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Subject: Upgrade to the Rapid Refresh (RAP) and the High-Resolution Rapid Refresh (HRRR) Analysis and Forecast System: Effective August 23, 2016

Effective on or about Tuesday, August 23, 2016, beginning with the 1200 Coordinated Universal Time (UTC) run, the National Centers for Environmental Prediction (NCEP) will implement Version 3 of the Rapid Refresh (RAP) and Version 2 of the High-Resolution Rapid Refresh (HRRR) systems.

A major change to the RAP will be an expanded computational domain which will now include Hawaii. This expansion will facilitate future NCEP plans for ensemble systems and in time improve the initialization of Short Range Ensemble Forecast (SREF) members that use the RAP for initial conditions.

Analysis Changes:

Both the RAP and HRRR will use an updated version of the Gridpoint Statistical Interpolation (GSI) analysis code. Refinements were made to the GSI to improve the assimilation of surface observations, soil moisture adjustment, and three-dimensional cloud and precipitation hydrometeors. In addition, the HRRR will start using the ensemble/hybrid data assimilation; it is already used in the RAP, but the weighting of the ensemble-based component in the RAP will increase from 0.50 to 0.75. In addition, while the RAP already cycles land-surface states, this cycling is being introduced into the HRRR. In HRRR Version 1, all runs are independent.

Other analysis changes include:

- Assimilating radial wind and mesonet data
- Applying Planetary Boundary Layer (PBL)-based pseudo-innovations for 2-meter temperatures (already used for 2-meter dew points)
- Changing the cloud-hydrometeor assimilation to avoid Meteorological Terminal Air Report (METAR)-based cloud building when satellite data shows clear skies at all times of day (currently used just in daytime)
- Introducing direct use of 2-meter temperature and dew point model diagnostics in the GSI.

Specific to the HRRR, the application of radar reflectivity data in the GSI to direct specification of 3-dimensional (3-D) hydrometeors is increased to apply to a broader range of weather conditions, including warm-season events with reflectivity up to 28 dBZ.

Changes to Model:

- The RAP and HRRR will both begin using Weather Research and Forecasting (WRF) version 3.6.1; both will continue to use the Advanced Research WRF (ARW) core.
- The Mellor-Yamada-Nakanishi-Niino (MYNN) planetary boundary layer scheme is being updated to include the effects of subgrid-scale clouds. The mixing length formulation in the boundary layer scheme and thermal roughness in the surface layer are being changed.
- The 9-level Rapid Update Cycle (RUC) land-surface model is being updated to add a mosaic approach for fractional snow cover, improve the fluxes from snow cover, and modify the wilting point for cropland use.
- Major updates are being made to the Thompson microphysics scheme, including making it aerosol-aware with use of an ice-friendly and water-friendly aerosol field.
- Shortwave and longwave radiation have been changed to use the Rapid Radiative Transfer Model global (RRTMG) scheme that includes the effects of aerosols and boundary layer subgrid-scale clouds.
- The WRF-ARW diagnostics for 2-meter temperature and dew point are being improved.
- The convective scheme in the RAP is changed from the Grell 3-D scheme to the scale-aware Grell-Freitas scheme. The HRRR, at 3 km horizontal resolution, explicitly resolves convection and does not use a convective scheme.

Many of these changes to the data assimilation, land-surface model, boundary layer scheme, microphysics, radiation, and (in the RAP only) convective scheme are designed to mitigate the low-level warm, dry bias in the RAP and HRRR, most notable during afternoons in the warm season. Significant reduction of these biases has been evident in extensive testing.

Output Changes:

The HRRR directory structure will be migrated out of nonoperational on the NCEP ftp and http servers. Data will also be available on both the primary and secondary servers.

OLD:

<http://nomads.ncep.noaa.gov/pub/data/nccf/nonoperational/com/hrrr/>

<ftp://ftp.ncep.noaa.gov/pub/data/nccf/nonoperational/com/hrrr/>

<http://www.ftp.ncep.noaa.gov/data/nccf/nonoperational/com/hrrr/>

NEW:

<http://nomads.ncep.noaa.gov/pub/data/nccf/com/hrrr/>

<ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/hrrr/>

<http://www.ftp.ncep.noaa.gov/data/nccf/com/hrrr/>

The forecast lengths of both the RAP and the HRRR will be extended on the NCEP servers:

<http://nomads.ncep.noaa.gov>

<ftp://ftpprd.ncep.noaa.gov>

<http://ftp.ncep.noaa.gov> http://nomads.ncep.noaa.gov/cgi-bin/filter_rap.pl

http://nomads.ncep.noaa.gov/cgi-bin/filter_rap32.pl

http://nomads.ncep.noaa.gov/cgi-bin/filter_hrrr_2d.pl

<http://nomads.ncep.noaa.gov:9090/dods/hrrr>

<http://nomads.ncep.noaa.gov:9090/dods/rap/>

The RAP hourly output will be extended from 18 to 21 hours for all cycles. The HRRR hourly output will be extended from 15 to 18 hours for all cycles.

Output files will be written directly to gridded binary version two (GRIB2) instead of first being written out to GRIB1 and converted to GRIB2. Users may see some differences with the encoding and are encouraged to upgrade their software to handle this. Please see the links below for upgraded code:

<http://www.nco.ncep.noaa.gov/pmb/codes/GRIB2>

<http://www.cpc.ncep.noaa.gov/products/wesley/wgrib2>

<ftp://ftp.cpc.ncep.noaa.gov/wd51we/wgrib>

The following GRIB1 RAP output is being discontinued on NCEP and NWS servers. The 40km Regional RAP will be discontinued here only. There will be no impacts to NOAAPort.

tgftp.nws.noaa.gov/SL.us008001/ST.opnl/MT.rap_CY.CC/RD.YYYYMMDD/PT.grid_DF.bb/

The GRIB2 equivalent is online at:

<http://nomads.ncep.noaa.gov/pub/data/nccf/com/rap/prod/rap.YYYYMMDD/>

`rap.tCCz.awp236pgrbfff.grib2`

`ftp://ftp.ncep.noaa.gov/pub/data/nccf/com/rap/prod/rap.YYYYMMDD/`

`rap.tCCz.awp236pgrbfff.grib2`

Where CC is cycle, FF is forecast hour (00-21), YYYYMMDD is year, month and day

The following file names will change to remove "tm00":

`rap.tCCz.wrfprshh.tm00.grib2 -> rap.tCCz.wrfprsfhh.grib2`

`rap.tCCz.wrfnatshh.tm00.grib2 -> rap.tCCz.wrfnatfhh.grib2`

Where CC is the cycle (00-23), and HH is the forecast hour (00- 21)

In conjunction with the expansion of the RAP domain, output on a new forecast grid will be added to the NCEP ftp/http servers, opendap and grib filter. RAP output on grid 243, which covers Hawaii and the eastern Pacific Ocean, will be available with names:

```
rap.tCCz.awp243fFF.grib2 rap243_CCz  
cgi-bin/filter_rap243.pl
```

Where CC is the cycle (00-23) and FF is the forecast hour (00-21)

The 3-hour pressure tendency field, available in several RAP output grids, will no longer be available. Users will need to compute this parameter on their own.

The value that represents the resolution and component flags of the grid definition template is changed in all RAP output from eight to 56. This indicates the resolved u and v components of vector quantities are relative to the defined grid in the direction of increasing x and y (or i and j) coordinates, respectively, and the i and j direction increments (representing dx and dy of the model), are stored within the grid definition templates for all RAP output grids.

The labeling of the following RAP parameters are being modified, mainly due to different conventions in the way direct grib2 output is post-processed. These changes apply to any and all RAP output grids on which the parameter is found:

Composite reflectivity (Discipline 0, Category 16, Number 196): The fixed surface type is changed from 200 (Entire Atmosphere (considered as a single layer)) to 10 (Entire Atmosphere).

U and V components of storm motion (Discipline 0, Category 2, Numbers 194 and 195): The current labeling of the first specified height level above ground as 6000 and the second level as 0 is changed so that 0 is the first level and 6000 is the second.

U and V components of vertical wind shear (Discipline 0, Category 2, Numbers 15 and 16): The current labeling of the first specified height level above ground as 6000 and the second level as 0 is changed so that 0 is the first level and 6000 is the second.

Total Cloud Cover (Discipline 0, Category 6, Number 1): The fixed surface type is changed from 200 (Entire Atmosphere (considered as a single layer)) to 10 (Entire Atmosphere).

Soil Moisture availability (Discipline 0, Category 0, Number 194): The fixed surface type is changed from 1 (surface) to 106 (depth below land surface), with the depth specified at 0 meters.

Relative humidity computed with respect to precipitable water (Discipline 0, Category 1, Number 242): The fixed surface type is changed from 200 (Entire Atmosphere (considered as a single layer)) to 10 (Entire Atmosphere).

For all soil moisture (Discipline 2, Category 0, Number 192) and soil temperatures (Discipline 2, Category 0, Number 2), the fixed surface type is still 106 (depth below land surface), but the depth is now reported as a range between 2 levels (with the chosen level listed as both levels) instead as a single level. As an example, soil moisture at 40 cm is currently listed as soil moisture at a depth of 0.40 meters; it will now be listed as soil moisture between a depth of 0.4 meters and 0.4 meters.

Changes to Labeling of Parameters in the HRRR:

For the lightning flash rate (Discipline 0, Category 17, Number 192), the fixed surface type is changed from 1 (Surface) to 10 (Entire Atmosphere).

The sea level pressure field (Discipline 0, Category 3, Number 1) is replaced by an alternate sea level pressure field (Discipline 0, Category 3, Number 198) to be consistent with the RAP.

The best lifted index field (Discipline 0, Category 7, Number 11) is changed to Discipline 0, Category 7, Number 193, making it consistent with the RAP.

The number of concentration of ice particles is changed from Discipline 0, Category 1, Number 207 to Discipline 0, Category 6, Number 29.

The number of concentration of rain is changed from Discipline 0, Category 255, Number 255 to Discipline 0, Category 1, Number 100.

RAP Precipitation Fields:

The RAP currently generates convective and non-convective precipitation totals. Total precipitation will be added to the output so users no longer need to sum the convective and non-convective amounts. To become consistent with other NCEP models that generate only total and convective precipitation, the run total and 1-hour accumulation non-convective precipitation fields will be eliminated in the 2017 RAP Version 4 upgrade. Users should start preparing for this change but all three precipitation parameters will be provided in RAP Version 3 to assist with the transition.

For the precipitation fields, RAP files currently contain run total and 1-hour accumulations for all forecast hours. In addition, forecast hours 5, 8, 11, 14 and 17 contain an additional 2-hour accumulation, while forecast hours 6, 9, 12, 15 and 18 contain an additional 3-hour accumulation. The 2-hour accumulations will be discontinued in all output files on NCEP and NWS servers but will be retained in files sent to the Advanced Weather Interactive Processing System (AWIPS). The 3-hour accumulations at hours 6, 9, 12, 15, 18 (and 21) will be retained.

Similar changes are made to the snow water equivalent field. The RAP output grids right now contain various combinations of instantaneous, run total and 1-, 2- or 3-hour accumulation of snow water equivalent. The output will be unified so that all grids at all output times have instantaneous, run total, and 1-hour accumulation of snow water equivalent. The files for all forecast hours divisible by three will

contain 3-hour accumulations of snow water equivalent. These snow water equivalent accumulations are being changed to contain contributions only from snow hydrometeors.

Two new winter precipitation fields are being added: accumulated snow depth that includes variable density hydrometeor accumulation, and snowmelt affects (Discipline 0, Category 1, Number 29) and accumulated graupel (Discipline 0, Category 1, Number 227), both available in 1-hour and run total amounts. Note that the parameter listing is for frozen rain because no parameter currently exists for graupel.

Changes to RAP Cloud Base Height / Ceiling:

The RAP output currently contains a parameter called cloud base height (fixed surface type 2) which actually represents the cloud ceiling. In this upgrade, cloud base height will actually represent the true cloud base height, and the old computation is now properly labeled as cloud ceiling (fixed surface type 215). This makes the RAP consistent with the current operational HRRR.

Added and Removed RAP and HRRR Parameters:

A full list of parameters added to and removed from all RAP and HRRR output grids can be found at:

<http://www.nco.ncep.noaa.gov/pmb/changes/docs/RAPv3HRRRv2Parameters.pdf>

Changes to NOAAPort:

With this upgrade, the volume of data transmitted over NOAAPort will increase due to GRIB packing changes:

-RAP 13km increase 80MB/cycle

-RAP 40km increase 6MB/cycle

In the future, NCEP will add the following products to NOAAPort. Please see the following documents for the details of these future additions:

RAP Puerto Rico:

http://www.nco.ncep.noaa.gov/pmb/changes/docs/AWIPS_RAPv3_200.pdf

HRRR sub-hourly output:

http://www.nco.ncep.noaa.gov/pmb/changes/docs/AWIPS_HRRRv2_SUBHOURLY.pdf

RAP 13km extended hourly forecast hours:

http://www.nco.ncep.noaa.gov/pmb/changes/docs/AWIPS_RAPv3_130.pdf

HRRR extended hourly forecast hours:

http://www.nco.ncep.noaa.gov/pmb/changes/docs/AWIPS_HRRRv2_ADDITIONS.pdf

Product Delivery Times:

HRRR analysis products are available approximately six minutes later in Version 2, but the delay is diminished as the forecast progresses such that the products arrive two minutes earlier by forecast hour 15. RAP analysis products are available three minutes later in Version 3, but the delay is diminished as the forecast progresses such that the products arrive at the same time by forecast hour 18.

Parallel Data Location:

A consistent parallel feed of data is available on the NCEP server via the following URLs:

<http://para.nomads.ncep.noaa.gov/pub/data/nccf/com/hrrr/para>

<http://para.nomads.ncep.noaa.gov/pub/data/nccf/com/rap/para>

For more general information about the RAP and HRRR, please see:

<http://rapidrefresh.noaa.gov>

NCEP urges all users to ensure their decoders can handle changes in content order, changes in the scaling factor component within the product definition section (PDS) of the GRIB files, and volume changes. These elements may change with future NCEP model implementations. NCEP will make every attempt to alert users to these changes before implementation.

For questions regarding this implementation, please contact:

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National Technical Implementation Notices are online at:

<https://www.weather.gov/notification/archive>

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