ESRL RAP/HRRR updates Jan-Apr 2014

Concluding with the 03 UTC 10 April 2014 cycle the ESRL/GSD RAP (13km) and HRRR (3km) have been upgraded to include all of the following data assimilation and model changes:

ESRL RAP 13-km Data Assimilation Changes (in chronological order):

(1) Updated Gridpoint Statistical Interpolation (GSI) package to a recent source code trunk revision **(change effective 06 UTC 12 March 2014)**.

- Important for consistency with trunk code
- Change in forecast quality - **small**

(2) Changed GSI hybrid data assimilation to increase the weight to 75% for model background error covariance derived from a GFS 80-member ensemble forecast at 60-km using the ensemble Kalman filter while decreasing the weight to 25% for static 3-D model background error covariance to further improve the assimilation of all observations. A slightly tighter fit to upper-level observations at the analysis time and throughout the forecast period can be expected **(change effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **high** for all applications and seasons

(3) Introduced cycled satellite radiance bias correction (for both angle and mass) in GSI during assimilation. Added AMSUA/MHS channels from METOP-B and GOES sounder data in radiance assimilation. Removed some upper level channels for AMSUA/GOES/HIRS4 data. A slightly tighter fit to upper-level observations at the analysis time and throughout the forecast period can be expected **(change effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **medium** for all applications and seasons

(4) Corrected soil temperature and moisture adjustments in GSI during data assimilation to avoid water points on the coarser analysis grid **(change effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **small** for all applications and seasons

(5) Corrected the non-variational cloud and precipitating hydrometeor analysis to (a) properly conserve virtual potential temperature during saturation of cloud bearing layers, (b) limit the saturation of cloud bearing layers to 100% relative humidity, and (c) properly scale rain number concentration in addition to rain-water mixing ratio when reducing model values to observed values at specific levels. An increase in low-level moisture and temperature can be expected in some cases where low-level (less than 1.2 km AGL) clouds are observed. A closer fit to lower-level observations in some cloudy areas can be expected at the analysis time **(changes effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **small** for all applications and seasons

(6) Changed the cycled snow cover fields through modifications in building of snow cover in the 00 UTC cycle based upon the Interactive Multisensor Snow and Ice Mapping System (IMS) snow cover analysis. A neighborhood gridpoint approach is now used to build snow based upon snow cover characteristics from surrounding gridpoint(s). The skin/snow temperature for points with built snow are now limited to no more than 272K **(change effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **medium** for 2m temperature in snow-cover or near-snow-cover areas, corrects large local surface temperature errors from erroneous snow cover, especially in spring and late winter (**small** overall)

(7) Enhanced the assimilation of surface dewpoint observations by accounting for the difference between the height of the lowest model level (~8 m AGL) and the height of the surface observation (2 m AGL). A reduction in moist bias of lower-level relative humidity through the forecast period can be expected **(change effective 17 UTC 05 April 2014)**.

- Change in forecast quality - **medium-high** for 2m dewpoint forecasts and related moisture fields for all seasons

ESRL RAP 13-km Model Changes (in chronological order):

(1) Updated Advanced Weather and Research Forecast model (WRF-ARW) from a version 3.4.1 code base to a version 3.5.1 code base including an updated Thompson microphysics version **(changes effective 06 UTC 12 March 2014)**.

- Important for consistency with community code
- Change in forecast quality - **small** overall

(2) Changed to the Grell-Freitas (GF) convective parameterization scheme (from an older Grell scheme). The scheme is designed to become less active as the grid size reduces to cloud-resolving scales with enhanced shallow cumulus parameterization. A tighter fit to upper-level observations can be expected at the analysis time and throughout the forecast period from improved convective forecasts. Improved precipitation forecasts can also be expected with a reduction in high bias of lower precipitation amounts (less than a half inch in a six hour period) and an improved bias of higher precipitation amounts (more than a half inch in a six hour period) **(change effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **high** for all applications and seasons, more so in warm season.

(3) Changed to the Rapid Radiative Transfer Model - Global (RRTMG) scheme for both shortwave and longwave radiation (from the previous Goddard/RRTM radiation schemes). The RRTMG scheme is designed to use a statistical method to resolve sub-grid scale cloud variability and includes the potential for improved interaction with the Thompson microphysics scheme and aerosols. The period between radiation calls has been increased from 10 min to 20 min during the forecast period, but an additional option has been enabled to interpolate shortwave radiation based on the updated solar zenith angle between radiation calls **(changes effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **medium** for surface solar radiation forecasts, **small** overall

(4) Enhanced RUC Land Surface Model (RUCLSM) including an increased thickness of the top snow layer and increased value of exchange coefficient for stable stratification in 2-m diagnostics when 2-m temperature is set equal to the first atmospheric level. These changes will help reduce the 2-m cold temperature bias over existing snow cover at night **(changes effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **high** for 2 m temperature forecasts over snowpack at night, **small** overall

(5) Enhanced Mellor-Yamada-Nakanishi-Niino (MYNN) planetary boundary layer (PBL) scheme including improved coupling of the PBL scheme with radiation feedback in the GF shallow cumulus convective parameterization scheme and a reduced thermal roughness length over snow. The thermal roughness change will help reduce the 2-m cold temperature bias over existing snow cover at night in concert with changes in (4) **(changes effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **medium-high** for 2 m temperature forecasts over snowpack at night, **medium** overall

(6) Relaxed the restriction for diagnosis of ice pellets (sleet) as a surface precipitation type and enforced diagnosis of 2-m dewpoint to be equal or less than the 2-m temperature **(changes effective 06 UTC 12 March 2014)**.

- Change in forecast quality - **medium** for 2 m temperature/dewpoint and precipitation type forecasts, **small** overall

(7) Increased the surface roughness length values to 1 m for urban and 20 cm for cropland land-use categories to help reduce the high wind speed bias near the surface **(changes effective 17 UTC 05 April 2014)**.

- Change in forecast quality - **medium** for near-surface wind forecasts, **small** overall

(8) Added seasonally varying MODIS vegetation fraction and fractional leaf area index for improved surface roughness, and sensible and latent heat fluxes **(change effective 17 UTC 05 April 2014)**.

- Change in forecast quality - **medium** especially for 2 m temperature/dewpoint and 10-m wind forecasts

(9) Added model terrain elevation blending near the lateral boundaries of the RAP domain for a smoother transition to the coarser resolution GFS grid and included a correction in vertical interpolation of GFS data for lateral boundary conditions. These changes enhance the numerical stability in the lateral boundary regions **(changes effective 06 UTC 12 March 2014 and 17 UTC 05 April 2014)**.

- Change in forecast quality - **small**

HRRR 3-km Data Assimilation Changes (in chronological order):

(Changes 1-5 below for HRRR assimilation match those also implemented for RAP)

(1) Updated Gridpoint Statistical Interpolation (GSI) package to a recent source code trunk revision **(change effective 08 UTC 08 April 2014)**.

- Important for consistency with trunk code
- Change in forecast quality - **small**

(2) Enabled GSI hybrid data assimilation with model background error covariances now including 75% from a flow (weather) dependence derived from a GFS 80-member ensemble forecast at 60-km using the Ensemble Kalman Filter in combination with 25% static 3-D model background error covariance to improve the assimilation of all observations. A slightly tighter fit to upper-level observations at the analysis time and throughout the forecast period can be expected **(change effective 08 UTC 08 April 2014)**.

- Change in forecast quality - **high** for all applications and seasons

(3) Corrected soil temperature and moisture adjustments in GSI during data assimilation to avoid water points on the coarser analysis grid **(change effective 08 UTC 08 April 2014)**.

- Change in forecast quality - **small** for all applications and seasons

(4) Corrected the non-variational cloud and precipitating hydrometeor analysis to (a) properly conserve virtual potential temperature during saturation of cloud bearing layers, (b) limit the saturation of cloud bearing layers to 100% relative humidity, and (c) properly scale rain number concentration in addition to rain-water mixing ratio when reducing model values to observed values at specific levels. An increase in low-level moisture and temperature can be expected in some cases where low-level (less than 1.2 km AGL) clouds are

observed. A closer fit to lower-level observations in some cloudy areas can be expected at the analysis time **(change effective 08 UTC 08 April 2014)**.

- Change in forecast quality - **small** for all applications and seasons

(5) Enhanced the assimilation of surface dewpoint observations by accounting for the difference between the height of the lowest model level (~8 m AGL) and the height of the surface observation (2 m AGL). A reduction in moist bias of lower-level relative humidity through the forecast period can be expected **(change effective 08 UTC 08 April 2014)**.

- Change in forecast quality - **medium-high** for 2m dewpoint forecasts and related moisture fields for all seasons

(6) (*Unique to HRRR*) Adjusted the assimilation of radar reflectivity-derived latent heating at 15min intervals through a 1-hour pre-forecast period by lowering the threshold for specification of latent heating from 35 dBZ to 28 dBZ and reducing the magnitude of the latent heating for a given reflectivity by a factor of four. The changes represent a broadening and weakening of the forcing applied from radar reflectivity observations to slightly reduce excessive convective storm development at the beginning of a HRRR forecast run **(change effective 08 UTC 08 April 2014)**.

- Change in forecast quality - **medium** for convective storm development and maintenance, **small** otherwise

HRRR 3-km Model Changes (in chronological order):

(1) Relaxed the restriction for diagnosis of ice pellets (sleet) as a surface precipitation type and enforced diagnosis of 2-m dewpoint to be equal or less than the 2-m temperature **(changes effective 05 UTC 13 March 2014)**.

- Change in forecast quality - **medium** for 2 m temperature/dewpoint and precipitation type forecasts, **small** overall

(2) Changed model initialization to retain snow cover over frozen water points from the RAP. This change promotes retention of snowpack and improved 2-m temperature forecasts over frozen water **(change effective 06 UTC 23 March 2014)**.

- Change in forecast quality - **small** overall

(3) Updated Advanced Weather and Research Forecast model (WRF-ARW) from a version 3.4.1 code base to a version 3.5.1 code base including an updated Thompson microphysics version **(changes effective 03 UTC 10 April 2014)**.

- Important for consistency with community code
- Change in forecast quality - **small** overall

(4) Changed to the Rapid Radiative Transfer Model - Global (RRTMG) scheme for both shortwave and longwave radiation (from the previous Goddard/RRTM schemes). This scheme is designed to use a statistical method to resolve sub-grid scale cloud variability and includes the potential for improved interaction with the Thompson microphysics scheme and aerosols. The period between radiation calls has been increased from 5 min to 15 min during the forecast period, but an additional option has been enabled to interpolate shortwave radiation based on the updated solar zenith angle between radiation calls **(changes effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **medium** for surface solar radiation forecasts, **small** overall

(5) Enhanced RUC Land Surface Model (RUCLSM) including an increased thickness of the top snow layer and increased value of exchange coefficient for stable stratification in 2-m diagnostics when 2-m temperature is set equal to the first atmospheric level. These changes will help reduce the 2-m cold temperature bias over existing snow cover at night **(changes effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **high** for 2 m temperature forecasts over snowpack at night, **small** overall

(6) Enhanced Mellor-Yamada-Nakanishi-Niino (MYNN) planetary boundary layer (PBL) scheme including a reduced thermal roughness length over snow. The thermal roughness change will help reduce the 2-m cold temperature bias over existing snow cover at night in concert with changes in (5) **(changes effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **medium-high** for 2 m temperature forecasts over snowpack at night, **medium** overall

(7) Increased the surface roughness length values to 1 m for urban and 20 cm for cropland land-use to help reduce the high wind speed bias near the surface **(changes effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **medium** for near-surface wind forecasts, **small** overall

(8) Added seasonally varying MODIS vegetation fraction and fractional leaf area index for improved surface roughness, and sensible and latent heat fluxes **(change effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **medium** especially for 2 m temperature/dewpoint and 10-m wind forecasts

(9) Added model terrain blending near the lateral boundaries of the HRRR domain for a smoother transition to the coarser-resolution RAP grid and included improved vertical interpolation of RAP data for lateral boundary conditions. These changes enhance the numerical stability in the lateral boundary regions **(change effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **small**

(10) Introduced 6th-order diffusion in regions with very shallow model surface slopes (relatively flat terrain) to reduce grid-scale noise in the mass and momentum fields by at least 25%, particularly in weather regimes with weak flow. This reduction in noise can prevent occurrence of very small scale, generally very weak, model reflectivity structures **(change effective 03 UTC 10 April 2014)**.

- Change in forecast quality - **small**

The ESRL RAP and HRRR data assimilation and model configurations will now remain “frozen”, with the exception of software bug fixes, through the remainder of the spring, summer and early fall with the next changes being applied on or after 01 November 2014.

A summary of all changes effective 03 UTC 10 April 2014 is presented in the following table:

ESRL RAPv3/HRRR-2014 Changes

	Model	Data Assimilation
RAP-ESRL (13 km)	WRFv3.5.1+ incl. physics changes Physics changes: Grell-Freitas convective scheme MYNN PBL update - Olson version RUC LSM update Thompson microphysics – v3.5.1 RRTMG radiation scheme Shallow cumulus parm w/ rad feed MODIS veg fraction/leaf area index	Merge with GSI trunk Increase ensemble weight in hybrid DA 8m→2m bkg for sfc Td assim Radiance bias correction New sat assimilation (NOAA-19, METOP-B, GOES, direct readout – RARS)
HRRR (3 km)	WRFv3.5.1+ incl. physics changes Physics changes: MYNN PBL update - Olson version RUC LSM update Thompson microphysics – v3.5.1 RRTMG radiation scheme MODIS veg fraction/leaf area index Numerics changes: 6th order diffusion in flat terrain Smooth terrain @lat BC	3-km hybrid ens/var assimilation (was var-only in 2013) 8m→2m bkg for sfc Td assim Radar LH – 4x less intense than 2013 (2x less intense than RAP but more local) Changes with high/medium importance for *overall* forecast skill

All of this information is also available on our website at:
http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf

(accessible via links under "Description" at http://rapidrefresh.noaa.gov/RAP and http://rapidrefresh.noaa.gov/HRRR)

All recent and current revisions of static files for the RAP and HRRR are available on our RAP and HRRR websites including WRF-ARW pre-processing (WPS) geography files, ungrib Vtables, metgrid tables, and WPS and WRF-ARW namelists.

The RAP and HRRR static files are located at:

http://rapidrefresh.noaa.gov/RAP/static

http://rapidrefresh.noaa.gov/HRRR/static