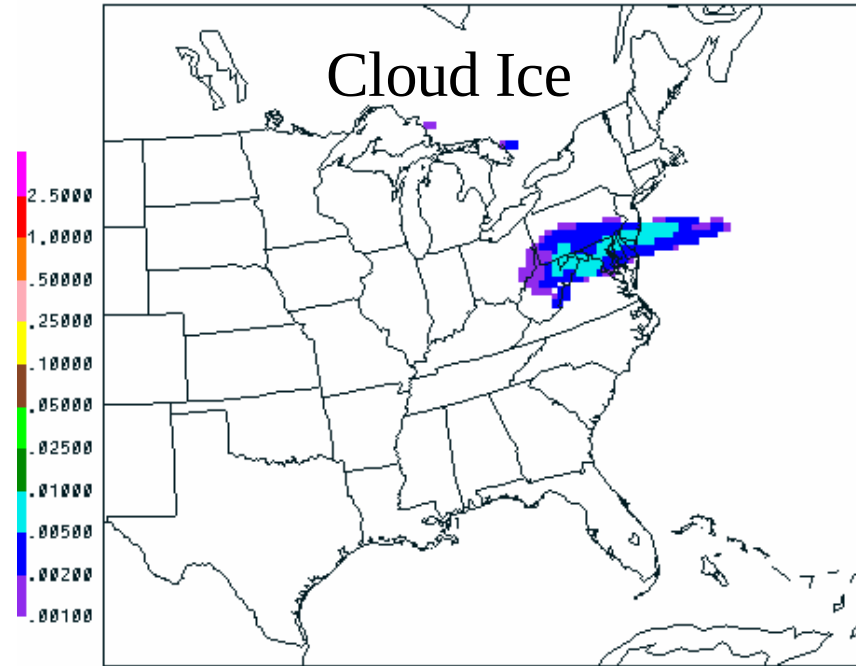
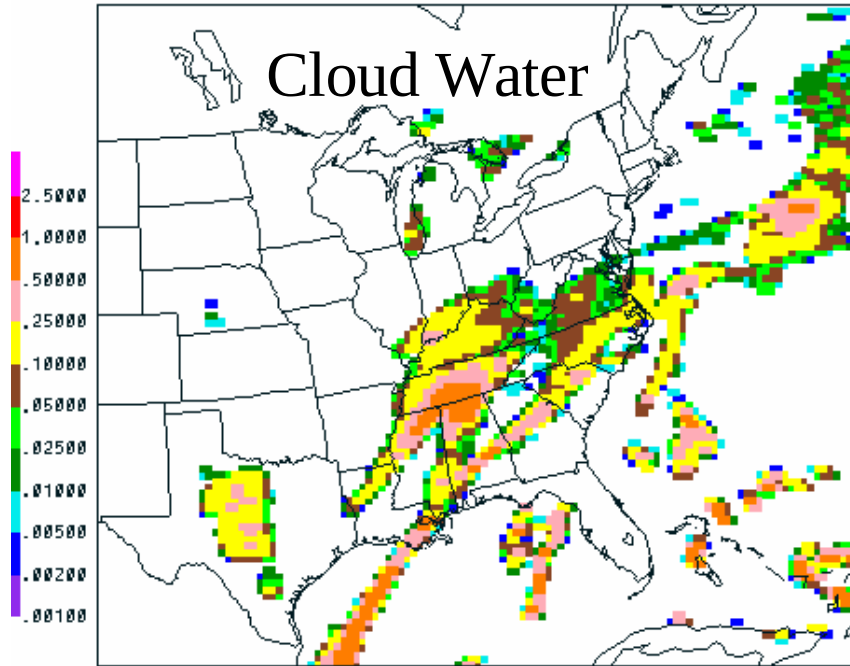
<u>Table 129</u>	<u>Parameter Name</u>
• 128	Probability anomaly of temperature
• 129	Probability anomaly of precipitation
• 131	Rain fraction of total liquid water
• 132	Ice fraction of total condensate
• 133	Rime Factor
• 134	Convective cloud efficiency
• 135	Total condensate
• 136	Total column-integrated cloud water
• 137	Total column-integrated cloud ice
• 138	Total column-integrated rain
• 139	Total column-integrated snow
• 140	Total column-integrated condensate
• 170	Ellrod Index

# Examples of the various hydrometeor fields now postable from the Eta

VALID 12Z 05 DEC 02      24-H      FCST  
32.5 KM LMB CON GRD



# More examples of fields poststable from Eta

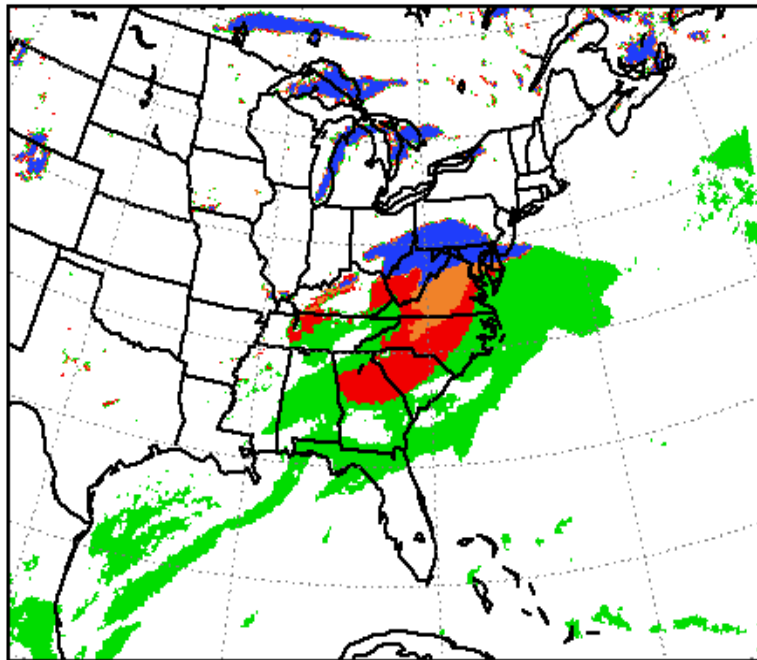




# Baldwin Type versus Precip Type Direct from Model

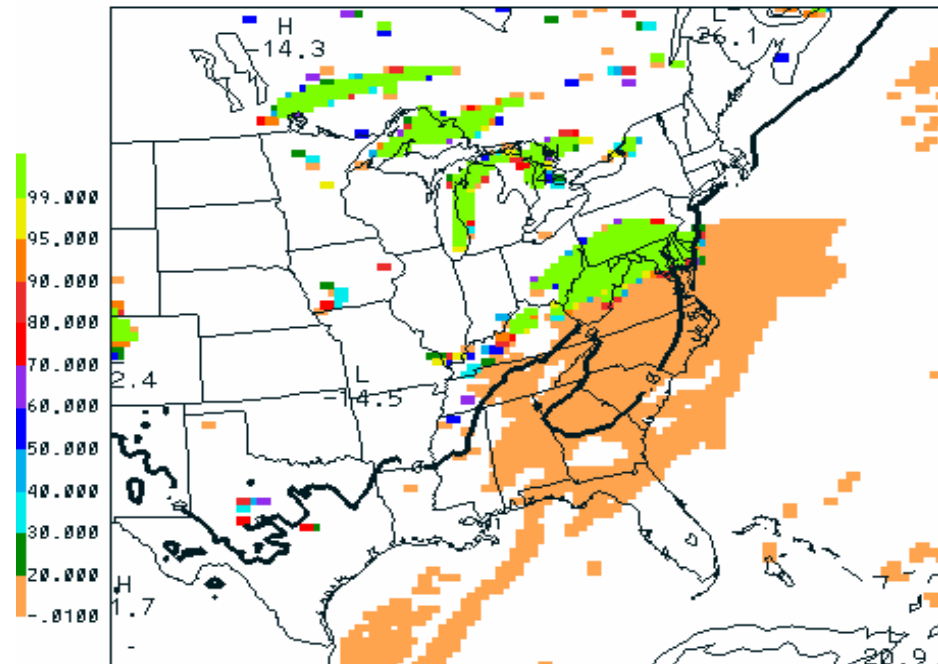
PRECIP TYPE ETAX 24H FCST VALID 12Z 05 DEC 2002

LEGEND  
 RAIN  
 ZR  
 IP  
 SNOW



Percent Froz Prep (%)

ETAX run  
 24-H FCST  
 VALID 12Z 05 DEC 02  
 32.5 KM LMB CON GRD



Baldwin Diagnosed Precip Type

Percent Frozen Direct from Model's

# Cloud Base Pressure Total

# Cloud Top Pressure Total

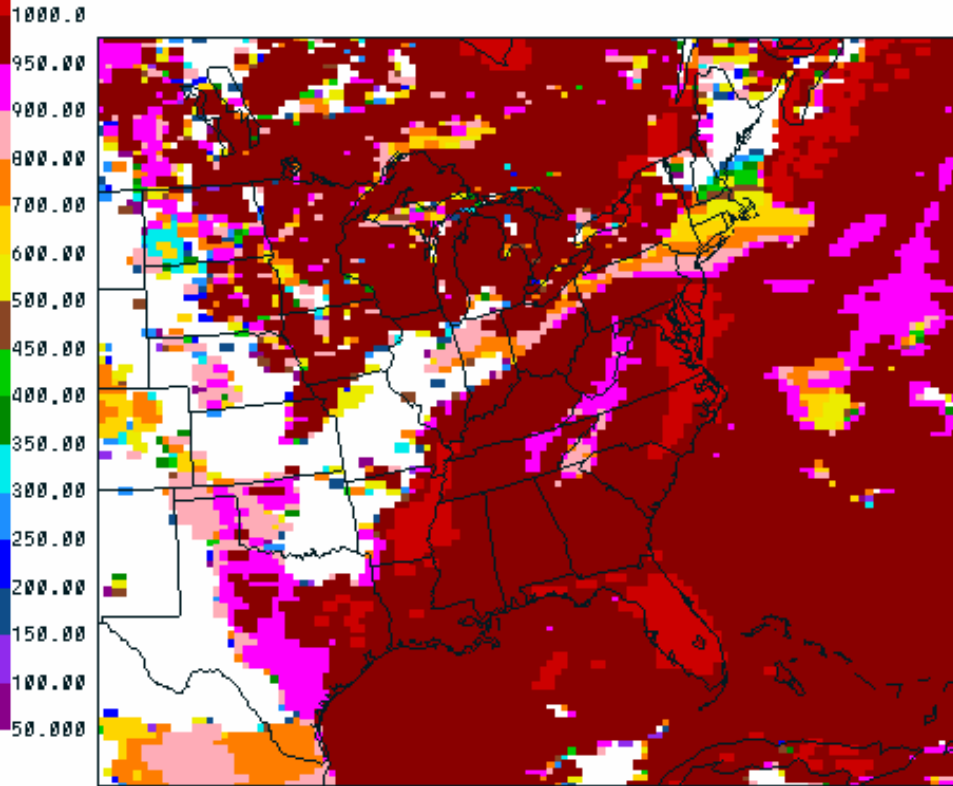
Cld base pres (mb)

ETAX run

24-H FCST

VALID 12Z 05 DEC 02

32.5 KM LMB CON GRD



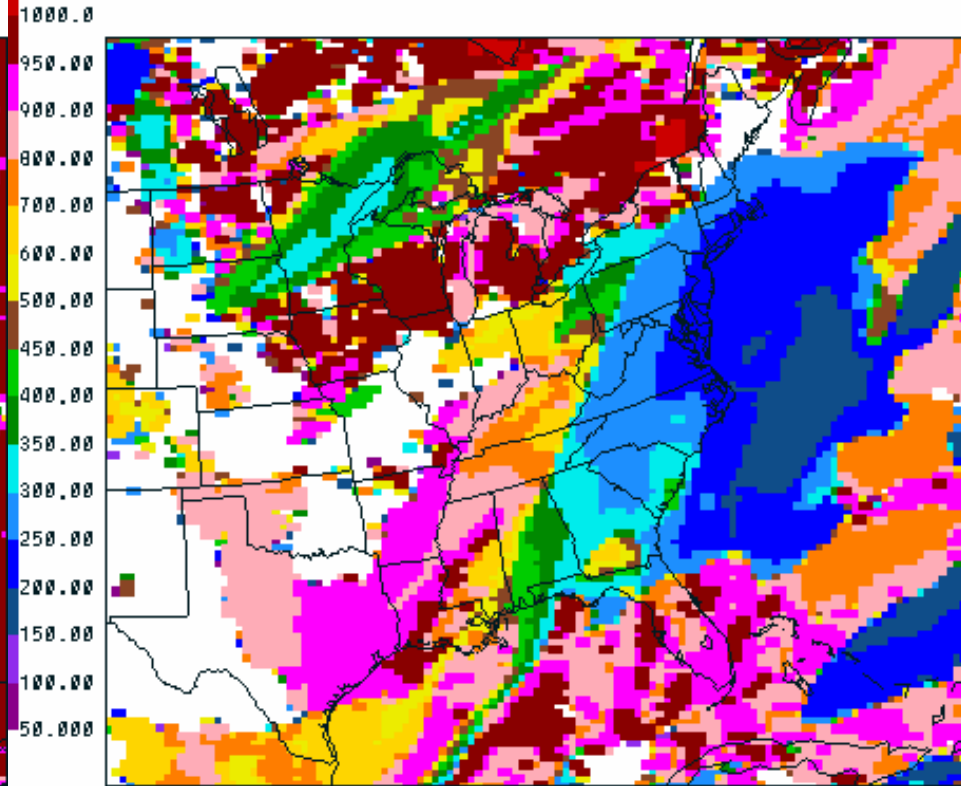
Cld top pres (mb)

ETAX run

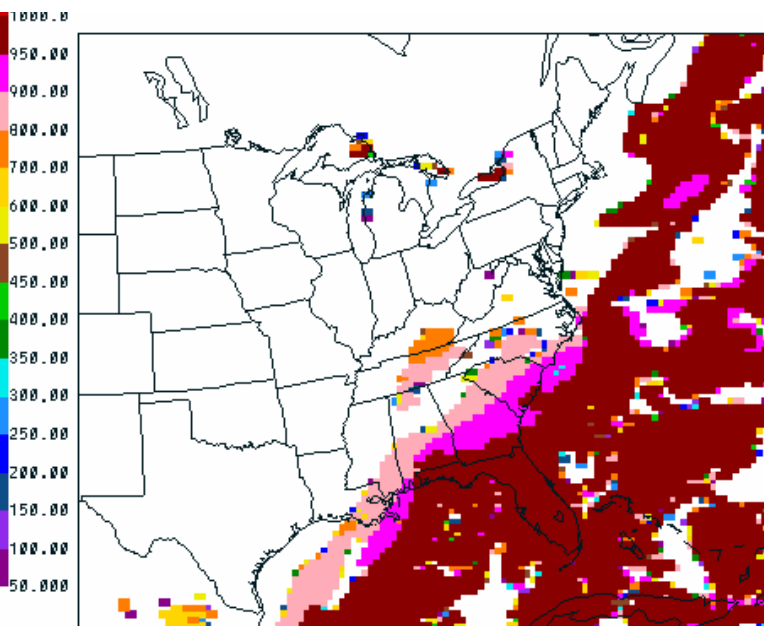
24-H FCST

VALID 12Z 05 DEC 02

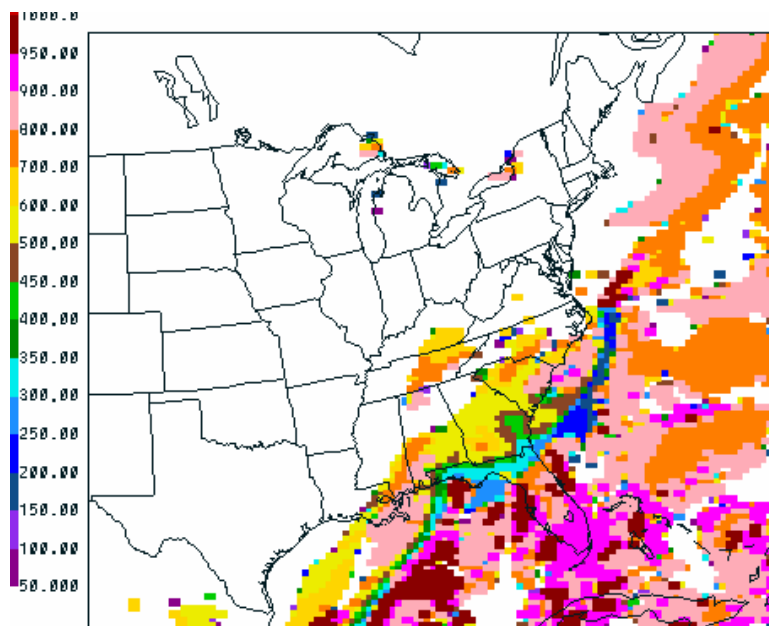
32.5 KM LMB CON GRD



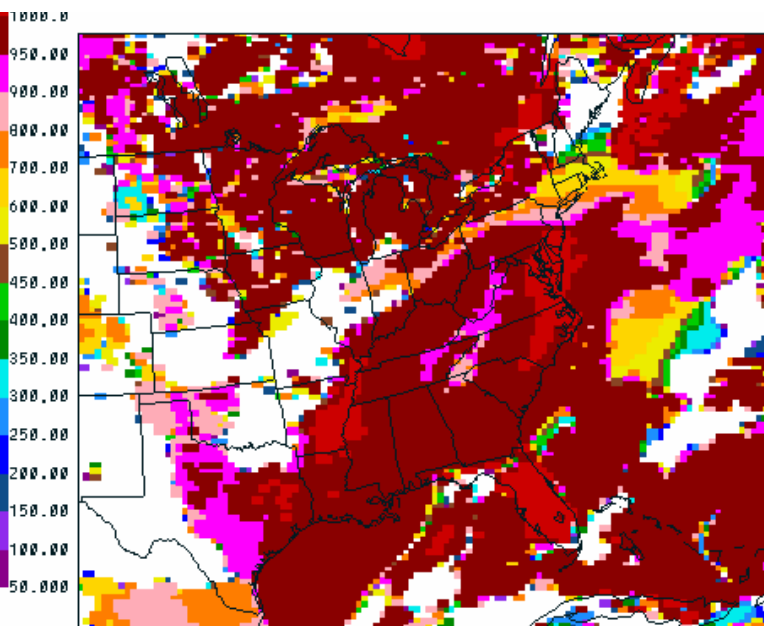
Cloud Base Pressure All Convective



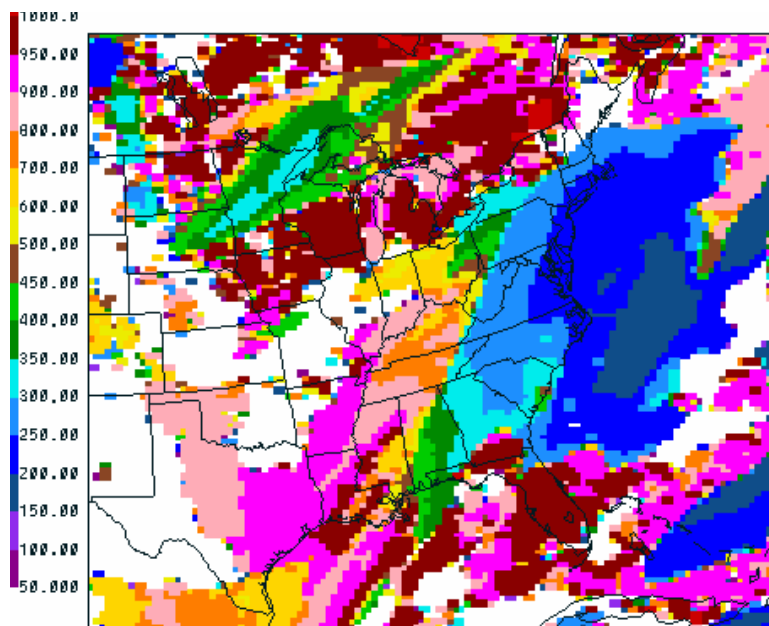
Cloud Top Pressure All Convective



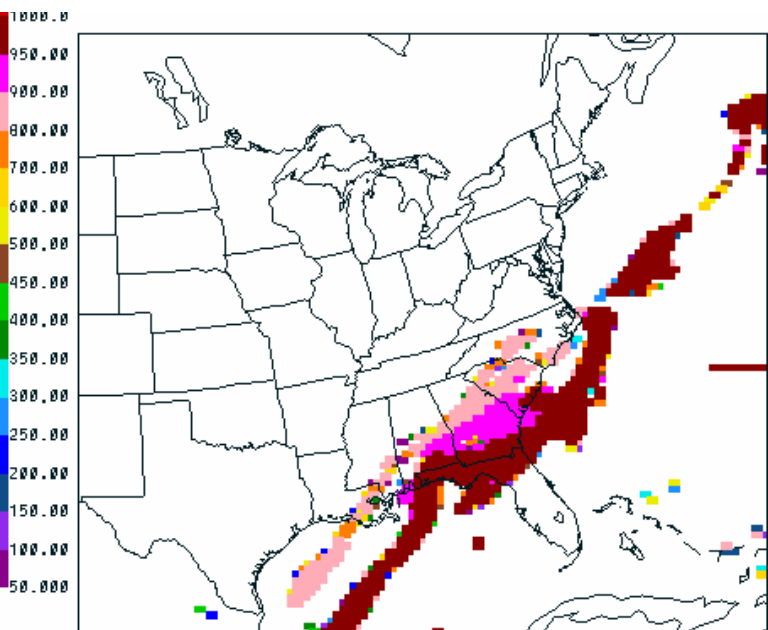
Cloud Base Pressure Gridscale



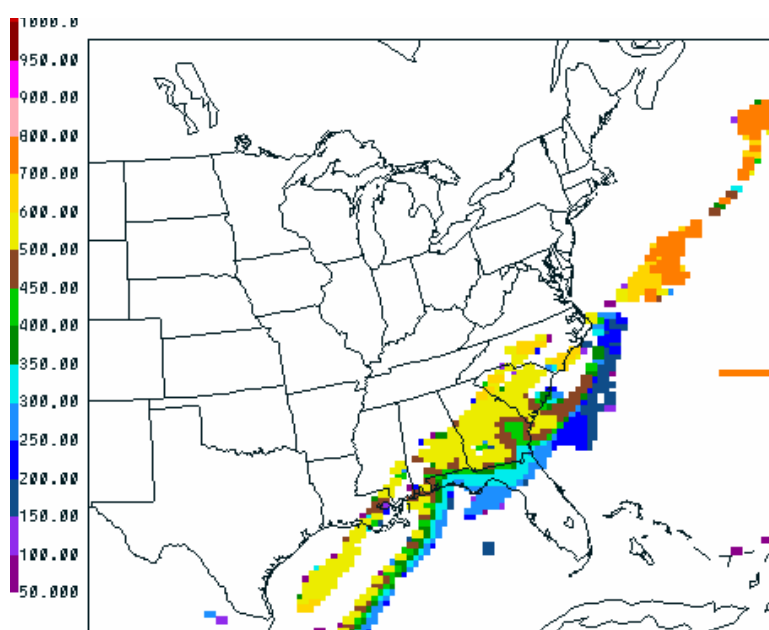
Cloud Top Pressure Gridscale



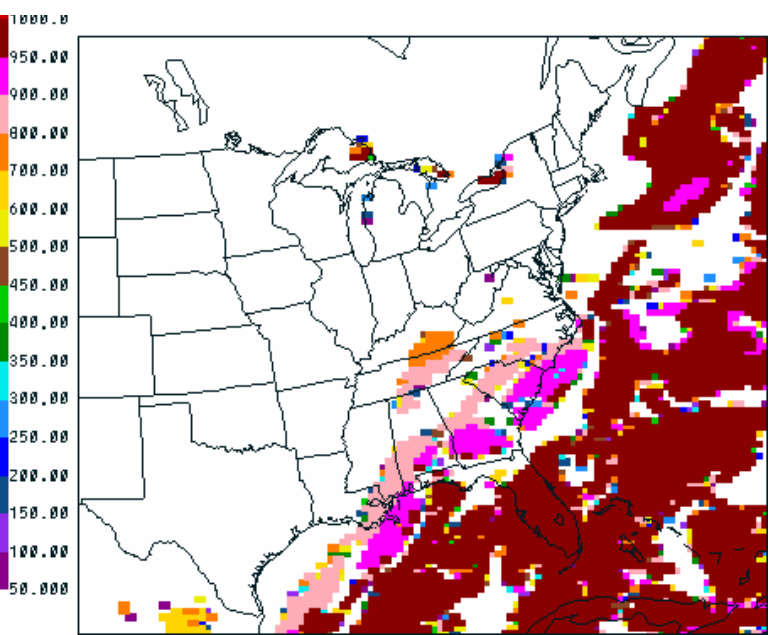
Cloud Base Pressure Deep Convective



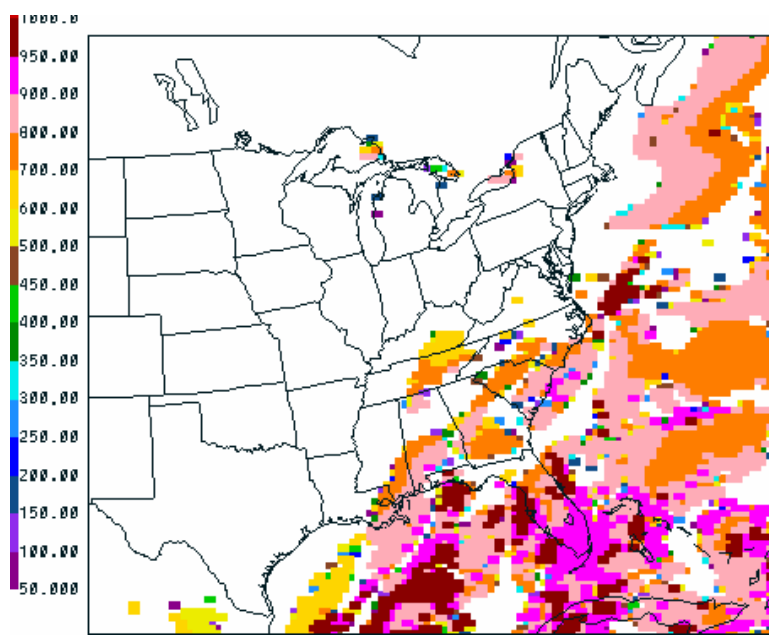
Cloud Top Pressure Deep Convective



Cloud Base Pressure Shallow



Cloud Top Pressure Shallow



# Additional Changes to the Eta Post

- Fixed computation of precipitable water to include only the water vapor
- Extended freezing level computation below model terrain height - requested by HPC
- Unified vapor pressure computation
- Eliminated super-saturation (sounding post)
- Updated visibility field to be consistent with hydrometeors coming out of new Ferrier gridscale scheme
- Updated cloud fraction fields to be consistent with radiation interactions in new Ferrier gridscale scheme
- Corrected the computation of the storm-motion vectors using layer-averaged winds instead of the mass-weighted average of wind - which is consistent with tests by the developers of the dynamic method for calculating storm-motion vectors, is expected to result in only very slight differences in the storm motion vectors and storm-relative helicity values.

# Super-Saturation Removed

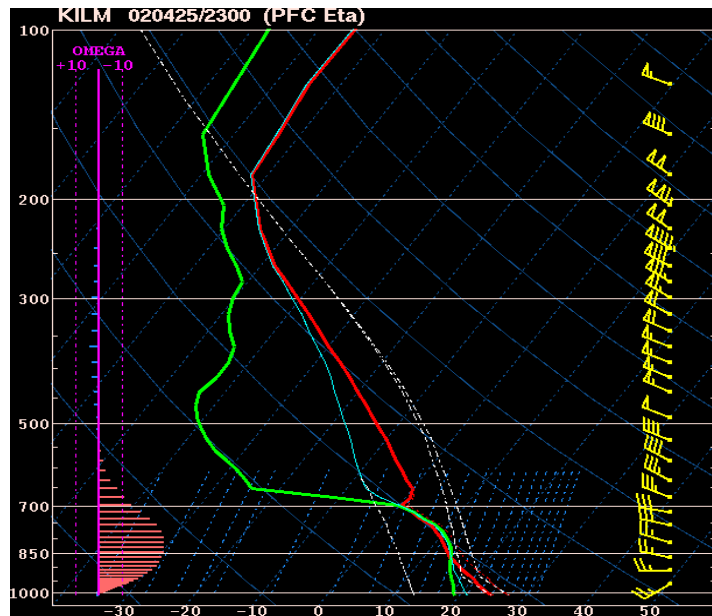
CLD WTR + T 800 MB

OPS run

24-H ETA FCST

VALID 00Z 26 APR 02

12KM/60LYRS



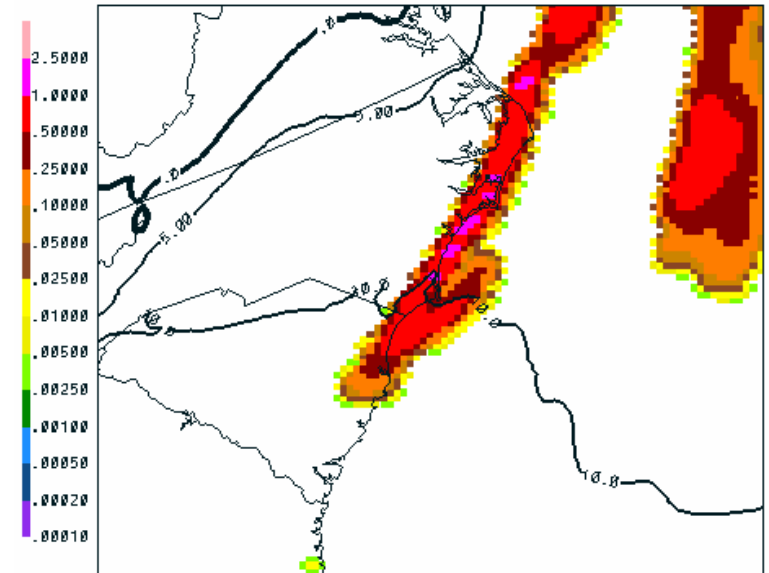
10xWV Pa/s T 800 mb

OPS run

24-H ETA FCST

12KM/60LYRS

VALID 00Z 26 APR 02



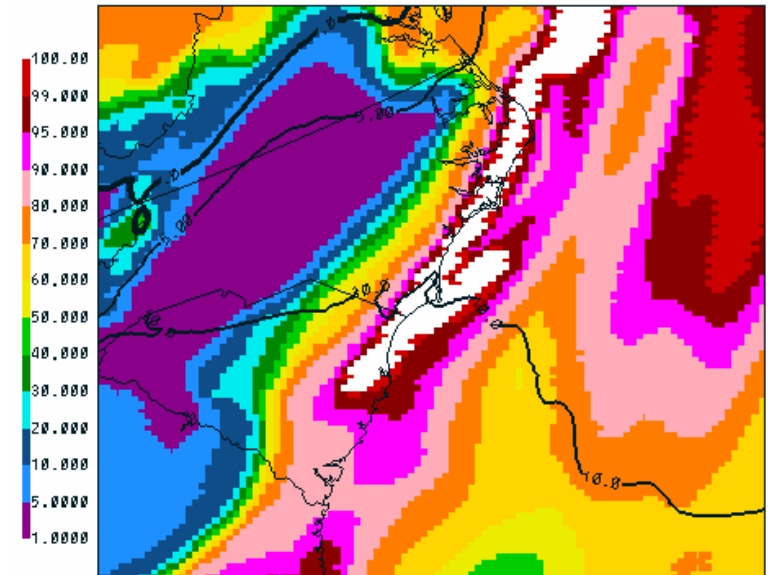
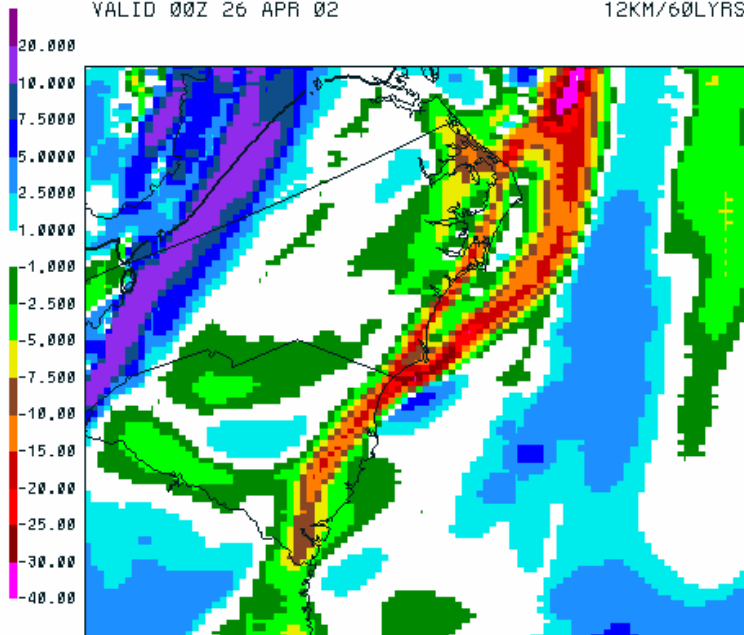
REL HUM + T 800 MB

OPS run

24-H ETA FCST

12KM/60LYRS

VALID 00Z 26 APR 02



# External Evaluation

- Notifications sent to SSDs, MSDs, SOOs, NCEP Service Centers & private sector folk
  - Etax availability of web results 17 January 2003
  - Notice of Intent to Change March 21+24, 2003
  - Final call for feedback 3 June, 2003

# HPC Feedback (Pete Manousos)

- The HPC supports the changes proposed for the Eta model. The Eta was available on our N-AWIPS display for only the last month or so. In our limited experience, we have not noticed any significant improvements. However, the Eta runs have shown nothing to indicate any problems that would cause us to oppose its implementation.



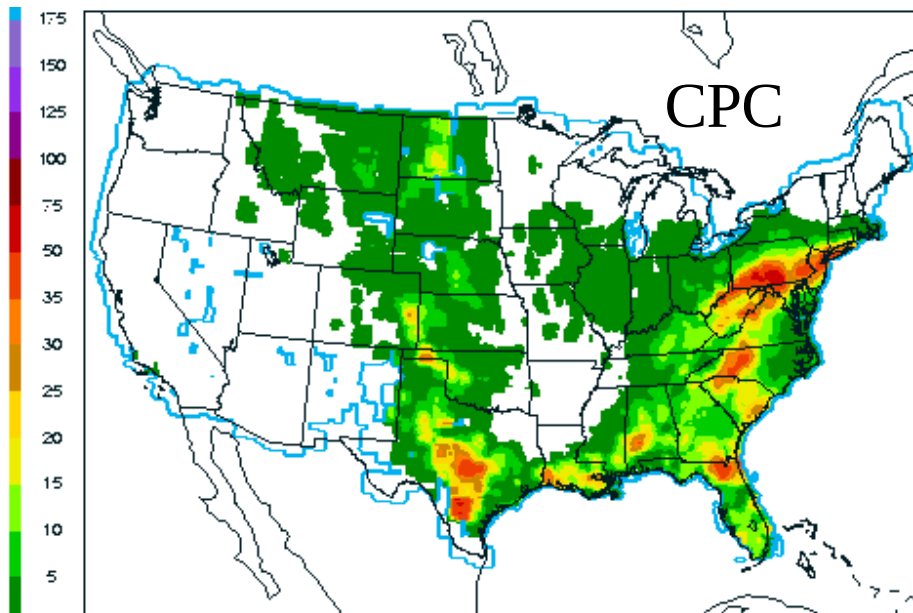
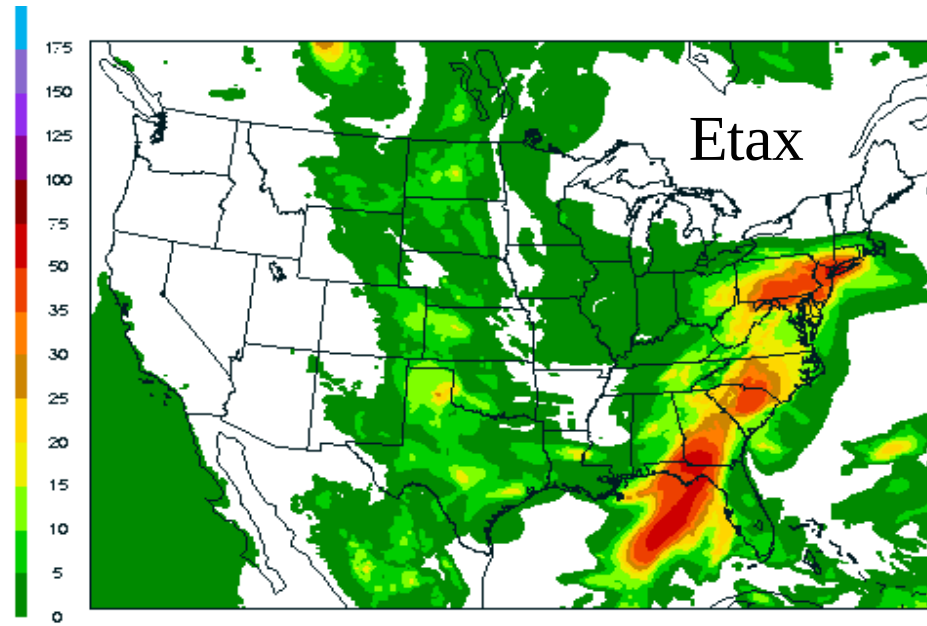
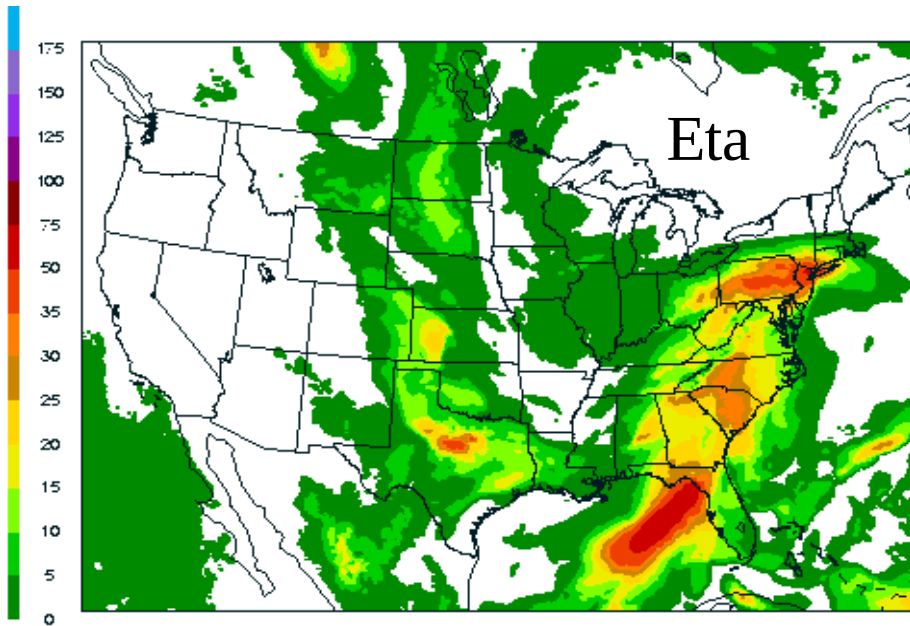
# AWC Feedback (Fred Mosher)

- The AWC supports the changes proposed for the Eta model. Our limited examination of the experimental runs of the Eta shows noticeable improvements in the ability to correctly forecast convection in the first 12 hours of the model. These convection improvements are most notable in the removal of false convective areas. The provisions to have hourly grids out through 36 hours will be especially useful to the AWC in that guidance fields will now be available at the valid times of our forecast products.

# Forecaster Feedback (Bill Nichols, Davenport, Iowa)

- Usually, the QPF's are extremely close. My observations suggest biggest variances noted with marginal forcing/moisture events and also sometimes in evolution of a current QPF field. I've not been able to assess systematic trends in the differences yet that operationally we can say is an improvement...will keep monitoring.
- Both model QPF schemes seem to suffer from RH problems in lower levels that sometimes manifest themselves (or don't) in QPF and Vertical Motion fields. I find these RH often overforecasted, and sometimes have major operational impacts. One example, last week, several runs of the ETA and ETAX show 80% plus RH that obviously wasn't going to happen (i.e. center arctic high)...not unusual...and yes, we were clear all day (DVV).
- Both schemes suffer from missing or underestimating shallow moisture convergence with decent low level forcing. Also...notorious for missing light flurries/sprinkles or even light showers in late winter and early spring with cold air aloft.
- In summary, the change to the new QPF fields would be modest at best...and for most operational forecasts, non sequitur; due to the daily larger scale challenges/biases of the model.

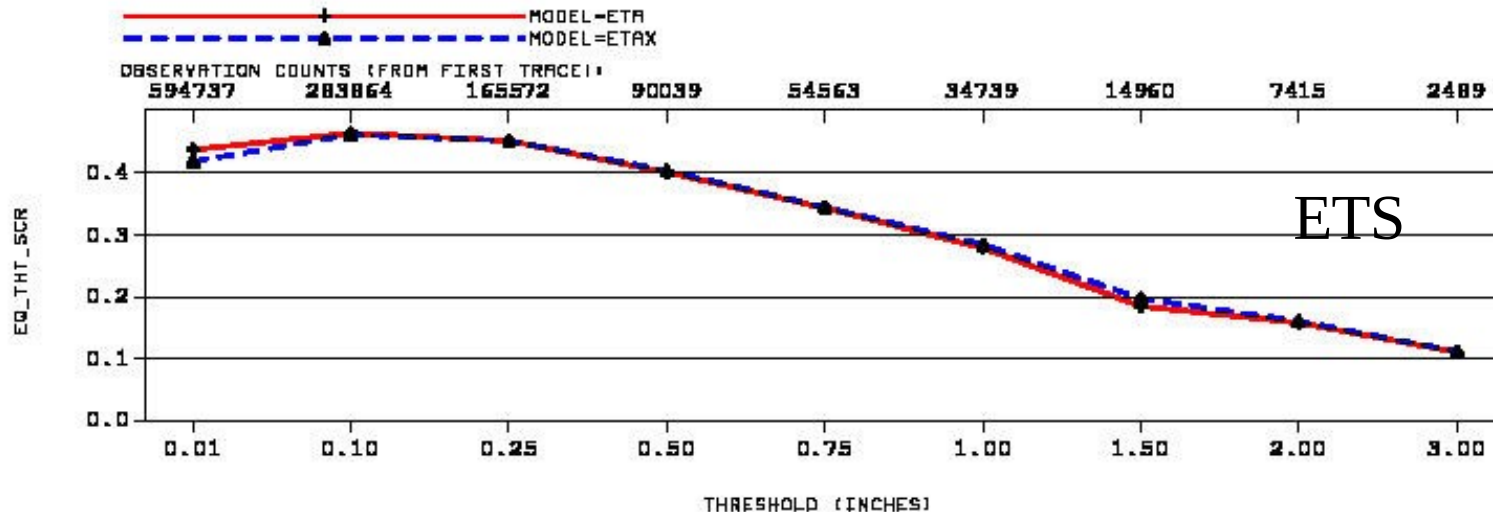
# Eta vs Etax for 4 June 2003



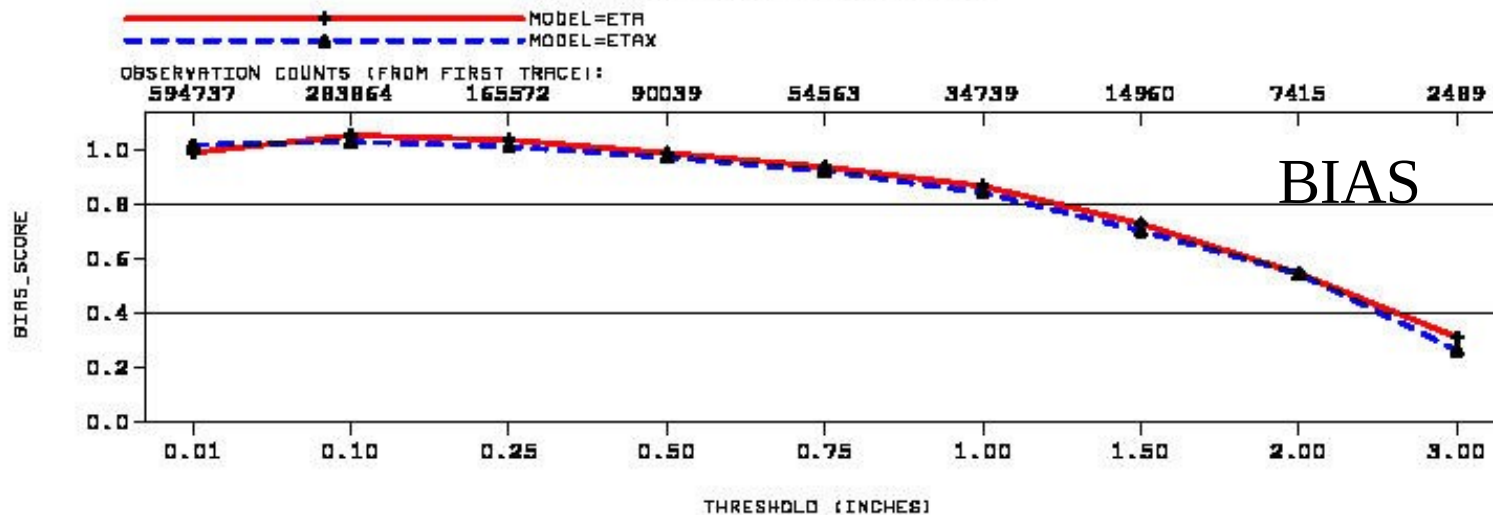
MD-DC-PA-NJ  
Downpour Case

# Bundle Verification Results 24hr QPF

24-h precipitation equitable threat score for ops Eta-12 and parallel Eta-12 with winter 2003 bundle for 24, 36, 48 and 60-h forecasts from 200209220000 to 200301052300



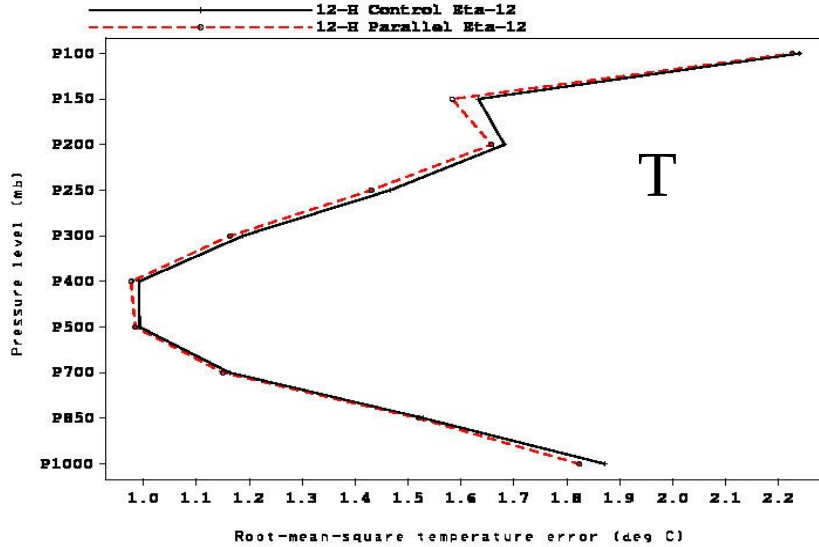
24-h precipitation bias score for ops Eta-12 and parallel Eta-12 with winter 2003 bundle 24, 36, 48 and 60-h from 200209220000 to 200301052300



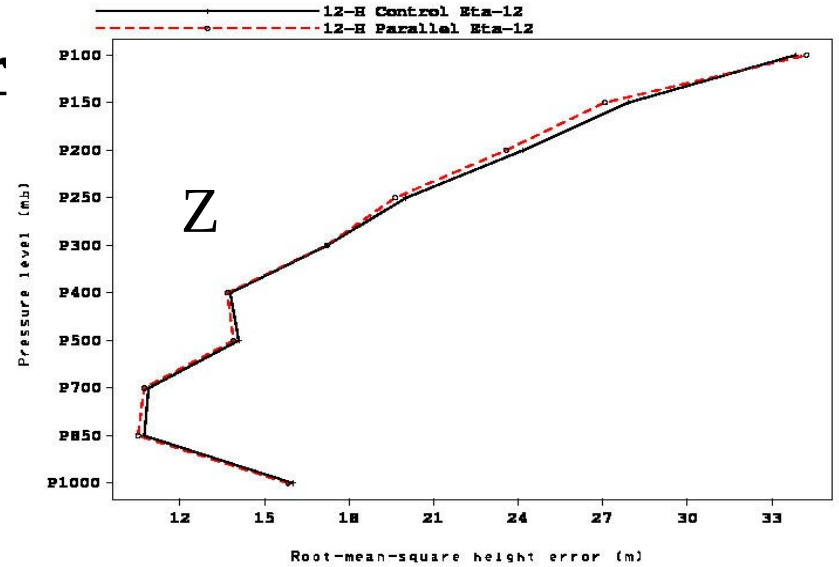


# Bundle Verification Results Upper-Air

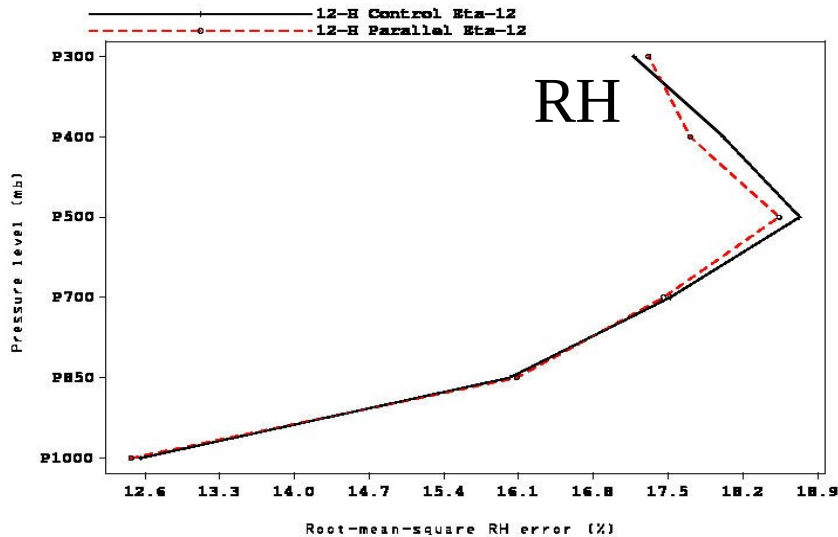
RMS temperature error vs. raobs over the CONUS for control Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 12-h forecast from 200209221200 to 200301051200



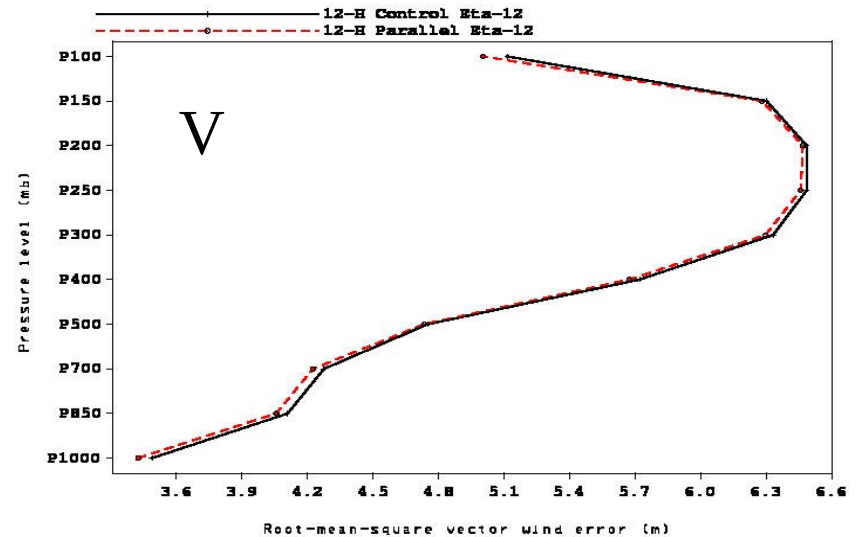
RMS height error vs. raobs over the CONUS for atl Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 12-h forecast from 200209221200 to 200301051200



RMS relative humidity error vs. raobs over the CONUS for atl Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 12-h forecasts from 200209221200 to 200301051200

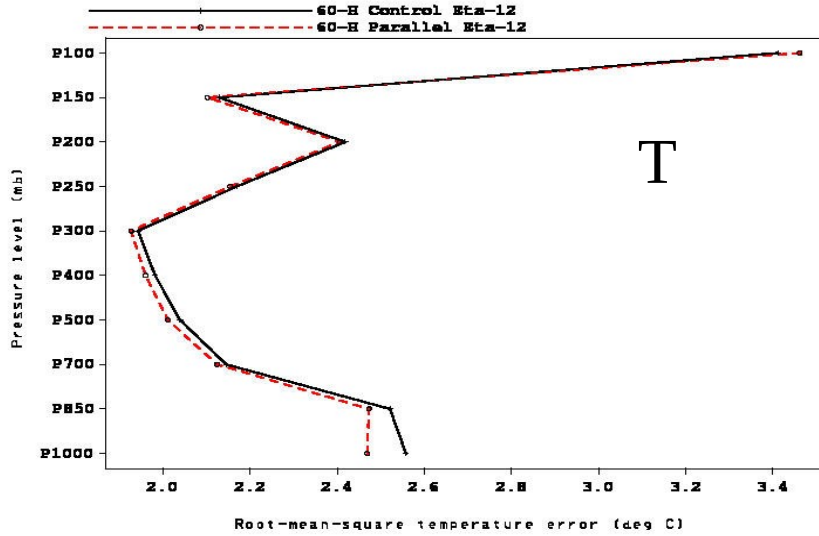


RMS vector wind error vs. raobs over the CONUS for control Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 12-h forecast from 200209221200 to 200301051200



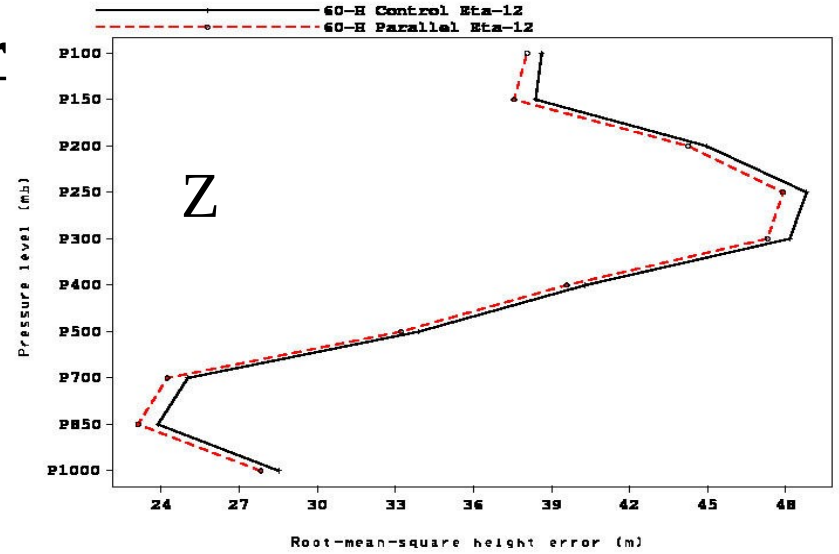
# Bundle Verification Results Upper-Air

RMS temperature error vs. raobs over the CONUS for control Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 60-h forecast from 200209221200 to 200301051200

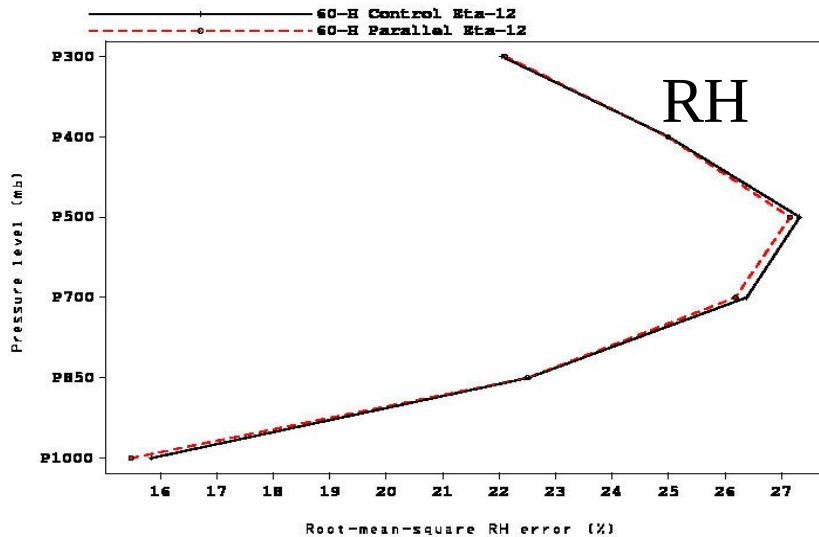


RMS height error vs. raobs over the CONUS for ctrl Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 60-h forecast from 200209221200 to 200301051200

**60 hr**



RMS relative humidity error vs. raobs over the CONUS for ctrl Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 60-h forecasts from 200209221200 to 200301051200



RMS vector wind error vs. raobs over the CONUS for control Eta-12 (solid) and parallel Eta-12 (with winter 2003 bundle) 60-h forecast from 200209221200 to 200301051200

