RAPID REFRESH (RAP) Upgrade V3.0.0 HIGH-RESOLUTION RAPID REFRESH (HRRR) Upgrade V2.0.0

EMC Change Configuration Board January 29, 2016

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Overview of Changes

- Updated versions of WRF-ARW model, GSI, and post
- Introduce ensemble/hybrid data assimilation in HRRR and greater weighting in RAP
- Enlarge RAP domain to match NAM
- Forecast length extension for both RAP and HRRR
- Update snow processes directly in the HRRR instead of relying on the interpolation of the RAP guess
- Add cycling of land-sfc fields in the HRRR
- Switch RAP to generate grib2 output directly from post
- Switch to using grib2 MRMS files and create backup capability
- Increase applications of assimilation of radar reflectivity data to a broader spectrum of weather conditions
- Add assimilation of mesonet and radial wind data
- Switch format of RAP history files from binary to parallel netcdf
- Switch format of HRRR history files from netcdf to parallel netcdf
- Add restart capability
- This project is an NWS and NCEP Annual Operating Plan (AOP) milestone for Q3 FY2016

Proposed RAP domain Expansion



Will facilitate development of upcoming NAM/RAP ensemble and aid in initialization of SREF ARW members

Forecast Extensions

- RAP will be increased from 18 to 21 hours
- HRRR will be increased from 15 to 18 hours
- HRRR extension to F18 and upcoming NAMRR implementation set the stage for HREF implementation in 2017

RAP/HRRR DEPENDENCIES

UPSTREAM: GFS, prepbufr, EnKF, MRMS

DOWNSTREAM-RAP: SREF, RTMA/URMA, HRRR, HYSPLIT, Verification **DOWNSTREAM-HRRR**: RTMA/URMA, Verification

Upstream dependencies require following enhancements:

- 1. Obsproc_rap_v2.1.0 released 1/29/16
- 2. Switching to hi-res EnKF input files with this upgrade

Downstream dependencies require following enhancements:

- 1. All HRRR changes accounted for in HRRRv2
- 2. RTMA/URMA upgrade (including common terrain/land mask files) being done simultaneously
- 3. HYSPLIT changes being coordinated with B Stunder
- 4. Verification updates coordinated with P Shafran

RESOURCES

- HRRRv1 runs with ~85 nodes
- HRRRv2 runs with ~110 nodes

- RAPv2 runs with ~25 nodes
- RAPv3 runs with ~50 nodes

RAP PRODUCT CHANGES

RAP currently generates:

- 13, 20, and 40 km hourly output on pressure levels (grid covering CONUS+)
- 13, 20 km hourly output on native levels (CONUS+)
- 11 km hourly Alaska output
- 13 km hourly full domain output for both native and pressure levels
- 32 km hourly full domain output
- 16 km hourly Puerto Rico output
- smartinit output for CONUS, AK, PR, Juneau zoom
- bufr sounding files

CHANGES

- RAP will output grib2 directly
- extra forecast hours
- add Hawaii grid (243) and smartinit grid
- expanded CONUS smartinit grid
- native grid files will increase in size based on domain change
- all output files will have additional parameters

HRRR PRODUCT CHANGES

HRRR currently generates:

- 3 km output on native and pressure levels and smaller file with sfc parameters
- 2.5 km NDFD/smartinit output
- 15 minute sub-hourly data (small subset of parameters)
- bufr sounding files

CHANGES

- all output files will have additional parameters
- extra forecast hours
- start sending sub-hourly output to AWIPS

CHARTER OVERVIEW

- Expected Benefits to End Users Associated with Upgrade
 - Significant improvement in 2-m temperature and dew point biases, particularly the warm,dry late afternoon bias
 - Mitigation of these biases significantly feeding back to boundary layer structure and instability,reflectivity, ceiling, and precip forecasts
 - Overall improved synoptics
 - Improvements to 10-m winds

RAPv3/HRRRv2 Warm/Dry Bias Mitigation



WCOSS Science Quarterly

RAPv3/HRRRv2

18 November 2015 2



Huge reductions in skin temps





With significant positive impact on 2-m temps



Mitigation of warm, dry bias leads to huge improvement for instability



Case Studies: HRRRv2 Improved Convective Forecasts



Case Studies HRRRv2: Winter Precipitation



DEVELOPMENT TESTING

- RAPv3/HRRRv2 developed/tested at GSD for 2+ years
- Code frozen February 2015
- Built at EMC in spring/summer 2015

VERIFICATION

- GSD will provide real-time and retrospective statistics, generated from their RAP/HRRR systems run with same version of code
- EMC Stats unreliable due to
 - too many broken cycles
 - inability to run the HRRR every hour due to contention for resources
 - error introduced into microphysics by IBM that is not in the ESRL backup
- Testing being performed to confirm that the systems match ¹⁶

Reproducibility from GSD to EMC



12-hr 2-m Temps





RAPv3 (GSD)

RAPv3 (EMC)





RAPv3 Winter Retro Verification: Surface



Reduced bias

Reduced fast bias

RAPv3 Summer Retro Verification: Surface



RAP Surface 12-hr Forecast Bias



RAPv3 Winter Retro Verification: UpperAir



Exper RAPv3

Oper RAPv2 RAPv3 - RAPv2 Difference

RAP Upper-Air 6-hr Forecast RMSE



RAP Upper-Air 12-hr Forecast RMSE



RAPv3 Summer Retro Verification: UpperAir

US 15 Jul - 15 Aug 2014

Exper RAPv3

Oper RAPv2 RAPv3 - RAPv2 Difference

RAP Upper-Air 12-hr Forecast RMSE









RAPv3 Winter Retro Verification: Precip

Eastern US 01 - 31 Jan 2015Exper RAPv3Oper RAPv2RAP Eastern US Precipitation 6-hr Forecast



RAPv3 Summer Retro Verification: Precip

Eastern US 15 Jul – 15 Aug 2014 Exper RAPv3 Oper RAPv2 RAP Eastern US Precipitation 6-hr Forecast



HRRRv2 Verification: Reflectivity (25 dBZ)

Eastern US 1 – 31 Jan 2015 Exper HRRRv2 Oper HRRRv1

HRRR Eastern US Precipitation 6-hr Forecast



HRRRv1 to v2 Reflectivity Forecast Skill



GSI minimization warning

Warning in minimization

- Final gnorm gross check failure:
 - in both the operational and parallel RAPs
 - changed the threshold on the convergence warning from the default of 3.5e-4 to 6.0e-3 to remove the convergence warnings
 - executed RAP regression test to see the impact of doubling the inner loop count (50 to 100)
 - A doubling of the runtime (8 to 15 min)
 - RAP retros with 50 inner loop and 100 inner loop produce almost identical forecast results (see next couple of slides)

Case study:

Final gnorm from GSI with 100 inner loops: **1.683612468420213871E-06** Final gnorm from GSI with 50 inner loops: **2.989984336024733972E-04**

- Gnorm check (reset):
 - Only in the operational RAP
 - This problem is resolved in the parallel RAP
 - inclusion of more radiance data (RARS)
 - cycled radiance bias correction

Vertical RMSE profile for 0 and 1 hour



Red: GSI with 50 inner loops

Vertical profile for 3 and 6 hour forecast



Red: GSI with 50 inner loops

Surface RMSE for 0 and 1 hour forecast



Red: GSI with 50 inner loops

Surface RMS and bias time series for 1 forecast



Red: GSI with 50 inner loops

Plan Schedule

- Concluded schedule
 - Project kick off meeting Mar 2, 2015
- Remaining schedule
 - EMC CCB meeting Jan 29, 2016
 - Code Handoff Feb 5, 2016
 - Submit TIN Feb 12, 2016
 - NCO 30-day parallel in April
 - Implementation May 12, 2016



Rapid Refresh v3.0.0 and High-Resolution Rapid Refresh v2.0.0 Project Status as of 12/11/2015



Project Information and Highlights

Lead: Geoff DiMego and Geoff Manikin, EMC and Steven Earle NCO

Scope: Significant upgrade that introduces:

- upgrades to model core and initialization;
- upgrade to assimilation of radar reflectivity data
- expansion of RAP domain to match NAM domain
- extension of forecast length for both models
- updated versions of RAP and HRRR to be implemented simultaneously

Expected Benefits:

- 1. Overall improved skill.
- 2. Mitigate severe warm, dry daytime bias.
- 3. Keep RAP and HRRR codes consistent.
- 4. Set the stage for future RAP/NAM ensemble.



<u>Issues/Risks</u>

Issues: cannot run every HRRR cycle in parallel

<u>Risks:</u> difficult to accurately verify model, now that some cycling is being added

Mitigation: must rely on supplemental ESRL statistics

Y <u>Scheduling</u>		
Milestone (NCEP)	Date	Status
Initial coordination with SPA team	02/20/2015 →3/3/2015	Complete
EMC testing complete / EMC CCB	03/15/2015 → 5/8 → 08/24 →11/13 → 1/15/2016	
Final Code Delivered to NCO	03/29/2015 → 5/26 →9/1 →11/20 → 1/22/2016	
Technical Information Notice Issued	4/13/2015 →6/1 →10/01 → 11/25 → 1/29/2016	
SPA begins prep work for 30 day test ** Requires 2 SPAs for this work	03/30/2015 →5/27 →9/2 → 11/23 → 1/25/2016	
30-day evaluation begins	5/4/2015 →6/29 →10/2 → 1/23/2016 → 3/28/2016	
30-day evaluation ends	6/2/2015 → 7/28 → 10/31 → 2/21/2016 → 4/28/2016	
IT testing ends	5/15/2015 → 7/15 →10/10 →2/15/2016 → 4/21/2016	
Management Briefing	06/19/2015 → 8/7 → 11/13 → 2/26/2016 →5/7	
Operational Implementation	6/23/2015 → 8/14 → 11/17 →3/1/2016 → 5/12	



Finances

Associated Costs: Funding Sources:

- HRRR and RAP task usage will both increase by 2x
- some additional AWIPS products will likely be added in conjunction with extension of forecast length





