Implementation of Eta Upgrade Bundle

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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

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 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 -5C and -10C.
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 $0.08 \times \min(1., \frac{Q_w}{Q_0})$, where $Q_w$ is the cloud water mixing ratio and $Q_0=0.1g/kg$ (10-4 kg/kg). The coefficients for ice in the model are equal to $500 \times Q_i$, 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

After 1\textsuperscript{st} Changes
Sample Total Cloud Cover

Before Changes

After 2\textsuperscript{nd} Changes

Better due to reduced longwave cooling
Surface Temperature Response

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

- Observed mean
- Control Eta-12
- Parallel Eta-12

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

ETS

BIAS

ETS

BIAS
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
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

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

<table>
<thead>
<tr>
<th>Parameter Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability anomaly of temperature</td>
</tr>
<tr>
<td>Probability anomaly of precipitation</td>
</tr>
<tr>
<td>Rain fraction of total liquid water</td>
</tr>
<tr>
<td>Ice fraction of total condensate</td>
</tr>
<tr>
<td>Rime Factor</td>
</tr>
<tr>
<td>Convective cloud efficiency</td>
</tr>
<tr>
<td>Total condensate</td>
</tr>
<tr>
<td>Total column-integrated cloud water</td>
</tr>
<tr>
<td>Total column-integrated cloud ice</td>
</tr>
<tr>
<td>Total column-integrated rain</td>
</tr>
<tr>
<td>Total column-integrated snow</td>
</tr>
<tr>
<td>Total column-integrated condensate</td>
</tr>
<tr>
<td>Ellrod Index</td>
</tr>
</tbody>
</table>
Examples of the various hydrometeor fields now postable from the Eta

Total Condensate
More examples of fields postable from Eta

Cloud Water

Cloud Ice

Rain

Snow
Baldwin Type versus Precip Type Direct from Model

Baldwin Diagnosed Precip Type

Percent Frozen Direct from Model’s Gridscale Scheme
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.
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 Etax 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 Etax 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 Sta-12 and parallel Sta-12 with winter 2003 bundle for 24, 36, 48 and 60-h forecasts from 200209220000 to 200301052300

ETS

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

BIAS
Bundle Verification Results Sfc RH

Mean 2-M RH vs. sfc obs (12Z cycle) over the Eastern US for ctl Eta-12 and parallel Eta-12 (with mod cld physics, assim of NEXRAD winds and GOES cloud) forecast from 200209220000 to 200211091200

- Observed mean
- Control Eta-12
- Parallel Eta-12
Bundle Verification Results Upper-Air

**T**

Root-mean-square temperature error (°C)

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

**Z**

Root-mean-square height error (m)

- RMS height error vs. raobs over the CONUS for ctl Sta-12 (solid) and parallel Sta-12 (with winter 2003 bundle) 12-h forecast from 200209221200 to 200301051200
- 12-H Control Sta-12
- 12-H Parallel Sta-12

**RH**

Root-mean-square RH error (%)

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

**V**

Root-mean-square vector wind error (m)

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

24 hr
Bundle Verification Results Upper-Air

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

60 hr

RMS relative humidity error vs. runs over the CONUS for control Sta-12 (solid) and parallel Sta-12 (with winter 2003 bundle) 60-h forecast from 200301051200 to 200301051200

RMS height error vs. runs over the CONUS for control Sta-12 (solid) and parallel Sta-12 (with winter 2003 bundle) 60-h forecast from 200301051200 to 200301051200

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