MDE Product Development Team
December 2012 - 1st Quarter Report (FY 2013)
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(Compiled and edited by S. Benjamin and B. Johnson)

Executive Summary

Task 12.5.4: Develop, test, implement and improve the Rapid Refresh (RAP)

- RAP at NCEP continues to run without any problems during the October-December 2012 period. RAP has continued to show more reliability than the previous RUC.
- RAP version 2 running at GSD, continuing to yield improved upper-air wind/temp/RH forecasts over RAP-NCEP. The same is true for surface moisture and precipitation forecasts.
- Further changes in testing in development (not primary) ESRL RAP including data assimilation and modeling improvements. All of these will be included in final Rapid Refresh v2 (RAPv2) with implementation at NCEP, now proposed for late 2013 to early 2014 after NCEP implementation moratorium is lifted.
- There are 3 parallel RAP cycles (dev1, dev2, dev3) now running on the Zeus NOAA research supercomputer located in Fairmont, WV. (dev1 – updated land-surface model and surface roughness, dev2 – WRFv3.4.1 + MYNN PBL, dev3 – hybrid/ensemble data assimilation). ESRL is also running on Zeus a parallel 3-km HRRR as well as an experimental 2D RTMA surface analysis application using HRRR forecast as background.

Task 12.5.5: Develop/test/implement improvements to operational data assimilation supporting RAP/NAM

- Rapid progress (with help from EMC personnel) on use of 80-member GFS global ensemble data to help specify background error covariance information for RAP via ensemble hybrid method. New RAP version running in real-time parallel environment with this ensemble data assimilation (RAP-dev3) yielding upper level forecast improvement compared to real-time RAPv2.
- Presentation on latest RAP data assimilation work at NCEP Production Suite Review.
- Continued rapid progress on testing and evaluation of various RAP data assimilation (and model) changes within the four parallel real-time RAP cycles (one running on JET, three running on ZEUS).
- Positive results (reduction in upper-level high relative humidity bias without degradation to low-level ceiling verification scores) from refined cloud analysis procedure, through selective use Effective Cloud Amount parameter provided by the CLAVR-x (Clouds from AVHRR [Advanced Very High Resolution Radiometer] Extended) satellite data.
- Real-time experimental HRRR-based RTMA 2D surface analysis and RUA cloud analysis running on Zeus with graphics (including "analysis – background" plots) available on web and quantitative "fit to observations" verification.
- Multiple presentations on latest RAP data assimilation work at AMS Integrated Observing and Assimilation Systems (IOAS) Conference.

Task 12.5.8: Improve physical processes in WRF (RAP and HRRR) and NAM models, especially for icing

- Integration of bug correction into RAP/ WRF regarding lack of radiation effects from snow mixing ratio in atmosphere, which has been contributing to a daytime warm bias in the RAP and HRRR at the surface.
- Improved lower-troposphere and near-surface forecasts of especially of wind are now being produced from the GSD/Olson version of MYNN boundary-layer scheme.

Task 12.5.24: Develop / test / implement improved 3-km HRRR

- Continued progress and encouraging results from retrospective HRRR experiments using a 3-km, 15-min cycling, one-hour pre-forecast radar assimilation period, is now planned to be applied in the real-time HRRR for 2013.
- Initial tests of a fully cycled 3-km assimilation using GSI for the HRRR and 3D 3-km application for the Rapidly Updated Analysis (RUA).
- Multiple presentations on latest HRRR results at AMS Aviation, Range, and Aerospace Meteorology (ARAM) Conference in January.

Task 12.5.4 Develop, test, implement, and improve the Rapid Refresh

ESRL/GSD

Task 5.4 involves the integrated testing and development of the model, assimilation, post-processing, and script components of the Rapid Refresh. While some changes in the RAP may fall specifically with assimilation (Task 5.5) or model physical parameterizations (Task 5.8), under this task we consider the fully integrated effects of all components of the RAP. The changes and problem areas listed below involved such cross-component investigation and testing.

Regarding the NCEP RAP

The operational RAP at NCEP ran without any technical problems (including with the post-processing) during the quarter. The RAP continues to show improved reliability over the previous RUC at NCEP.

Ming Hu and Geoff Manikin report progress on getting the NCEP RAP converted over to the new WCOSS computer in collaboration with George Vandenberg and Geoff Manikin of NCEP. The main issue so far has been byte swapping in binary files (e.g., radar reflectivity) used in the preprocessing code. Solutions to this are available and tested, but they may not be the most efficient ones.

Regarding the ESRL RAP

GSD continued to evaluate the updated RAP version 2 at ESRL with its significant data assimilation and modeling modifications implemented in March 2012 and discussed in previous MDE reports. It was noted in many previous MDE reports that because of RAPv2's superior performance by the Storm Prediction Center's own verification measures the SPC had requested implementation of RAPv2 prior to the 2013 convection season. However, because of the current moratorium on new implementations due to conversion to the new Linux-based WCOSS computer and the anticipated backlog of implementations once the moratorium is lifted, the RAPv2 implementation will not occur until between late 2013 to March 2014.

Given this changed situation with regard to the next RAP implementation at NCEP, the two principal thrusts of RAP work at ESRL/GSD during the October – December quarter were toward:

1. Further improvements to the RAP in preparation for freezing the HRRR for the summer 2013 convection season and transfer of RAPv2 code to NCEP for pre-implementation testing later in 2013, and
2. Enhancements to the HRRR in preparation for 2013's convective season.

A major transition necessitated by change in the mission of the Jet computer in Boulder toward more dedication to NOAA's Hurricane Forecast Improvement Project turns out to be a step forward in GSD's capability for testing of both RAP and HRRR. This substantial effort was completed in October with transfer of developmental RAP cycles from Jet to the Zeus supercomputer at the NOAA Environmental Security Computing Center (NESCC) in West Virginia. Now there are three development RAP cycles running on Zeus in addition to the RAP primary that continues to run on Jet. The HRRR initialized from the RAP primary also continues to run on Jet.

Capitalizing on GSD's extensive verification capabilities, GSD is using a combination of parallel real-time cycles and 1-2 week retrospective runs to test various RAP enhancements and comparing these results against the ongoing RAPv2 configuration running in the RAP-primary on Jet. At present we are dedicating one of the Zeus cycles to testing involving GSI, and the other two for various model enhancements. Ongoing or planned near-term testing using the RAP-dev1 or RAP-dev2 cycles running on Zeus includes the following:

- WRF version 3.4.1 released in August (with GSD enhancements) in RAP-dev2: v3.4.1 proved easier to port than v3.3.1 and is running stably with the latest GSD mods to the MYNN PBL scheme (see task 8 for details on the latter)
- Modifications to the cloud analysis in RAP to use satellite cloud observations more completely and better account for partial cloudiness (task 5.5)
- New GSI background error covariance files (task 5.5) for the RAP

- Regional hybrid (ensemble) variational option in GSI applied to the RAP; this was highly successful (task 5.5)
- Major upgrades to the RUC land-surface model (LSM) and changes to surface roughness fields (more accurate 10m winds) and
- Various versions and name list options for the Grell convection (task 5.8)
- Modification of Goddard short-wave radiation to account for snow aloft (task 5.8)
- Latest version of the MYNN boundary-layer scheme with improved coupling to the RUC LSM (task 5.8)

We anticipate this ongoing work will lead to a version of the RAP within the next 2 months that will be significantly improved over the March 2012 version that, in turn, was a decided improvement over the RAPv1 that remains operational at NCEP.

Following the end of the summer 2012 CoSPA freeze period early in the quarter, we have been developing or testing several possible HRRR enhancements for both assimilation and model. This includes:

- A new radar assimilation procedure for the HRRR that promises improved HRRR forecasts in the first 1-4h; this will be part of the 2013 HRRR configuration
- HRRR direct 3km cloud analysis (instead of relying on 13km RAP cloud fields)
- Partial cycling of HRRR off of RAP using all available data, analogous to what is now done with the RAP partial cycling using GFS
- Comparison of Dudhia short-wave radiation (currently in HRRR, includes attenuation of short-wave radiation by snow) with Goddard short wave that includes the Greg Thompson fixes to include attenuation by snow.
- Nine-level vs. six-level RUC LSM configuration (beneficial at 3km HRRR as well as in 13km RAP)

More discussion of some of these is under appropriate tasks later in this report.

Other activities, some noted more fully under other tasks, also were undertaken during the quarter:

- Evaluation of the Earth Networks, Inc. lightning data for use as a possible alternative to the Vaisala GLD360 lightning product.
- Retrospective testing of satellite radiance bias corrections and choice of background error (Task 5).
- Tanya Smirnova and Steven Peckham worked with the NCAR WRF developers to ensure that GSD WRF enhancements for RAP are qualified for inclusion into the WRF repository. Some of these were checked into the NCAR WRF repository in early December and others are awaiting submission. We anticipate that most will become part of the WRFV3.5 release in spring 2013.
- Retrospective testing for both RAP and HRRR of the impacts of proprietary in situ tower wind data and other special data is underway under funding from the DOE Wind Forecast Improvement Project.

<u>Other details on the ESRL RAP</u>

An operating system upgrade on the Boulder supercomputer Jet resulted in a multiday outage of the HRRR in early December as Curtis Alexander and others spent several days to get HRRR (and its parent, the ESRL primary RAP) running reliably again with modified “WorkFlow Manager” scripts. This OS upgrade also appeared to have been the cause of failure of the code to update the SST for the GSD RAP cycles to the latest available high-resolution analysis from NCEP.

Work continued on upgrades to the GSD cloud analysis within the GSI. Several retro experiments were made during the quarter in an effort to allow assimilation of full-column satellite-based cloud fields without engendering a very strong middle-troposphere moisture (RH) bias. See Task 5 for more details.

Work, which had been started in September to test the latest WRF release (v3.4.1, released in August) continued. Getting the code to compile and run proved much less challenging than last year’s changeover to v3.3.1, in which we were also forced to continue use of the v3.2.1 Grell convective parameterization scheme to avoid serious degradation in RAP forecast performance for upper level winds. The newest Grell 3-d convective scheme (called the Grell-Freitas or G-F scheme after Saulo Freitas of Brazil, who has been collaborating with Georg) being

prepared for WRFv3.5 will also be tested retrospectively in the near future before a final decision is made regarding the RAP configuration to be used to initialize the HRRR for the 2013 convection season.

As part of the preparation for converting to the WRFv3.4.1 code, David Dowell ensured that the inline reflectivity code in the Thompson microphysics module was being used to compute reflectivity, rather than the outdated UniPost code.

Toward further improvement in the RAP and HRRR near-surface forecasts, Tanya Smirnova and Joe Olson found some bugs in the moisture-flux coupling of the MYNN boundary-layer scheme with the RUC land-surface model (LSM). These fixes, which served to reduce the flux, proved important in reducing the nocturnal development of low cloud over snow covered areas apart from that separately obtained by invoking the Katata fog deposition routine that had earlier been introduced into the MYNN. Tanya will be working with Steven Peckham of GSD to get these LSM changes as well as the surface roughness changes into the NCAR WRF repository for inclusion in the WRFv3.5 release scheduled for spring 2013.

The Thompson microphysics in WRFv3.4.1 introduced correctly accounting for the cooling effect of evaporation in unsaturated air on retarding the melting of snow. Now, snow only melts when the wet-bulb temperature of the air is > 0C.

A nearest neighbor procedure for interpolating hydrometeors from the 13km RAP grid to the 3km HRRR grid (as opposed to the former bilinear interpolation) in the WRF preprocessor successfully eliminated inflation in cloud coverage in the process of initializing the HRRR.]

12.5.4.1 Ongoing (NCEP, GSD)
Maintain hourly RAP runs and provide grids of SAV and AHP guidance products.

NCEP
Subtasks

12.5.4.1 Maintain hourly RAP runs and provide grids of SAV and AHP guidance products.

The primary RAP support for this quarter was the transition effort to the new WCOSS supercomputer. The entire RAP codes and scripts are being modified to run in the new environment, and the complete system is being pieced together on WCOSS. All codes have now been successfully compiled, and the ongoing effort is modifying scripts to allow the codes to run. The final steps will be to preserve run times and verify that the model output closely matches that from the current operational environment. (Manikin)

GSD
After having no non-radar data available for the GSD RAP primary cycle since the RUC stopped running operationally at NCEP on 1 May, early PrepBUFR files (with incomplete radiosonde observations) were again made available to GSD on 27 November by NCEP Central Operations (NCO) for the 00z and 12z RAP runs at ESRL to initialize the HRRR. This is noted in a FAQ webpage for the HRRR at **http://ruc.noaa.gov/faq/HRRR.faq.html.**

GSD continues to make pgrb and bgrb files from the ESRL/GSD RAP-primary (RAPv2) real-time 1-h cycle available from its FTP site for users in NWS and other labs).

12.5.4.2 Ongoing (NCEP, GSD)
Provide vendors with gridded model data via Family of Services and the FAA Bulk Weather Data Telecommunications Gateway.

NCEP
NCEP maintained real-time availability of SAV and AHP guidance to all vendors from the operational hourly RAP on pressure surfaces via the NWS Family of Services (FOS) data feed and via the FAA Bulk Weather Data Telecommunications Gateway (FBWDTG). (EMC&NCO)

12.5.4.3 Ongoing (NCEP, GSD)
Provide full grids from RAP runs on NCEP and NWS/OPS servers.

NCEP
NCEP maintained real-time availability of full resolution gridded data from the operational RAP runs via anonymous ftp access via the NCEP server site at **ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/rap/prod/** and at the NWS/OPS site at **ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/** in hourly directories named MT.rap_CY.00 through MT.rap_CY.23. This includes hourly BUFR soundings and output grids, which undergo no interpolation. Both sites now contain only grids in GRIB2 format **http://www.nco.ncep.noaa.gov/pmb/docs/GRIB1_to_GRIB2.shtml.** Gridded RAP fields are now also available on **NOMADS** for the CONUS domain on 13 km grid #130 and the larger North American domain on 32 km grid #221. A limited set of fields from the RAP runs (and other NCEP models) can also be viewed at **http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller**. (EMC&NCO)

12.5.4.4 Ongoing (NCEP, GSD)
Maintain access to model verification data.

NCEP
NCEP maintained its capability and provided access to routine verifications of the operational RAP analyses and forecasts. These include grid-to-station verifications versus rawinsonde, surface, aircraft, Profiler, and VAD data computed periodically at NCEP and accessible via NCEP's Mesoscale Modeling Branch website: **http://www.emc.ncep.noaa.gov/mmb/research/meso.verf.html** . (EMC)

12.5.4.5 Ongoing (GSD, NCEP)
Ongoing evaluation of performance of real-time and retrospective runs of RAP system for SAVs, AHPs

The Rapid Refresh was implemented at NCEP in 2012 and its performance is being routinely monitored. (Manikin)

GSD
GSD's verification of the RAP is available from **http://ruc.noaa.gov/stats**. Fig. 1 under 5.5 is taken from this verification run by ESRL, as are many of the figures from the recent presentation on the RAP/HRRR at the 4-6 December 2012 NCEP model review meeting - **http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf**

NCEP
The Rapid Refresh was implemented at NCEP on 1 May and its performance is being routinely monitored. (Manikin)

12.5.4.6 1 August 2012 **(ESRL, NCEP)**
NCEP will not accept code before 1 Feb 2013 so we will continue to report on this task until that time. Initial software for RAPv2 changes ready for porting to EMC.

GSD
COMPLETE. The RAPv2 code was indeed ready by 1 August 2012. As of Dec 2012, the RAPv2 version (now with further enhancements) running at GSD continues to perform well and fixes the most serious operational RAPv1 issues. Access to Tide, the development portion of the new IBM Linux-based WCOSS computer at NCEP has been granted by NCEP. Ming Hu has been working with NCEP on certain aspects of RAP data ingest as part of the conversion of RAPv1 to the WCOSS computer.

NCEP
The RAPv1 implementation delay put the RAPv2 upgrade is on hold until after the moratorium ends, no sooner than September 2013. Transition of RAPv1 and RAPv2 codes and scripts to the new WCOSS computers has begun and accounts for ESRL's RAPv2 developers have been granted. ESRL staff (Ming Hu) has been helping with NCEP staff to accomplish the WCOSS transition (Manikin)

12.5.4.7 31 Jan 2012 **(ESRL)**
Complete testing and evaluation at ESRL of new Rapid Refresh capabilities in model physics (see 12.5.8) and data assimilation (see 12.5.5, 12.5.15) toward consideration in the upgrade to the RAP (RAPv2) at NCEP in 2013.

COMPLETE - The configuration of the Rapid Refresh (RAP-primary at ESRL) for the summer 2012 was set in mid-March 2012. We therefore call this task "complete", but other improvements are being added and will be included in code for the RAPv2 that will be transferred to NCEP/EMC later in 2013.

12.5.4.8 31 May 2012 **(ESRL, NCEP)**
Porting of RAP code to NCOSS.

GSD
GSD has been helping NCEP with the WCOSS transition for RAP. GSD's experience in having been running RAP on the similar Zeus supercomputer has been invaluable.

NCEP
Part of this subtask will be to do the experiments necessary to decide which of these alternatives gives the more useful ensemble diversity for aviation application, by means of real-time and retrospective testing on the RAP domain. (31 May 12)

At the request of several NWS Forecast Offices, 6 sub-regions in CONUS and 4 sub-regions in Alaska were added to the NARRE-TL product display webpage. The source code and scripts of NARRE-TL were ported to new WCOSS machine, modified and successfully compiled. Tests of the NARRE-TL on WCOSS with a canned data set were completed and a comparison against the same runs on the CCS showed no difference in results. An RFC to implement the NARRE-TL on WCOSS was filed with NCO. (Binbin Zhou and Jun Du)

12.5.4.9 ~~**12 Dec 2012**~~ (28 May 13) **(ESRL, NCEP)**
Complete testing at EMC of RAPv2 code, pending NCEP readiness.

NCEP
RAPv2 is delayed due to the late implementation of RAPv1 and the NCEP WCOSS transition. ESRL has provided code to EMC for the GSI, and it will be tested by EMC in the new computer environment (WCOSS) in CY13. Initial tests on the existing computer (CCS) show that the code update leads to better fits to RAOB data and overall model improvement. Implementation is not likely to occur prior to June 2013. (Manikin)

12.5.4.9a Submit Request for Change (RFC) and modified codes for RAPv2 from EMC to NCO, pending NCEP readiness. (15 Jun 12)
RAPv2 is delayed due to the late implementation of RAPv1 and the NCO moratorium on model changes. Transition of RAPv1 and RAPv2 codes and scripts to the new WCOSS computers has begun and accounts for ESRL's RAPv2 developers have been granted. (Manikin)

12.5.4.10 Commence work toward rendering RAP code, including potential physics suite options, operable within the NEMS (NOAA Environmental Modeling System, which is based on the Earth System Modeling Framework (ESMF), in compliance with the Sept 2007 Rapid Refresh MOU between NCEP and GSD. (1 Jul 12) - Request: Defer until Jan 2013

GSD
Work on this project (modification of WRF-ARW to use NEMS/ESMF) will begin [at ESRL/GSD] when GSD's efforts with NEMS on the FIM global model are complete, a higher priority to allow incorporation FIM into a NEMS-based experimental global ensemble at NCEP. ESRL continues to work primarily on bringing the FIM global model into NEMS compliance and working with NCEP to make further modifications to NEMS. NEMS design for the global model will set the direction for making ARW NEMS-compatible. Based on this prioritization, Jan 2013 is a more realistic date for this task (S. Benjamin)

NCEP
Work on this project has begun [at ESRL/GSD] now that RAPv1 model was implemented at NCEP on 1 May. The practice of keeping dynamics and physics as separate components, a technical aspect of prior NEMS designs, has been broadened to allow their combination into a single solver. This was used successfully in the NMMB. ESRL is expected to take advantage of that in their efforts to include RAP in NEMS. (Black, DiMego)

12.5.4.11 Present improved plan for bringing ARW model code into compliance with then current version of NEMS. (30 Sep 12)

Discussions continue at GSD and at NCEP on how to use ARW within NEMS. It now appears that all agree that ARW will be used in NEMS without splitting physics and dynamics components, which will make this task far easier and straightforward.

Deliverables
All Option A unless noted otherwise.

12.5.4.E1 20 Dec 2011 (ESRL)
Report on Rapid Refresh status and plans to NCEP Operational Model Production Suite Review meeting.

Complete. Steve Weygandt and Curtis Alexander made a joint presentation on the RAP and the HRRR at the NCEP Production Suite Review 4-6 December 2012. Available at
http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf

12.5.4E2 (1 Feb 12) (Manikin)
Update documentation for operational Rapid Refresh.

CURRENT EFFORTS: The Rapid Refresh was implemented at NCEP on 1 May 2012 to replace the Rapid Update Cycle. (Manikin)

PLANNED EFFORTS: Item is completed.

12.5.4E3 1 Mar 2013 (**GSD)**
Final code ready for transfer to EMC for Rapid Refresh upgrade change package to be implemented in (new wording) late 2013 to early 2014.

CURRENT EFFORTS: Work on this project will begin once the operational RAPv1 model is transitioned to the new NCEP WCOSS supercomputer. (Manikin)

PLANNED EFFORTS: Convert RAPv1 to new NCEP computer then bring in RAPv2 for testing and implementation in FY13.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation delayed the RAPv2 upgrade until after the moratorium, likely no sooner than June 2013. Move this deadline to 1 March 2013.

12.5.4.E4 (**30 Mar 12)** **(ESRL)**
Report on testing of RAP assimilation/model improvements toward planned RAPv2 upgrade.

COMPLETE.
GSD has made numerous reports on the RAPv2 improvements, most recently in the NCEP Model Reviews in December 2012 **http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf.**

NCEP

12.5.4E5 (modified to 30 Sept 2013) (Manikin)
Pending computer resource availability, complete testing at EMC of Rapid Refresh version 2 changes to operational RAP at NCEP.

CURRENT EFFORTS: Work on this project will begin once the operational RAPv1 model is transitioned to the new NCEP WCOSS supercomputer. (Manikin)

PLANNED EFFORTS: Convert RAPv1 to new NCEP computer then bring in RAPv2 for testing and implementation in FY13.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation delayed the RAPv2 upgrade until after the moratorium, likely no sooner than Sept 2013. Move this deadline to 30 Sept 2013.

12.5.4E6 (ongoing) ESRL, NCEP
Perform configuration management for Rapid Refresh, including thorough documentation, and respond promptly to any code malfunctions or performance issues. No major changes were needed to the RAP during the final quarter of 2012. RAP questions continue to be posted and answered under the RAP forum at **http://ruc.noaa.gov/forum/eval/**. NCEP has coordinated a change on 19 Nov 2012 toward full hourly output from NWS (details under **http://www.nws.noaa.gov/om/notification/tin11-19aab_ruc.htm**). Yet another change to increase precision of RAP surface pressure fields was planned for 27 Nov – details under **http://www.nws.noaa.gov/om/notification/tin12-51rap_bgrb.htm**.

CURRENT EFFORTS: Work is underway to make the transition to the new NCEP supercomputing environment. The operational Rapid Refresh codes must first be modified to successfully compile. Then work will begin on script modification needed to run the model on the new system. WCOSS accounts for ESRL's RAPv2 developers have been granted. (Manikin)

PLANNED EFFORTS: Implementation of the RAPv2 will have to wait until after the moratorium during which all of NCEP Production has to be moved to the WCOSS. The moratorium will last from September 2012 through at least the end of May 2013.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

12.5.4E7 Ongoing ESRL, NCEP
Monitor Rapid Refresh performance, respond to any problems detected by ESRL, NCEP, or any RAP users, diagnose cause, and develop solution to RAP software, test changes and coordinate with NCO on implementation.

CURRENT EFFORTS: The Rapid Refresh performance is being monitored daily. (Manikin)

PLANNED EFFORTS: Convert RAPv1 to new NCEP WCOSS then bring in RAPv2 for testing and implementation in FY13.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: Since RAP was developed on a Linux based computer at ESRL/GSD, no major problems have been encountered.

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

12.5.4.E8 30 Nov 2012 (ESRL/GSD)
Report on overall planned changes for the FY13 upgrade to the Rapid Refresh.

COMPLETE. Report (from NCEP model review in early Dec 2012) is available at
http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf

Task 12.5.5 Develop, test, and implement improvements to the operational data assimilation supporting Rapid Refresh and North American Mesoscale runs.

ESRL/GSD
Work proceeded on several fronts:

1. With assistance from EMC personnel, Ming Hu made rapid progress in his work to test application of the GSI hybrid ensemble capability to the Rapid Refresh, using ensemble information from the 80-member global GFS ensemble data assimilation system. Following initial single observation tests, Ming made code and script changes to include this capability in a real-time parallel RAP system on Zeus (Dev3), using a blending factor for 0.5 for weighting the ensemble-based background error covariance relative to the standard 3DVAR formulation. Results have been very encouraging with significant reduction in upper-level forecast errors for relative humidity and especially winds. Fig. 1 shows the forecast impact from use the hybrid ensemble for +6 hour forecast from the first 5 days of use in a real-time cycle. Results are most impressive for winds, followed by relative humidity with less impact (though still positive) for temperatures. For some forecast times, there has been some degradation in forecast skill at low-levels and work is ongoing to investigate the cause and mitigate this degradation.

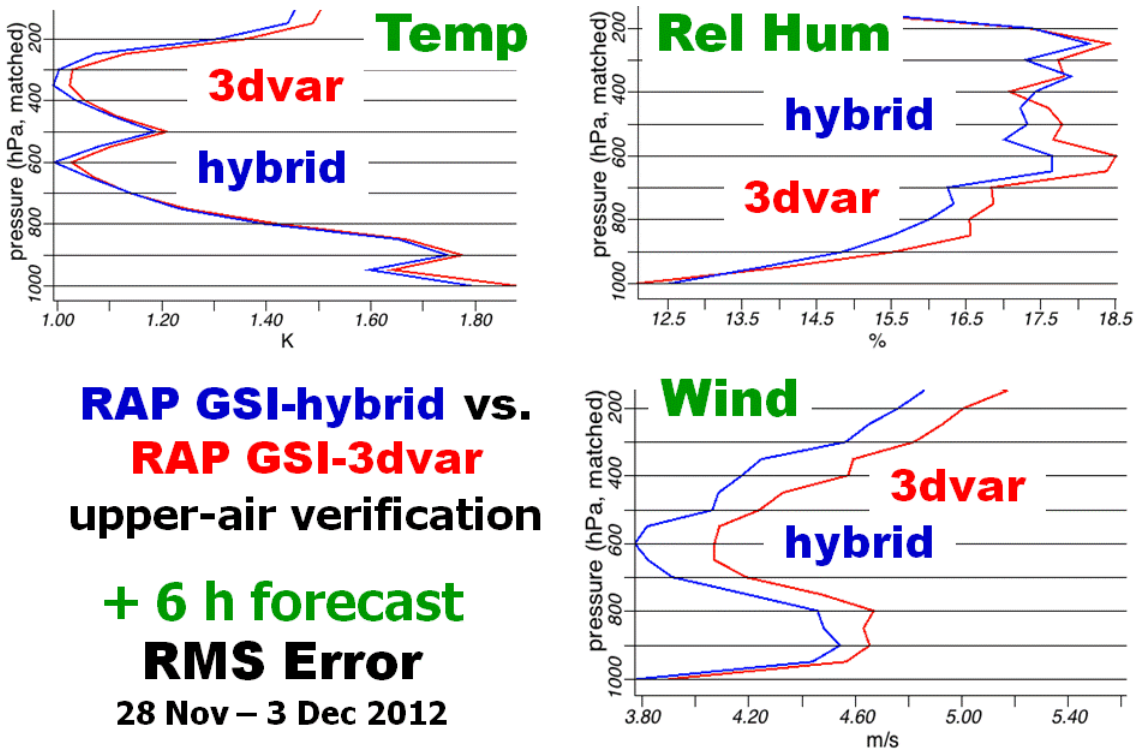


Fig. 1. Comparison of +6 hr. upper-air forecast skill (verified against radiosonde data) for a real-time parallel cycle using the hybrid ensemble (EnKF) data assimilation (with ensemble information from the 80-member global ensemble DA system) [blue curve, "hybrid"] against the primary RAP v2 real-time cycle

using a standard GSI 3DVAR configuration [red curve, "3dvar]. Similar results were found with a longer 30-day period (22 Nov to 22 Dec).

2. Extensive scripting other work was completed to enhance the reliability of the real-time "dev" RAP on Zeus, so that it is running with nearly the same reliability as the GSD JET "RAP-v2". Also two additional real-time dev RAP cycles were added to the Zeus system, allowing more rapid real-time evaluation of potential upgrades to the RAP.

3. With help from NCEP personnel, Patrick Hofmann and GSD colleagues now have an HRRR-based real-time "RTMA (Real-Time Mesoscale Analysis)" surface analysis running on Zeus. Also, Ming Hu and colleagues at GSD now have a real-time "RUA (Rapidly Updated Analysis)" cloud analysis running on Zeus. Graphical output from both of these analyses is available on the GSD website at: **http://rapidrefresh.noaa.gov/hrrr_dev1/**

    - [For the RTMA, select "HRRR dev1 RTMA" under the model header and for the RUA, select "HRRR dev1 RUA" under the model header]. The RTMA analysis with a HRRR background will allow NOAA/NWS to provide a much-improved surface analysis and surface frontal diagnostic products for aviation applications including CoSPA. A recent addition is the creation real-time "analysis – background" plots, which has been helpful in examining the analysis performance. Also, a quantitative fit to observation verification has recently been added, confirming that the RTMA more closely fits the observations that the HRRR.

4. Haidao Lin has completed additional tests to evaluate aspects of the bias correction and channel selection challenges for mesoscale assimilation of AIRS data within the RAP (using GSI) and presented results from this work at the Joint Center for Satellite Data Assimilation (JCSDA) workshop in October and in the AMS Annual Meeting in January 2013.

5. Several GSD/AMB scientists visited the NCEP Environmental Modeling Center in both October and December for a series of meetings to discuss various aspects of mesoscale modeling and especially assimilation. Haidao Lin served as AMB lead for several meetings with EMC/JCSDA satellite data assimilation experts to discuss aspects of mesoscale data assimilation, including bias correction, and channel selection / model top blending. Ming Hu was AMB lead for several meetings on topics including among others hybrid ensemble DA. Patrick Hofmann was AMB lead for meetings pertaining to the RTMA and surface analysis.

6. Associated with the December visit, Steve Weygandt, Curtis Alexander, and Stan Benjamin gave a combined presentation at the NCEP Production Suite Review overviewing recent progress on the RAP, HRRR, and FIM weather prediction systems. The PPT slides for this presentation can be found at **http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf**

7. GSD personnel made a number of presentations on RAP-related data assimilation work at the various conferences associated with the AMS Annual Meeting.

They can be accessed at: **http://ruc.noaa.gov/ppt_pres/AMS_2013**

Subtasks

12.5.5.1 31 Dec 2011 (GSD)
Further refinement to the radial velocity analysis component of GSI for Rapid Refresh 2 configuration.

Completed. Results from inclusion of radial velocity data assimilation in parallel versions of the RAP conducted in late 2011 and early 2012 still showed generally neutral impact.

12.5.5.1a 30 Oct 2012 (ESRL, NCEP)
Complete preparation of initial GSI changes for RAPv2 changes ported to EMC.

ESRL
Changes are complete and in the real-time experimental RAP-v2 running on the GSD JET supercomputer. Changes are ready for transfer to the NCEP WCOSS computer as soon as the transitional moratorium is lifted.

Looking back as an overview, work on RAPv2 was delayed, due to delays in implementation of RAPv1 (completed May 1, 2012). Considerable work on this occurred during Oct 11 – Mar 12 at GSD. A nearly complete version 2 of the RAP was frozen at GSD in March for the 2012 CoSPA season (parent to the HRRR). This version includes many improvements to the analysis (use of pseudo-innovations for surface moisture, soil temperature and moisture adjustment based on surface innovations, conservation of virtual potential temperature in moistening associated with cloud building, limits of precipitable water innovations) that have resulted in better precipitation and moisture forecasts. With the NCEP computer implementation moratorium now expected to last into Spring 2013, additional work toward RAPv2 enhancements will resume following the end of ESRL RAP summer evaluation code freeze (Oct. 31). Key aspects include improved cloud analysis to allow cloud building at upper levels without introducing a moist bias, improved background error covariance specification (from either generation of new RAP-specific background error covariance files using GEN_BE or from use of global EnKF-based background error covariance files). Other work has included retrospective testing of use of expanded AMV observations (yielded slight impact) and continued evaluation of modification to the cloud building procedure (use of effective cloud amount to determine a cloud fraction for use in limiting the cloud building region).

12.5.5.1b 31 Dec 2011 (GSD)
Complete initial testing at ESRL of improved satellite radiance assimilation capability (bias correction, time windows, etc.) for RAPv2.

Initial bias correction work was previously completed with forecast improvement evident. Ongoing retrospective testing led by Haidao Lin to evaluate further enhancements from the bias correction. All this work is being done on the new supercomputer, Zeus, following successful transition of RAP to Zeus. Additional work by Haidao Lin has included running a two-month retro to examine bias correction spin-up issues for various instruments, channels, and predictors within the RAP system. Results confirm that some of the bias correction coefficient predictors for some instrument channels rapidly stabilize, but for others that are not stabilized even at two months. This is presumably due to the limited data coverage for the various satellite radiance types over the limited regional domain. Despite these bias correction predictor spin-up issues, retrospective tests showed worse forecast verification scores (against raobs) without the cycled bias correction coefficient predictors.

12.5.5.3 Implement proper vertical covariance localization and test the hybrid DA system using EnKF covariance. (Completed 31 Jan 2012)

NCEP
EnKF members are being used in the NAM parallels on CCS and NOAA R&D which take advantage of the simple hybrid approach for background error covariance specification in the GSI. Testing a full-blown regional EnKF data assimilation system is planned for FY13. (Wu, Rogers)

12.5.5.4 31 Aug 2012 (ESRL) COMPLETED
Complete testing of GSI changes for RAPv2 at ESRL.

This task is considered to be complete because the original set of changes for RAPv2 will been completed and extensively tested in the ESRL real-time experimental RAP/HRRR (frozen since Spring 2012).
Results from this test evaluation show substantial improvement in near surface and convective environmental fields. However, with NCEP unable to implement RAPv2 until late 2013 or early 2014, ESRL will continue to test additional RAPv2 enhancements into 2013, and these changes will all go into the NCEP implementation of RAPv2.

12.5.5.5 1 Feb 2012 (GSD, NCEP) COMPLETED
Test version of GSI appropriate for 3-km High-Resolution Rapid Refresh (HRRR) configuration, including use of level-2 radar radial wind and reflectivity data.

GSD
This task was completed in January 2012. However, work continues in improving the 3km GSI assimilation since that time.

Work continues to optimize the 3-km sub-hourly assimilation procedure for real-time application. In the system, a one-hour pre-forecast integration is completed, in which 4 application of the diabatic DFI-based radar assimilation is completed. The WRF ARW code has been modified to accomplish within a single model executable. At present, however, four separate applications of the GSI (over the 3-km HRRR domain) are needed to create the radar reflectivity-based temperature tendency arrays. We are currently investigating needed changes to the GSI cloud analysis to allow all for the creation of all four of these temperature tendency arrays at a single time. The change would significantly reduce run-time for this pre-forecast spin-up period, increasing the likelihood that we can run it in real-time. It was decided to NOT include this in the operational version of the HRRR for spring/summer 2012.

Ming Hu has recently successfully run this 3-km GSI cloud analysis on both ESRL JET and ZEUS supercomputers, getting about 4 min run time (64 cores on JET, 72 cores on ZEUS). David Dowell continues to evaluate different strategies for 3-km radar data assimilation using GSI. Ming Hu is examining impact of 3-km cloud analysis on HRRR forecasts.

Work continues on this task, with completion of 3-km GSI analysis including specification of precipitation hydrometeors from radar reflectivity data. Output files from these analyses will be provided to Ken Howard and MRMS team as part of the coordinated work toward the Rapidly Updated Analysis (RUA) product. Work has progressed on two closely related tasks: 1) Work by Patrick Hofmann (in conjunction with Manuel Pondeca – NCEP/EMC) in testing of the 3-km 2DVAR "RTMA type" analysis using HRRR background fields and 2) Work by Ming Hu/David Dowell/Curtis Alexander in running a 3-km GSI analysis to support sub-hourly (15-min) 3-km pre-forecast radar assimilation cycling experiments. Curtis Alexander reported results of this at the AMS Severe Local Storms Conference in Nashville. Follow-up work continues with encouraging results (see task 5.24 for details)

NCEP
Testing of the radar data decoder for dual-polarity variables continued. Parallel testing began on the new QC package and decoder. The new QC package tends to reject more data, and more "blue disks" in reflectivity were rejected. Some of the radar data cannot be decoded properly with either the new or old decoders so NCEP will fix its new decoder. The new Doppler radar (dual pol) Level2 decoder was modified to handle incomplete data volumes. When a volume scan is not completed normally, the new decoder will still build a whole volume scan and give missing values to the incomplete scans. Due to a difference in scan strategies, both the decoder and the QC package had to be modified to handle all scan modes. (Shun Liu)

12.5.5.6 ***change to Jun 2013*** **(GSD)**
Complete testing of Rapid Refresh GSI modifications for RAPv2 at EMC, transfer code to NCO, pending NCEP readiness.
Delays in the initial Rapid Refresh implementation will delay the Rapid Refresh upgrade to FY2014
A large set of changes to reduce the high bias in RAP moisture and precipitation forecasts has already been fully tested and included in all three ESRL GSD real-time parallel RAP runs and is in the frozen code for the RAP that serves as the parent for the HRRR in the summer 2012 real-time evaluation.

Dec 2012 update – additional RAP data assimilation (and model) changes are being tested and evaluated within the four GSD real-time parallel cycles and within retrospective runs and will soon be frozen for 2013 RAP/HRRR evaluation. These changes include use of information from the 80-member global ensemble to provide anisotropic error covariance information within the GSI hybrid assimilation system and enhancements to the cloud analysis to enable full-column cloud building.

12.5.5.7 ***changed to September 2013*** **(NCEP, ESRL)**
Submit Request for Change (RFC) and modified GSI code for RAPv2 from EMC to NCO, pending NCEP readiness.
A package of revisions from ESRL/GSD was committed to NCEP's GSI repository in 2012 for the 2013 implementation. The changes that were made follows: Add aircraft observation rejection list to toss bad aircraft

temperature, wind, and moisture observations; Add PBL pseudo observations based on surface temperature, moisture, (181,187,183) and wind (281,283,287); Add subroutine to calculate PBL height, which will be used in PBL pseudo observation and cloud analysis; Linear variation of observation error inflation below surface for q, t; Add code in speed observation innovation calculation to use observation height instead of pressure to get observation vertical grid coordinate; Add additional QC for PBL profiler 223, 224, 227; Limit the low level moisture analysis increment over ocean; Update the START_TIME for ARW NetCDF format to reflect the right analysis time; PW adjustment based on the terrain and the innovation limitation; Enhancements and bug fixes to the GSD cloud analysis; and Bug fix for reading cloud observation in setuprhsall.f90. (Manikin, Wu, Lueken, Hu (GSD)

12.5.5.9 31 May 2012 (NCEP and GSD)
Report on testing of 2DVAR GSI assimilation of high spatial and temporal mesonet surface data using analysis grids with 2.5-km or finer resolution and HRRR as background. (Possible 15-minute update for RTMA to support CoSPA, pending Convective Weather PDT support.)

NCEP
All six operational RTMA models (CONUS-5km, CONUS-2.5km, Alaska-6km, Hawaii-2.5km, Puerto Rico-2.5km, and Guam-2.5km) have been successfully tested on the WCOSS machine. Substantial changes were made to the RTMA post-processing in order to reduce the code's excessive memory usage. Work has been initiated to enhance the observation blacklists and accept lists generated from the RTMA innovation statistics. This idea tests the sensitivity of the lists to the geographical restriction applied in selecting the METAR observations used to compute the baseline statistics. (Manuel Pondeca, Steve Levine)

GSD
Manuel Pondeca at NCEP provided the 2DVAR configured GSI code and some guidance to Patrick Hofmann at GSD, who has completed basic tests of a version using the HRRR model as input and modified the scripts to be consistent with the GSD RAP run environment on JET and ZEUS. Related work on this has been completed by Ming Hu, who has run a 3-km version of the full 3DVAR and used these fields to initialize the HRRR,

Follow-up work by Patrick Hofmann continues, with an HRRR-based 3-km RTMA now running in real-time on Zeus and real-time graphics and verification.

Dec 2012 update – HRRR-based 3-km RTMA continues to run in real-time with web graphics (including A-B plots) and verification. Verification shows that the 3-km GSI-based RTMA analysis better fits the surface observation (especially for winds) that the 1 hour HRRR forecast (background fields for the analysis).

12.5.5.10 1 Jan 2013 (CAPS, ESRL)
Develop dual-resolution capabilities of EnKF and test it for RAP configurations.
CAPS has developed a dual-resolution system and obtained good results and recently submitted a manuscript for publication on the work.

GSD developed and tested a full resolution version EnKF for RAP during the spring 2012. Results indicated too little spread within the ensemble and an associated degradation in forecast skill. Results were presented at the Numerical Weather Prediction Conference in Montreal in late May 2012 and follow-up tasks to increase the ensemble spread were identified. In fall of 2012, related work to use global ensemble information from the GFS ensemble data assimilation system was begun and has rapidly progressed, yielding impressive gains in upper-level forecast verification. Follow-up work to evaluate the potential value added from use of a regional ensemble over use of just global ensemble information will occur in 2013. GSD will work with NCEP on this task.

12.5.5.11 *Changed to 31 Dec 2012* (EMC, ESRL) (Task modified due to unavailability of CAPS for most of FY12)
Complete initial test of 13km EnKF/hybrid results using background error covariance derived from a regional ensemble.
GSD

Ming Hu has now obtained very encouraging results from real-time tests of the 13km RAP in an EnKF mode using the background error covariance derived from the 80-member GFS ensemble data assimilation system.

This result will be compared from 2 other options:

1. New fixed background error covariance derived from RAP forecasts over a 6+-month period using the GEN_BE (i.e., GENerate Background Error).
2. Evolving background error covariance from a regional data assimilation ensemble. As reported earlier,

Ming Hu has built a 40-member 13-km RAP EnKF / hybrid data assimilation system on ZEUS and completed a 4 day retrospective test. Initial examination of results indicates too small a spread.

As part of this comparison of the sensitivity of the RAP EnKF / hybrid ensemble to choice of regional vs. global covariance fields, issues associated the small spread in the regional ensemble will be addressed (see task 12.5.5.10)

Further work to evaluate the sensitivity of the RAP EnKF / hybrid ensemble to choice of regional vs. global covariance fields awaits resolution of the small spread issue (see task 12.5.5.10)

NCEP
The analysis code with hybrid variational-ensemble ability was ported to the WCOSS computer. Code changes were necessary to run GSI on this little endian machine. The regional HYBENS options were put in when dual resolution was not available. Since the dual resolution was functional, the code needed to be cleaned up for the options to work with dual resolution and these code changes were completed. (Wan-Shu Wu)

12.5.5.12 31 July 2012 (NCEP)
If authorized by NCEP Director, implement initialization of the convection-resolving NAM nests and HiResWindow runs using CAPS/Shun Liu improved techniques for radial velocity analysis in GSI together with Diabatic Digital Filter use of 88D reflectivity Mosaic.

NCEP
It was found that the derived temperature tendency from the cloud analysis package is noisy, so a filter was added to the derived temperature tendency. The performance of this change was tested and had a neutral forecast impact. NDAS scripts and GSI codes used in NDAS were modified to use GSD's cloud analysis package. The NMMB with digital filter was run with current NDAS parallel scripts and the cloud analysis package was merged into GSI codes used by NDAS parallel. The cloud analysis package is being merged into GSI codes on the NOAA R&D machine. (Shun Liu)

12.5.5.13 31 July 2012 (NCEP)
Based on case-study testing and refinement of the research quality code, deliver result in an 'experimental' code for an upgrade package (e.g. improved satellite channel bias correction, improved use of WSR-88D radial wind and/or satellite radiances and/or retuned covariance's to the GSI for FY2013 change package to the NAM.

NCEP
Two versions of the GSI code were ported to NCEP's new WCOSS computer system and tested. The GSI version that will be used with the global system produced very different analysis results from the operational NDAS running on CCS. These differences will preclude use of this code in the NDAS/NAM on WCOSS, and will have to go into operations in the next upgrade following the completion of the WCOSS transition. The current operational NDAS/NAM GSI [with a bug fix] was also ported to WCOSS and produced similar results to CCS. Both versions ran successfully on WCOSS. After parallel tests with neutral impact on the NOAA R&D computer, the new GPS refractivity data and radiances from GOES 15 were included in the official CCS NDAS parallel. The IASI Metop-A ozone channels inadvertently used in both the operational global and the regional assimilations were turned off in the NDAS parallels to fix this error for the next implementation. The ozone field value input to the radiative forward model CRTM in the regional analysis was zero instead of undefined, which would allow the use of climatology values inside CRTM. Since GSI initializes the first guess fields, ozone values of zero were used in the radiance forward model in the regional analysis. Off-line parallels were set up to test the impact of using ozone from the global system in the NDAS CRTM, and this fix produced no impact on the NDAS forecasts. A possible reason why the system works with this bug might be that the ozone contribution was taken into account through the

radiance variational bias correction. The variational quality control in NDAS was tuned and the impact parallel test was set up and run. (Wan-Shu Wu)

Testing of enhancements in the use of satellite radiance data in the NDAS continued. Initial cycling tests without 84-hr forecasts indicated improved use of radiance data in the NDAS. Parallel tests with 84-hr forecasts and verification started running on the NOAA R&D system at the end of the quarter. (Zhu, Parrish)

12.5.5.14a 1 August 2012 (CAPS, ESRL)
Explore the use of time-lagged ensemble for increasing the ensemble size within the EnKF and EnKF hybrid.
Oct 12 update -- Ming Hu has completed Initial single-observation tests of promising approach to regional EnKF hybrid of using of global ensemble members to provide BEC information.

Further work to evaluate the sensitivity of the RAP EnKF / hybrid ensemble to use of time-lagged ensembles awaits resolution of the small spread issue (see task 12.5.5.10)

12.5.5.15 30 August 2012 (GSD, NCEP) COMPLETED
Finalize the multi-scale multi-pass configuration for analyzing radial velocity and other data. Report initial results with RAP and HRRR testing.

GSD
Oct. update -- Additional more extensive testing has been completed by Curtis Alexander including application of a fully cycled 15-min. updating GSI applied at 3-km.

As reported earlier, David Dowell, Curtis Alexander, and Eric James has completed experiments with a series of second pass 3-km analyses at 15-min. intervals during a one-hour pre-forecast cycle to initialize the HRRR. Initial tests have only included use of radar reflectivity data and the forward model portion of the radar DFI code and yielded modest improvement in the first few hours of the HRRR forecast. Separately, Ming Hu has run the full GSI over the 3-km HRRR domain, assimilating all observations, successfully demonstrating the practicality of running the full GSI on the full 3D 3-km HRRR domain. Follow up work will focus on conducting controlled experiments to evaluate the forecast impact from this 2nd pass of the full GSI on the 3-km domain for inclusion of specific observation types (radial velocity, surface observations, etc.)

NCEP
No new report this month.

12.5.5.E1 1 April 2012 (GSD)
New version of GSI including revised radial wind assimilation ready for NCEP for RAP upgrade.

COMPLETE: RAP retrospective tests with inclusion of level radial yielding neutral forecast impact, resulting in inclusion of these data in frozen version 2 of RAP. Code transfer to NCEP delayed due to postponement in NCEP implementation of RAP version 1.

12.5.5E3 Changed to 28 June 2013 **(ESRL)**
Final GSI code transfer complete to EMC as part of Rapid Refresh v2 package to be implemented later in FY13

ESRL
Final GSI upgrades are now in testing in experimental versions of the RAP. The main modification to GSI

NCEP
CURRENT EFFORTS: Initial GSI code transfer from ESRL/GSD was accomplished after the RAPv1 was implemented in May 2012.

PLANNED EFFORTS: Convert RAPv1 GSI code to WCOSS then start testing RAPv2 GSI code.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation will delay the RAPv2 upgrade until after the moratorium, likely no sooner than Sept 2013. Move this deadline to 28 June 2013.

Deliverables

12.5.5.E1. Perform systematic tests and fine tune EnKF and EnKF-GSI hybrid DA systems for RAP grid, running at 1/3 of the RAP resolution for computational efficiency (CAPS) 9/30/2012

Ming Hu has obtained very encouraging results from real-time tests of the 13km RAP in an EnKF mode using the background error covariance derived from the 80-member GFS ensemble data assimilation system. This capability is being further evaluated in a real-time parallel RAP cycle and is a very likely candidate for inclusion in the version of the GSD RAP that is frozen for 2013 evaluation.

12.5.5.E2. Report on initial results of the EnKF and hybrid DA systems for the RAP configuration (CAPS, ESRL) 9/30/2012

During this quarter, efforts were made to tune the configuration settings of the EnKF system including vertical localization and fixed inflation coefficient for the assimilation of Advanced Microwave Sounding Unit-A (AMSU-A) satellite radiance data. Dozens of EnKF experiments with different inflation and localization parameter combinations were conducted. Until now, for experiments within EnKF framework, the best results verified against sounding data shows that the assimilation of AMSU-A reduces the forecast errors of RH, U and V, but increases the forecast error of T slightly within the first 12 hours of forecast. When verified against surface station observations, the EnKF experiment with AMSU-A is either comparable or better than the one without radiance assimilation.

In December, we further investigated the AMSU-A impact on the 13 km grid precipitation forecast. All the experiments were rerun using the latest GSI and EnKF version, which we upgraded in the last quarter. Fig. 2 shows the averaged GSS scores of all the 13 km precipitation forecasts. For the small threshold 0.1mm, the assimilation of AMSU-A consistently improves the precipitation forecast skill for both EnKF and GSI DA. For the high threshold 2.5 mm, the assimilation of AMSU-A improves the forecast for most of forecast hours. For comparison between EnKF and GSI, the EnKF experiment with AMSU-A is still better than corresponding GSI experiment for most of forecast hours, especially in the first few hours forecast. However, the GSI seems to benefit more from the assimilation of AMSU-A data.

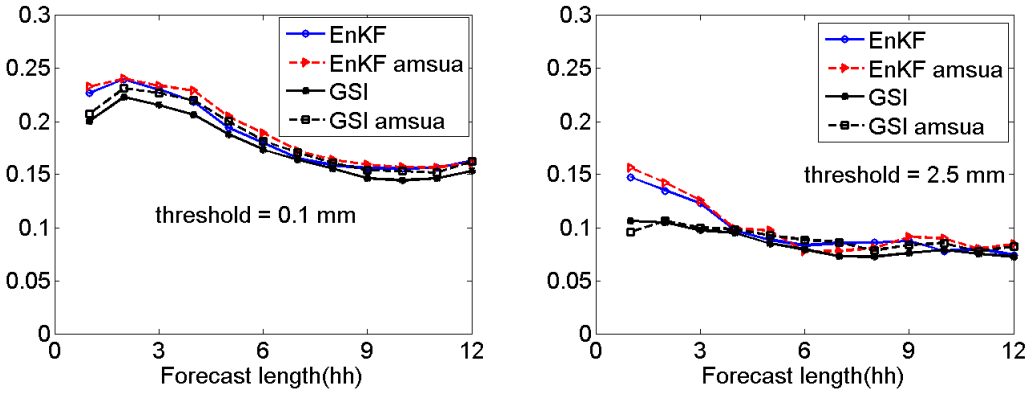


Fig.2. Average hourly precipitation GSSs of RAP 13-km forecasts for thresholds (left) 0.1 mm h^{-1}, and (right) 2.5 mm h^{-1}.

In the last quarter, we hypothesized that the height- and observation-type-dependent localization used in pure EnKF was responsible for the difference between the hybrid with full flow-dependent covariance and the pure EnKF. Earlier in this quarter, we implemented the height dependent localization into the GSI-hybrid. To see if that is true, we ran EnKF-hybrid analyses in multiple steps, with each step using only a group of observations having the same localization, just like pure EnKF; the difference between the pure EnKF and hybrid analyses became

much smaller, confirming our hypothesis. Running EnKF/hybrid pairs in multiple steps (which is desirable) is expensive, indicating one less flexible aspect of the hybrid algorithm compared to the serial EnKF algorithm.

Because of a drastic reduction of funding support to CAPS starting from October 2012, progress will be much slower unless a similar funding level is restored.

12.5.5E3 (Changed to 1 Mar 2013) (NCEP)
Final GSI code transfer complete to EMC for Rapid Refresh v2 change package to be implemented in spring 2013. (Combined with 12.5.5E1)

CURRENT EFFORTS: Initial GSI code transfer from ESRL/GSD was accomplished after the RAPv1 was implemented in May 2012.

PLANNED EFFORTS: Convert RAPv1 GSI code to WCOSS then start testing RAPv2 GSI code.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation will delay the RAPv2 upgrade until after the moratorium, likely no sooner than May 2013. Move this deadline to 1 March 2013.

12.5.5.E4 1 Sept 2013 (GSD, NCEP)
Pending EMC, and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit GSI code as part of upgrade for Rapid Refresh v2 software to NCO, pending NCEP readiness.

ESRL
Progress with RAPv2 at ESRL is very promising and would allow this schedule, pending NCEP's readiness to start testing and NCEP's need to get in some other implementations with RAPv2 implementation not having occurred until 1 May 2012.

NCEP
CURRENT EFFORTS: Work began on RAPv2 after the RAPv1 was implemented on 1 May 2012.

PLANNED EFFORTS: RFCs will be filed after the moratorium, likely no sooner than May 2013.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation have delayed the RAPv2 upgrade until after the moratorium, likely no sooner than Sept 2013. Move this deadline to 1 Sept 2013.

12.5.5.E5 Change to 1 Sept 2013 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RAP at NCEP.

ESRL
Request for date change to Sept 2013 per delays forced by NCEP's moratorium during its change to its new WCOSS computer.

NCEP
CURRENT EFFORTS: Work will begin in earnest after the moratorium in 2013.

PLANNED EFFORTS: Transition the RAPv1 onto WCOSS, then test RAPv2, which runs on Zeus in the meantime.
PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation have delayed the RAPv2 upgrade until after the moratorium, likely no sooner than Sept 2013. Move this deadline to 1 Sept 2013.

12.5.5.E6 Feb 2013 (EMC, ESRL)
Report on the results of EnKF and hybrid DA systems for the RAP and future NARRE configuration.

CAPS has not been available for MDE work in FY12 until the last quarter due to a contractual agreement problem. EMC and ESRL will provide some initial results in their Q4 MDE reports. Encouraging results from OU/CAPS dual-resolution (40/13 km) test and good progress by Ming Hu on building 13-km test system (see subtask 12.5.5.10). Ming Hu and CAPS personnel presented summaries of this work at an ensemble data assimilation workshop in late April.

GSD and EMC personnel met at NCWCP on 9 Oct. and discussed NARRE configuration aspects with emphasis on data assimilation (DA). DA Options include each system having it own data assimilation or more likely a shared ensemble hybrid DA system. Configuration options include use of background error covariance (BEC) information from the global EnKF system (much less expensive computationally, but may poorly represent mesoscale covariances) and running a regional ensemble for DA (may do better with regional covariance, but much more computationally expensive). Initial testing is focusing on use of global EnKF BEC information.

As noted above, AMB has recently obtained very encouraging results from use of the global ensemble data in a RAP hybrid ensemble system. Initial real-time tests show a significant reduction in upper-level forecast verification (against raobs). This capability is being further evaluated in a real-time parallel RAP cycle and is a very likely candidate for inclusion in the version of the GSD RAP that is frozen for 2013 evaluation and the RAP version 2 planned for NCEP implementation in late 2013 to early 2014.

CURRENT EFFORTS: Based on the degree of success of the simple use of global EnKF ensembles in specifying the background error in GSI in the NAM parallel testing, EMC has recommended in October 2012 that RAPv2 consider using this technique which is readily available now in the GSI. ESRL immediately followed that advice and started successful real-time RAP testing using global ensembles for hybrid assimilation.

PLANNED EFFORTS: Work will begin after the RAPv1 is ported to WCOSS and RAPv2 is running there as well.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: Delays in the initial RAPv1 implementation have delayed the RAPv2 upgrade until after the moratorium, likely no sooner than Sept 2013

12.5.5.E7 1 July 2013 (NCEP) (deferred to mid 2013 from original deadline)
Subject to NCEP Director approval, implement NEMS/NMMB version of GSI (e.g. strong constraint, revised bkg+obs errors) in NAM/NDAS.

CURRENT EFFORTS: Early in FY12, the porting of GSI into NEMS was put on hold while the global EnKF implementation was completed and especially until EnKF can be extended to the smaller scale NAM & RAP applications. Tests with hourly updated NAM in FY13 on Zeus will help determine if having both the forecast model and GSI in a single executable will be worth the effort. The EMC Data Assimilation Team Lead and others feel having GSI in NEMS will be restrictive and too complicated. The savings in time due to greatly reduced data motion will have to be great to offset these negative aspects of moving GSI into NEMS. (DiMego, Rogers)

The hybrid ensemble analysis with a new GSI version was tested and runs on both CCS and Zeus. New VAD winds, GPSRO bending angles and GOES 15 satellite radiances were turned on after impact studies showed at least neutral if not positive impact. Variational quality control was added to the NDAS and the impact tests are running with an off line parallel. (Wan-Shu Wu)

PLANNED EFFORTS: Provide NCO with the necessary assistance for pre-implementation tests. Prepare presentations to meet all the requirements for major implementations after WCOSS transition. (Wan-Shu Wu)

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: The new analysis package is ready to be implemented, but needs pre-implementation tests and NCEP Director's approval after WCOSS transition.

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

12.5.5.E8 30 Sept 2012 (GSD)
Report on initial results of 13km EnKF for RAP configuration. (Modified title)

COMPLETE. In late April, Ming reported on this work via a poster presentation summarizing initial results at an ensemble assimilation workshop. This poster report is available at:
http://ruc.noaa.gov/pdf/HU_EnKF_wkshp_May_2012_FINALx.pdf

A presentation Ming Hu gave at the AMS Integrated Observing and Assimilation System Conference (early Jan 2013), that summarizes the encouraging results from the use of the global ensemble information, can be found at:
http://ruc.noaa.gov/ppt_pres/RAP_hybrid_AMS_2013_final.pptx

Oct. update -- Ming Hu has completed Initial single-observation tests of promising approach to regional EnKF hybrid of using of global ensemble members to provide BEC information.

12.5.5.E9 30 Sept 2012 (ESRL/GSD)
Report on planned GSI changes for the FY13 upgrade to the Rapid Refresh.

COMPLETE. Report at June AMS conference on Numerical Weather Prediction
http://ruc.noaa.gov/pdf/NWP_2012_RAP_GSI_hu_final.pdf

Task 12.5.8 Improve physical processes in the WRF (RAP and HRRR) and NAM models, especially including those that affect aircraft icing.

GSD
Work continues with application to both RAP and HRRR with most aspects of the physics receiving some attention during the quarter. Most emphasis was given to the land-surface model (LSM), boundary layer and convection. This is detailed under Subtask #1 below.

NCAR/RAL
CURRENT EFFORTS: During the month of November, code additions/changes we made to the Thompson et al (2008) microphysics scheme to incorporate the effects of aerosols on cloud droplet and ice/snow sizes. This is necessary in order to alter the radiation scheme to account properly for changes to cloud properties due to aerosols because the current radiation schemes assume constant cloud properties. Initial modifications are being made to the RRTMG radiation code and we expect the modifications can be duplicated in the Goddard radiation scheme as well.

PLANNED EFFORTS: Most of the effort will concentrate on the testing and full implementation of the Thompson et al (2008) "aerosol-aware" microphysics scheme. The scheme continues to be prepared for large-scale, long-duration simulations to be started near the end of calendar year 2012 since the new NCAR supercomputer center will become available.

PROBLEMS/ISSUES ENCOUNTERED OR ANTICIPATED: As in the prior two months, delays encountered due to staff working other projects. However, we anticipate resuming this work at a more typical level in December and beyond.

SUBTASKS:

12.5.8.1 1 Oct 2011 (GSD)

Based on ongoing GSD RAP evaluation and feedback from users of the newly operational RAP, including other AWRP PDTs, continue developing and begin testing a suite of upgraded or new physics packages using developmental RR real-time cycles and retrospective periods at GSD, in preparation for RAP upgrade (RAPv2).

Experiments with various modifications to the RUC LSM and land-surface fields used by the LSM were made during the quarter and resulting changes are likely to become part of the RAP configuration that will drive the HRRR during the 2013 convective season as well as be part of the RAPv2 code transfer to NCEP later in 2013. The motivations for this work were:

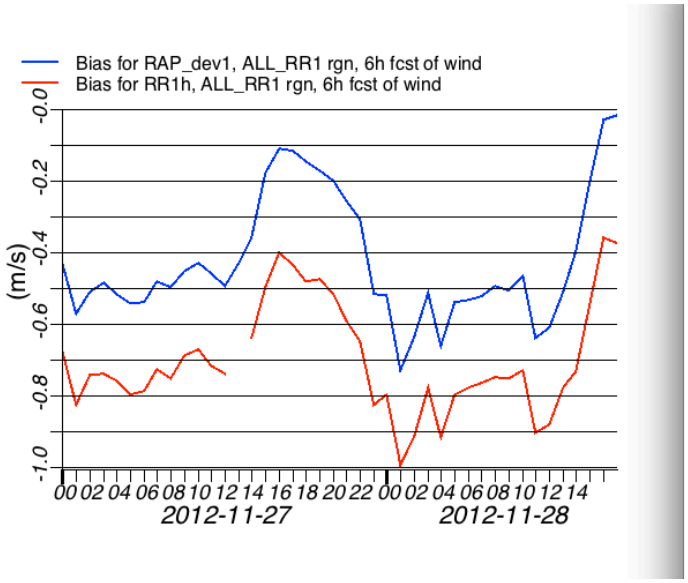
1. To improve temperature forecasts during the evening transition, during which a notable warm bias was observed using both the MYJ and MYNN boundary-layer / surface-layer schemes, and

2. To improve 10-100m wind forecasts, particularly at night.

As described in the FY12Q4 report, Tanya Smirnova tested the RUC LSM with 9 levels instead of 6 to obtain more accurate surface heat fluxes and more rapid cool down of the soil through better resolution of heat transport in the soil during the evening transition. This change has been running most of the quarter in the RAP-dev1 cycle on Zeus and results have confirmed that the increased resolution improves 2-m temperature forecasts during the evening transition without leading to cold biases at other times of the day or in winter conditions of snow cover and reduced insolation. The following modifications to land-use and land-surface properties also have been exercised in real time (RAP-dev1 cycle on Zeus) for much of the quarter, with satisfactory results:

- Using an exponentially weighted average (instead of a linear average) to determine the roughness length for momentum over a model grid square
- Making the roughness seasonally dependent in areas of cropland to simulate the increased roughness during the growing season and decrease after harvesting
- Increasing roughness over forested areas
- Incorporating a leaf-area index (LAI) that is a function of land-use type and vegetation fraction (seasonally dependent).

An example of improved 10-m wind performance (relative to without these changes—RR1h, the RAP primary cycle on Jet--is shown in Fig 3 below.



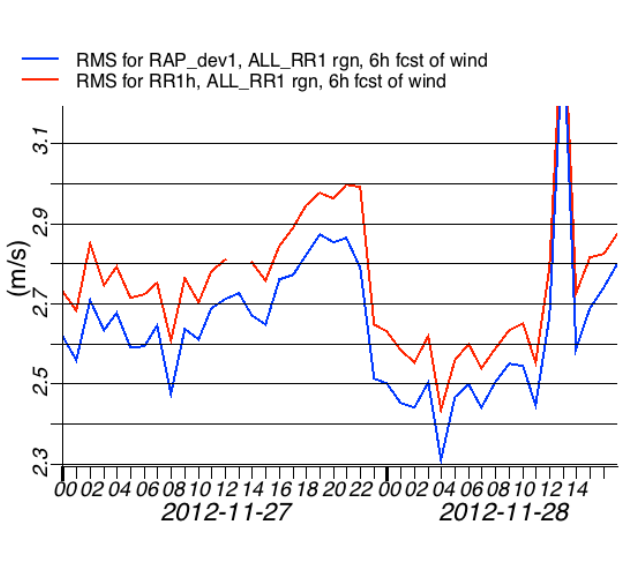


Fig. 3. Wind-speed bias (left, negative values mean high wind speed bias) and root-mean-square vector error (right) comparison for 10-m wind as verified against METAR observations over the RAP domain. Red curve is from RAP-primary cycle using 6-layer version of RUC LSM and old surface roughness formulation. Blue curve is using the 9-level version of the LSM and the new surface roughness described under 12.5.8.1.

Tanya Smirnova made a concerted effort during the quarter and Joe Olson to determine what was causing excessive latent-heat flux at night under conditions of snow cover when the MYNN PBL scheme is used together with the RUC LSM. (This excessive latent-heat flux is the proximate cause of the persistent problem of over-prediction of nighttime fog and low ceiling with the MYNN, noted in previous MDE reports.) This revealed a problem, discovered in December, with the coupling between the RUC LSM and the MYNN surface layer scheme. Fixing this bug largely alleviated the MYNN fog problem without resorting to the fog-droplet gravitational settling routine that was made available (independently) by a WRF developer from Japan and was extensively tested and modified by Joe Olson in collaboration with NCAR WRF developers earlier in the quarter.

Our tests of WRFv3.4.1 with the release version of the Grell scheme show slight degradation of skill in temperature and wind, as anticipated. This was tested with and without the option to incorporate attenuation of incoming solar radiation by (parameterized) convection. The latest version of the Grell convective parameterization [known as the Grell-Frietas (or G-F) scheme after Saulo Freitas of Brazil] has very recently been made available for testing in RAP and fixes some alleged bugs in v3.4.1. Testing of this latest version is about to begin at this writing.

Other physics related work with WRFv3.4.1 during the quarter included introduction by Greg Thompson of a more precise snow / graupel melting algorithm that now only allows melting when the wet-bulb temperature of the air is > 0C. Also, David Dowell made sure that the inline reflectivity calculation in module_mp_thompson is the source of the output reflectivity when v3.4.1 is used. This ensures that HRRR reflectivity output is consistent with the Thompson microphysics.

Future experiments with the HRRR will include testing of the Goddard short-wave scheme with Greg Thompson's fix to incorporate attenuation by snow.

GSD has had some discussions with the NCAR WRF developers concerning small-scale oscillations in low-level fields under conditions of steep terrain slope and strong surface wind when the 6th order diffusion is turned on. However, a definitive solution awaits further effort.

12.5.8.3 1 July 2012 (NCAR/RAL)
Continue to increase the complexity and possible interactions between various aerosol constituents and microphysics. For example, the first version of the scheme uses a constant hygroscopicity value whereas different aerosol constituents have different values of this parameter. Also, as the grid spacing of HRRR decreases, NCAR and GSD will incorporate large urban sources of sulfates and other aerosols directly into the model.

12.5.8.4 1 July 2012 (NCAR/RAL)
More closely couple/link the aerosols and cloud droplet/ice characteristics to the radiation scheme(s). Aerosols directly affect the radiation, but also indirectly affect radiation through changes in cloud characteristics. Both are essentially ignored at this time. Also, directly utilize model output variables of cloud species and aerosols to develop better ceiling & visibility forecasts.

12.5.8.5 1 July 2012 (NCAR/RAL)
Assemble a series of well-known benchmark case studies pertaining to the new aerosol-microphysics package in order to evaluate future improvements as well as test its sensitivities. Cases will be picked from intensive operation periods of large field programs such as PacDEx, PLOWS, IMPROVE, VOCALs, etc.

12.5.8.6 1 Sept 2012 (GSD and NCAR/RAL)
Transfer the NCAR coupled aerosol-microphysics scheme into test versions of RR and HRRR and begin testing on individual cases (including HRRR summertime Mesoscale Convective System cases) using climatological aerosol distributions.

CURRENT EFFORTS at NCAR/RAP:

During the month of December, the Thompson et al (2008) microphysics scheme with explicit treatment of aerosols was updated to the latest WRF release (v3.4.1). A few bugs were discovered and corrected when migrating the code to a newer version. Compared to the version previously used a couple years ago, the updated code utilizes newer, higher-resolution aerosol input data from the GOCART aerosol model. Whereas the prior version used 2x2.5 degree data, the new aerosol input data has a spacing of 0.5x1.25 degrees. Another upgrade is the incorporation of organic carbon aerosols as an additional CCN source. The various codes have been ported to the new NCAR supercomputer, Yellowstone, and are being prepared for multiple case study tests.

In addition, the initial implementation of new cloud droplet and ice crystal sizes being directly input to the RRTMG scheme appears to be successful. More testing is needed to be certain, but the microphysical scheme produces explicit droplet and crystal sizes that are more directly used in the radiation scheme than internal assumptions of RRTMG, which has no knowledge of explicit sizes produced by the microphysics scheme. This effort is nearly complete and will be transferred to the WRF community code in the next few months.

PLANNED EFFORTS:

The codes for preparing the initial climatological aerosol data and the newer version of the Thompson et al (2008) scheme will be transferred to NOAA-ESRL upon successful implementation and testing.

PROBLEMS/ISSUES ENCOUNTERED OR ANTICIPATED:

There were minor delays with porting the latest codes to Yellowstone plus various times when Yellowstone had outages due to being a brand new computing system.

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE:

12.5.8.7 Change to 1 Nov 2012 (GSD and NCAR/RAL)
Begin coupling the NCAR aerosol-microphysics scheme with highly simplified version of the GOCART option in WRF-Chem being developed by GSD.

GSD: The potential of this approach will be reevaluated in discussions with NCAR.

12.5.8.8 Moved to Jan 2013 (GSD)
Based on RAP experience and recent WRF physics progress, begin development and testing of physics enhancements for RAPv3 implementation and for future versions of the HRRR.

12.5.8.13 30 July 2012 (NCAR/MMM)
Deliver a WRF Users' Workshop and WRF Tutorial for the User Community

NCAR is organizing a WRF tutorial, to be held at Foothills Lab January 28–February 5, 2013. There will be a WRF tutorial and a MET (Model Evaluation Tools) tutorial, with the number of participants at up to 60 for WRF and 40 for MET. Details may be found at: **http://www.mmm.ucar.edu/events/tutorial_131/index.php**.

PLANNED EFFORTS: NCAR will deliver the next WRF tutorial in Boulder on January 28–February 5, 2013.

UPDATES TO SCHEDULE: NONE

12.5.8.14 30 Sept 2012 (NCAR/MMM)
Incorporate physics and dynamics Improvements into WRF

NCAR and the WRF Release Committee continued to prepare for the next major release, which will be WRF Version 3.5. The release is planned for Spring 2013. Candidate features include software framework improvements, new physics options, new observation types for WRFDA, and WRF-Chem additions. Details may be found at: **http://www.wrf-model.org/release.php.**

The freeze date for the code has passed, and the received contributions are now being tested. Bugfixes are being made as necessary. The first limited, friendly-user release will be made at the end of January.

Jimy Dudhia (NCAR/MMM) has been preparing developer-supplied updated code for the WRF repository for the V3.5 release. In December he concentrated on the major additions of the CAM microphysics scheme and the CLM4 land-surface model. He also added updated codes for the MYNN PBL and BouLac PBL schemes and for the PX LSM. The latter will include NLCD40 land-use data tables, a new US vegetation dataset.

Dudhia resolved several issues found by WRF software engineers in physics related to code producing undefined or infinite values. These fixes will be in V3.5.

Jimy Dudhia collaborated with Stephanie Evan (NOAA/ESRL) on microphysical modifications for the tropical tropopause layer (TTL). The results showed that improvements could be obtained from changes in the WSM5 microphysics scheme.

Dudhia worked with Mukul Tewari and Greg Thompson (NCAR/RAL) to separate cloud optical properties from the radiation scheme. This provides better compatibility with microphysics properties. A choice is now provided for the microphysics to specify its own effective radius for radiation.
Lastly, Dudhia collaborated with Craig Mattocks (Univ. Miami) and David Nolan (Univ. Miami) on a new surface drag formulation for hurricanes.

PLANNED EFFORTS: The development and incorporation of new physics and dynamics for WRF for the RAP will continue through FY13Q2.

UPDATES TO SCHEDULE: NONE

12.5.8.15 Ongoing (GSD)
Continue development of the RUC LSM for application to RAP
Application for (RAPv2 in FY12 and RAPv3 in 2013) and HRRR, based on feedback from users, with particular emphasis on improving treatment of snow, sea ice and tundra, and use of upgraded ground surface datasets now available through the V3.3 WRF Preprocessing System (e.g., MODIS vegetation, lake surface temperature for lakes other than the Great Lakes).

GSD: Very good results from 9-layer RUC LSM and other enhancements to use of fixed surface fields – see subtask 1. These are now in parallel testing, and are likely to be made part of the RAPv2 suite of changes, as well as being incorporated into the HRRR.

Deliverables

12.5.8.E1 Defer to 1 Feb 2013 (ESRL, NCEP)
Final model physics code transfer complete to EMC for Rapid Refresh 2 upgrade change package.

UPDATE TO DELIVERABLE:
Change to early FY13 due to late implementation of initial RAP. Code is essentially ready, but will make a few smaller physics modifications (mostly to land-surface model) before the deadline if they pass cold-season and warm-season tests.

12.5.8.E2 1 Sept 2013 (GSD, NCEP)
Pending NCEP computer readiness and EMC and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh 2 software to NCO.

UPDATE TO DELIVERABLE:
Change to Sept 2013 due to NCEP implementation forcing delay for overall RAPv2 implementation.

12.5.8.E4 No earlier than **1 Oct 2013 (ESRL, NCEP)**
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RAP at NCEP.

UPDATE TO DELIVERABLE:
Change to fall 2013 due to NCEP WCOSS implementation, forcing delay for overall RAPv2 implementation.

12.5.8.E5 Delayed to Feb 2013 (NCAR/RAL and GSD)
Transfer the coupled aerosol-microphysics scheme into a test version of HRRR.

Delayed until the scheme is more thoroughly tested by NCAR. Through coordination between NCAR-RAL and AWRP office, the delivery date for this item is delayed until 28 February 2013.

12.5.8E6 30 July 2012 (NCAR/MMM)
Deliver a WRF Users' Workshop and a WRF tutorial for the user community.
Complete

12.5.8.E7 ***15 Sept 2013*** **(NCAR/RAL)**
A written report by mid September 2012 summarizing enhancements made to the model physics packages.

COMPLETE as of Nov 2012.
This summary is provided below:

Changes to Thompson et al (2008) microphysics code from V3.3.1 to V3.4

1. Changes to graupel density and y-intercept parameters to attempt to improve squall line convection representation.

2. Minor change to snow terminal velocity to allow slightly faster fall speeds for larger snow size to improve match to observations, most specifically for convection. There is no effective difference for smaller snow sizes generally associated with widespread snowstorms or aircraft icing events.

3. Maximum ice number concentration was decreased from 500 per Liter to 250 per Liter based on comparisons of upper-level clouds from satellite data. A larger number allows too much cloud ice aloft and it also affects aircraft icing because the increased number will more actively deplete super cooled liquid water clouds.

4. Minor change to cloud water to rain auto conversion for number concentration of rain. Effect is a reduction of rain number and therefore generally increased size of droplets produced from the collision-coalescence process. This is intended to reduce initial cold-pool strength from leading-edge convection due to enhanced evaporation by large number of small droplets.

5. A bug fix for variable SR - fraction of frozen to total precipitation. There was a minor problem with extremely small amounts of frozen hydrometeors (snow and/or graupel) surviving to the ground in very warm conditions due to numerics. This led to a misleading value of SR, which is purely a diagnostic variable but affected the land-surface scheme.

Changes to Thompson et al (2008) microphysics code from V3.4 to V3.4.1

1) Addition of radar reflectivity for a total of 8 microphysics schemes:

a) Thompson
b) Morrison
c) GSFC - Goddard
d) Purdue-Lin
e) WSM5
f) WSM6
g) WDM5
h) WDM6

2) Changes to diagnosed graupel y-intercept parameter and its limits. Based on 2012 data from the OU-CAPS Spring Experimental Forecast Program and more detailed inspection of radar reflectivity histograms, relatively minor changes were made to permit slightly higher maximum reflectivity's due to graupel/hail to match better the observations from WSR-88D radar data.

3) Minor changes to rain self-collection and break-up. Sensitivity experiments of idealized 3-D squall lines and comparison to other bulk microphysics schemes (as part of the Cloud Modeling Workshop held in July 2012) showed sufficient evidence to alter rain number to represent better convective squall lines.

4) Bug fix for melting snow. Evidence by Bjorn-Egil Nygaard of Oslo University revealed that snow was melting at 0 deg C dry bulb temperature rather than 0 deg C wet bulb temperature. A very simple code adjustment following Jason Milbrandt's scheme was adopted in the Thompson microphysics code.

12.5.8.E8 30 Sept 2012 (ESRL/GSD)
Report on overall planned model physics changes for the FY13 upgrade to the Rapid Refresh.

Complete. A report was given in Steve Weygandt's presentation at the AMS Severe Local Storms Conference on the Rapid Refresh. This had been already largely set as of March 2012 for the frozen ESRL RAP for summer-2012 CoSPA/HRRR. The only additional changes to RAPv2 physics likely at this point are 1) fix to snow/radiation problem in short-wave radiation, 2) use of the 9-layer soil/vegetation land-surface model, and likely, 3) use of WRFv3.4.1, the more recent version.

12.5.8.E9 30 Sept 2012 (NCAR/MMM)
Incorporate physics and dynamics improvements from the user community, GSD, and NCEP into WRF for use in the Rapid Refresh system. In collaboration with GSD, assist in the evaluation of those physics schemes for the RAP that may be tested using the ARW. Perform testing for code acceptance and implementation into WRF repository. Assist in the implementation of WRF bug fixes.

Complete. This was accomplished with changes in WRFv3.4.1. MMM now continues to finalize changes for WRFv3.5 to be released by March-April 2013. Some of these upgrades are already being considered for the RAPv2 version to be ported to NCEP around Feb 2013.

Task 12.5.24
FY 2012, also Priority 7: Develop, test, implement and improve the 3-km WRF-based HRRR

Task 5.24 specifically treats development and testing of the 3-km HRRR model itself. Development and testing work on assimilation of radar data at the 3-km scale is under Task 5.19.
Work proceeded on several fronts in October-December:

1. The 2012 warm season HRRR evaluation period was concluded on Oct. 31, 2012 as planned. Overall HRRR forecast performance and run reliability was excellent. In general, the over prediction of convection noted at times during the 2011 evaluation was significantly reduced in 2012 (evident in both objective skill score evaluation and subjective examination of case study examples). This improvement is largely associated with improvements to the parent RAP-v2 system. An additional enhancement is a much-improved capability for accurately predicting the evolution of mesoscale convective systems especially bow echoes. The excellent prediction of the devastating derecho event on June 29, 2012 in the Mid-Atlantic States as a very good example of this enhanced capability. Steve Weygandt reported on the impact of these RAP enhancements on the resultant HRRR forecasts at the recent AMS Severe Local Storms Conference.

2. Recent work led by Curtis Alexander and colleagues has focused on adding significant new capabilities within the realm of 3-km assimilation. Building upon previous group work led by David Dowell, Curtis has further tested a procedure to complete a 1-hour 3-km HRRR pre-forecast with 4 cycled applications (one every 15 min) of the radar DFI procedure on the HRRR 3-km domain. Retrospective tests of this procedure (Fig. 4 below) showed improvement in short-range HRRR forecasts, with the improvements extending out through about 6 hours.

3. Curtis Alexander and colleagues conducted further research to test a significant new capability for the HRRR – fully cycled hourly application of the GSI analysis using all observations on the 3-km HRRR grid. Results of a limited retrospective test were encouraging. Curtis Alexander reported on these experiments at the recent AMS Severe Local Storms Conference. He also showed the results at the recent NCEP production Suite Review. Fig. 3 below shows verification from a retrospective comparison of the 3-km radar assimilation vs.no 3-km radar assimilation. The results show a positive impact out through 5 hours.

4. Steve Weygandt, Curtis Alexander, and Stan Benjamin recently gave a combined presentation at the NCEP Production Suite Review, overviewing recent progress on the RAP, HRRR, and FIM weather prediction systems. The PPT slides for this presentation can be found at:
http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf

5. Steve Weygandt completed some HRRR sensitivity tests for the June 29 Mid-Atlantic derecho event, documenting that the upgrades to the RAP from 2011 (RAP v1, running operationally at NCEP) to 2012 (RAP v2) made a crucial difference in the ability of the HRRR to successfully predict the derecho.

6. GSD personnel recently gave two talks related to the HRRR at the recent AMS Aviation, Range, and Aerospace (ARAM) Conference. Steve Weygandt described RAP data assimilation work impacting the HRRR and Curtis Alexander provided an extensive overview of the HRRR including a summary of new 3-km assimilation results, improvements to the HRRR echo-top forecast and a summary of HRRR reliability and future plans. The PPTs from these talks can be found at:
http://ruc.noaa.gov/ppt_pres/AMS_2013

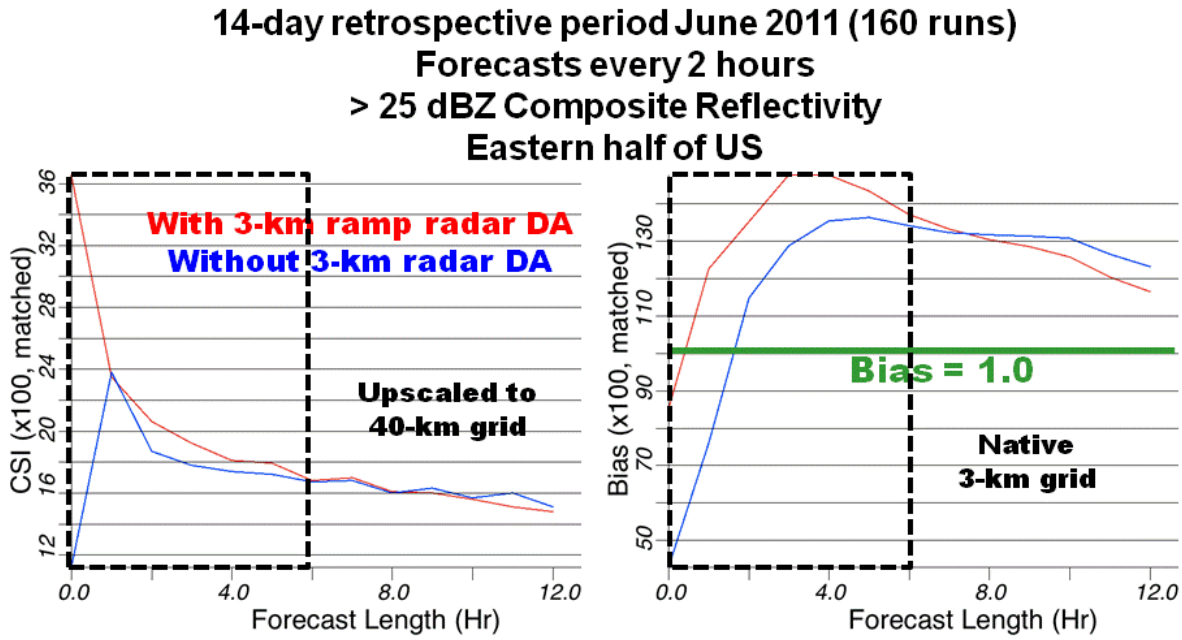


Fig. 4. Comparison of reflectivity forecast skill (measured by CSI) and bias as a function of forecast length for 14-day retrospective cycles with and without the 3-km 15-min cycled hour pre-forecast reflectivity data assimilation period. The red curve ("with 3-km radar DA") shows improvement relative to the blue curve ("NO 3-km radar DA) out through about the first 6 hours.

12.5.24.1 15 Jan 2012 (GSD, with assistance as needed from NCAR/RAL, NCAR/MMM, CAPS, MIT/LL)

Initial design for the assimilation/modeling configuration for the HRRR during the 2012 summer convection forecasting (CoSPA) exercise.

As detailed above, extensive retrospective testing of the coupled RAP / HRRR data assimilation / forecast system for the August 11-21 period is complete. All changes to the RAP / HRRR system have been incorporated into the GSD runs and impact on HRRR are very positive. GSD real-time RAP / HRRR system with all these upgrades was frozen on March 9, 2012 for 2012 evaluation.

12.5.24.3 30 Sept 2012 (GSD)

Complete 2012 HRRR summer evaluation using modeling and assimilation modifications determined in 2011 exercise. Collaborate on analysis of HRRR tests and deliver summary of results. COMPLETE

Deliverables

Complete. An initial report with a preliminary summary of results (reliability, skill scores, case examples) is available at **http://ruc.noaa.gov/pdf/HRRR_summer-2012_prelim_summary.pdf**

12.5.24.E1 1 April 2012 (ESRL/GSD)

Incorporate all assimilation and model changes that affect the HRRR into a frozen version of HRRR (and parent Rapid Refresh) for the summer 2012 exercise.

Complete. As detailed above, work was completed on improvements to RAP / HRRR system for 2012 in advance of the freeze date in March 2012. Frozen on March 9, 2012

12.5.24.E2 15 Sept 2012 (NOAA/ESRL/GSD)

Complete FY12 evaluation with revised 3-km HRRR running every 1 h.

- **Conduct real-time summer 2012 HRRR forecasts using 3-km WRF initialized with radar-enhanced Rapid Refresh over full CONUS domain, monitor performance, modify code/scripts as needed, maintain high reliability working with ESRL computer facility**
- **Coordinate with other AWRP users and other collaborators, including coordination of HRRR grid transfers**
- **Provide project management**
- **Lead writing of report on summer 2012 HRRR experiments**

Complete. Real-time project ongoing with good results so far. Excellent HRRR forecast for many cases including the June 29, 2012 derecho event that caused at least 22 fatalities and extensive damage over a wide area from the Ohio Valley into the Mid-Atlantic States (see HRRR forecast images above).

Report on computing resource status on NCEP CCS, NOAA R&D Site A and NOAA R&D Site B with regards to possible implementation of HRRR.

Complete. A report summarizing the current status was completed and sent on July 15th with the June quarterly report and is also available at **http://ruc.noaa.gov/pdf/HRRR_computing_resources.pdf.**

Status of MDE Deliverables – 15 Jan 2013

Legend: ☐ Deliverable on schedule; ☑ Deliverable submitted; ☐ Deliverable overdue

Deliverable and Related Task	Due Date	Status	Comment
12.5.4 Develop, test, implement, and improve the Rapid Refresh			Updated 15 Jan 2013: All RAPv2 milestones are now further delayed until late 2013 or early 2014, as noted below and in earlier monthly and quarterly reports. The version of RAPv2 that will be implemented at NCEP continues to get better with this delay as the continued development further improves the NCEP version of RAPv2.
12.5.4.1 Maintain hourly RAP runs and provide grids of SAV and AHP guidance products (ESRL, NCEP)	Ongoing	☐	
12.5.4.E1 Report on Rapid Refresh Status (ESRL)	12/20/11	☑	
12.5.4.7 Complete testing and evaluation of new RAP capabilities (model physics and data assimilation) – RAPv1 (ESRL)	01/31/12	☑	
12.5.4.E2 Update documentation for operational Rapid Refresh (ESRL)	02/01/12	☑	
12.5.4.6 Initial software for RAPv2 changes ready for porting to EMC (ESRL)	08/01/12	☑	
12.5.4.E4 Report on testing of RAP assimilation/model improvements (ESRL)	03/30/12	☑	
12.5.4.E3 Final code ready for transfer to EMC for Rapid Refresh v2 change package (ESRL)	3/01/13	☐	
12.5.4.E5 Complete testing at EMC of RAPv2 code, pending NCEP readiness (NCEP, ESRL)	8/31/13	☐	Delayed further to August 2013 based on NCEP's estimate on delays from the WCOSS computer transition and related change moratorium. This task was originally for a RAPv3 but is now linked to RAPv2.
12.5.4.E6 Perform config mgmt. for RAP (ESRL, NCEP)	Ongoing	☐	
12.5.4.E7 Monitor RAP performance, respond to problems, diagnose causes, develop solutions. (ESRL, NCEP)	Ongoing	☐	
12.5.4.E8 Report on overall planned changes for FY13 upgrade to Rapid Refresh (ESRL)	11/30/12	☑	http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf
12.5.5 Develop, test, and implement improvements to the Rapid Refresh and the NAM data assimilation			
12.5.5.E1 New version of GSI including revised radial wind assimilation ready for FY13 RAPv2 upgrade (ESRL)	04/01/12	☑	Complete in that RAP-ESRL frozen for HRRR is essentially that planned for RAPv2 @NCEP.
12.5.5.E3 Finalize GSI code ready for transfer to EMC for RAPv2 (ESRL)	02/28/13	☐	
12.5.5.E4 Pending EMC and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit GSI code for RAPv2 software to NCO, pending NCEP	09/01/13	☐	Delayed further to Sept 2013 based on NCEP delay estimates.

readiness (NCEP, ESRL)			
12.5.5.E5 Pending computer resources, implement RAPv2 at NCEP (NCEP, ESRL)	11/01/13	☐	Nov 2013 is the earliest estimate, with Sept 2013 as the earliest possible date for the RFCs.
12.5.5.E6 Report on results of EnKF and hybrid DA systems for the RAP configuration (EMC, ESRL)	02/15/13	☐	Delayed until Feb 2013 although ESRL and EMC have a very good plan on RAP EnKF assimilation following initial success with EnKF/hybrid assimilation in the current parallel NAM.
12.5.5.E7 Subject to NCEP Director approval, implement NEMS/NMMB version of GSI in NAM/NDAS (NCEP)	Deferred to 7/1/13	☐	
12.5.5.E8 Report on initial 13km EnKF testing for RAP configuration (ESRL)	09/30/12	☑	Study completed. Excellent results with EnKF data assimilation using global ensemble assimilation grids now established for both RAP and NAM.
12.5.5.E9 Report on planned GSI changes for the RAPv2 upgrade to the Rapid Refresh (ESRL)	09/30/12	☑	Earlier reports also completed but this is the latest one: http://ruc.noaa.gov/pdf/NCEP_PSR_2012_RAP_FINALx.pdf
12.5.8 Improve physical processes in the WRF, especially including those that affect aircraft icing			
12.5.8.E1 Final model physics code transfer complete to EMC for RAPv2 upgrade change package to be implemented by early 2013 (ESRL)	6/01/13	☐	Task is essentially complete now in ESRL RAPv2 but will keep the door open for additional physics mods until spring 2013, given the likely RAPv2 implementation until late 2013 or early 2014.
12.5.8.E2 Pending NCEP computer readiness and EMC and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh v2 software to NCO (ESRL, NCEP)	9/1/13	☐	Changed again Jan 13 with further NCEP delays on RAPv2.
12.5.8.E4 Pending computer resources, implement RAPv2 at NCEP with new physics configuration (ESRL, NCEP))	11/01/13	☐	Delayed further to fall 2013 to March 2014 per new NCEP direction
12.5.8.E5 Transfer the coupled aerosol-microphysics scheme into a test version of HRRR (NCAR/RAL)	02/15/13	☐	NCAR reports approval from FAA/AWRP on this new delay (as of Dec 12)
12.5.8.E6 Deliver WRF Users' Workshop and WRF tutorial (NCAR/MMM)	07/30/12	☑	
12.5.8.E7 Report on enhancements made to WRF model physics (NCAR/RAL)	09/15/13	☑	Complete (Dec 12) and included in Nov 12 report.
12.5.8.E8 Report summarizing enhancements made to the model physics packages (ESRL)	09/30/12	☑	
12.5.8.E9 Incorporate physics improvements into WRF for future RAP and HRRR (NCAR/MMM)	09/30/12	☑	
12.5.24 Develop, test, implement and improve the 3-km WRF-based High Resolution Rapid Refresh			
12.5.24.1 Initial design for the assimilation/modeling configuration for the	01/15/12	☑	

HRRR during the 2012 CoSPA Prototype Summer Operations			
12.5.24.E1 Incorporate all assimilation and modeling changes into HRRR for Summer 2012	04/01/12	☑	
12.5.24.E2 Complete FY12 evaluation with revised 3-km HRRR running every 1 h. (ESRL) • Conduct real-time summer 2012 HRRR forecasts using 3-km WRF initialized with radar-enhanced Rapid Refresh over full CONUS domain, monitor performance, modify code/scripts as needed, maintain high reliability working with ESRL computer facility • Coordinate with other AWRP users and other collaborators, including coordination of HRRR grid transfers • Provide project management • Lead writing of report on summer 2012 HRRR experiments	09/15/12	☑	
12.5.24.E2a Report on computing resource status on NCEP CCS, NOAA R&D Site A and NOAA R&D Site B with regards to possible implementation of HRRR (NCEP, ESRL)	06/01/12	☑	Completed 7/13/2012, available at http://ruc.noaa.gov/pdf/HRRR_computing_resources_13jul2012.pdf