MDE Product Development Team
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With contributions from **Geoff DiMego** and **Mary Hart** (NCEP/EMC);
Stan Benjamin, John Brown, and **Steve Weygandt** (NOAA/ESRL/GSD);
Jordan Powers (NCAR/MMM); **Roy Rasmussen and Greg Thompson** (NCAR/RAL);
and **Ming Xue** (CAPS).

(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 November 2012
- 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. (dev1, dev2 dev3). (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.
- 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.
- Presentation on latest RAP data assimilation work at NCEP Production Suite Review.

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.
- Testing and development continues of GSD/Olson version of MYNN PBL 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.
- Initial tests of a fully cycled 3-km assimilation using GSI for the HRRR.

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 full-integrated effects of all components of the RAP. The changes and problem areas listed below involved such cross-component investigation and testing.

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

GSD continues to evaluate the updated RAP version 2 at ESRL with its significant data assimilation and modeling modifications implemented at GSD in March 2012 and discussed in previous MDE reports. It was noted in the FY12Q4 report 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, NCEP now estimates that 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.

The two principal thrusts of RAP work at ESRL/GSD during November 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 in March 2013, and
2. Enhancements to the HRRR in preparation for 2013's convective season.

Now that there are 3 RAP cycles running somewhat reliably on the NOAA Zeus supercomputer, as well as the ongoing RAP-primary on Jet that supports the HRRR, we are using a combination of parallel real-time cycles and 1-2 week retrospective runs to test various RAP enhancements and compare against the ongoing RAPv2 configuration running in the RAP-primary on Jet using our extensive verification capabilities. 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.

- Testing of 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 trunk version of the MYNN PBL scheme (see task 8 for details on the latter)
- Recent GSI release with many code changes and enhancements (see task 5.5
- 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
- Exploratory running of a preliminary regional hybrid variational version of GSI applied to the RAP (task 5.5).
- Upgrades to the RUC land-surface model (LSM) from 6 levels to 9 levels (more accurate surface temperatures), changes to surface roughness fields (more accurate 10m winds) and 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 in place of the current MYJ (task 5.8)

We are also looking ahead to a RAPv3 implementation in 2014 (or, more likely a delayed RAPv2 implementation to 2014), which would be considerably advanced over the RAPv2 currently running as the RAP-primary, prior to the advent of the NARRE (North American Rapid Refresh Ensemble), likely implementation in late FY15 or 16.

Now that the summer 2012 CoSPA freeze period for the GSD RAP primary cycle feeding the HRRR has ended, we have laid plans and begun intensive testing of 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
- 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
- Modification of RAP / HRRR vertical-layer configuration for more accurate low-level wind forecasts
- Comparison of Dudhia short-wave (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, were also underway during November.

- We continue to evaluate the Earth Networks, Inc. lightning data for use as a possible backup to the Vaisala GLD360 lightning product.
- Retrospective testing of satellite radiance bias corrections and choice of background error continues (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. These were checked into the NCAR WRF repository in early December and 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.

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

NCEP
Efforts are now focused on porting all RAP code & scripts over to the new WCOSS computer platform. The codes for the first update to the RAP (aka RAPv2), featuring new versions of the WRF-ARW and GSI analysis code, will be ported to the new WCOSS machine after the operational version of the RAP is successfully running on WCOSS. Now that NCEP is in a moratorium on implementations, the upgrade to RAPv2 is not likely to be scheduled until FY 2014. (Geoff 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 AIV 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

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 Nov 2012, the RAPv2 version 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.

NCEP
Delays in the initial RAPv1 implementation will delay the RAPv2 upgrade until after the moratorium, likely no sooner than June 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 applied for. (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 has been set since mid-March. This version of the RAP is nearly equivalent to the RAPv2 version envisioned for NCEP by late 2012 (postponed to 2013 due to upcoming NCEP moratorium). We therefore call this task "complete", but other smaller changes may yet be added at a later time before code for the RAPv2 is transferred to NCEP/EMC in early 2013.

12.5.4.8 31 May 2012 **(ESRL, NCEP)**

The NARRE-TL codes have been ported to the WCOSS and successfully compiled and tested on the new system. The WCOSS version gives the same results as the CCS operational codes. A fix has been tested and submitted to NCO to fix the ceiling and visibility problem in the SREF for AWC and other aviation community members. Currently 11 of the SREF members don't produce the correct visibility and 4 members don't produce correct ceiling fields. This fix will be implemented in early December. All SREF codes have been ported to the WCOSS machine in Reston, VA known as Tide. The codes have all been successfully compiled on Tide and validation of the model results has begun. (BinBin Zhou and Jun Du)

GSD
As reported last month, further productive discussions on NARRE design occurred in early October between GSD and NCEP to make further plans, especially on how to incorporate ensemble data assimilation into the NARRE and now likely even into RAPv2.

NCEP
After several NWS Forecast Offices made the request, 6 sub-regions in CONUS and 4 Alaskan sub-regions were added to the NARRE product web page. The source codes for the regional ensemble were ported to the new WCOSS machine, compiled, and preparations for the first test run were begun. (BinBin Zhou and Jun Du)

12.5.4.9 12 Dec 2012 (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 NCO moratorium on model changes. ESRL has provided code to EMC for the GSI, and it will be tested by EMC in the new computer environment (WCOSS) in FY13. 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 applied for. (Manikin) Access to Tide, the development portion of the new IBM Linux-based WCOSS computer at NCEP has been granted by NCEP to key GSD scientists working on the RAP.

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 will begin [at ESRL/GSD] now that RAPv1 model was implemented at NCEP on 1 May. The practice of keeping dynamics and physics as separate components, which was 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: COMPLETE. The Rapid Refresh was implemented at NCEP on 1 May to replace the Rapid Update Cycle. (Manikin)

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: GSD continued to work toward one final set of changes in late 2012 toward transfer to NCEP by April 2013. Essentially, this task is already complete with the March 2012 version of RAPv2 at ESRL, but some further improvements based on spring-summer-2013 testing of RAPv2 will be added to the RAP code package to be sent to NCEP.

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

PLANNED EFFORTS for NCEP: Convert RAPv1 to new NCEP computer then brings 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 will delay 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. Extensive testing complete or underway for frozen RAPv2 for summer 2012 CoSPA/HRRR.

NCEP
12.5.4E5 (modified to 31 May 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 WCOSS 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 30 June 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 in November 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 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**.

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: ESRL and RAP continue to monitor RAP performance in real time, and inter-compare results with other operational model and (at ESRL) with experimental versions of the RAP including RAPv2.

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. Ming has also applied the NCAR GEN_BE utility to sets of RAP grids to obtain improved estimates of background error covariance fields.

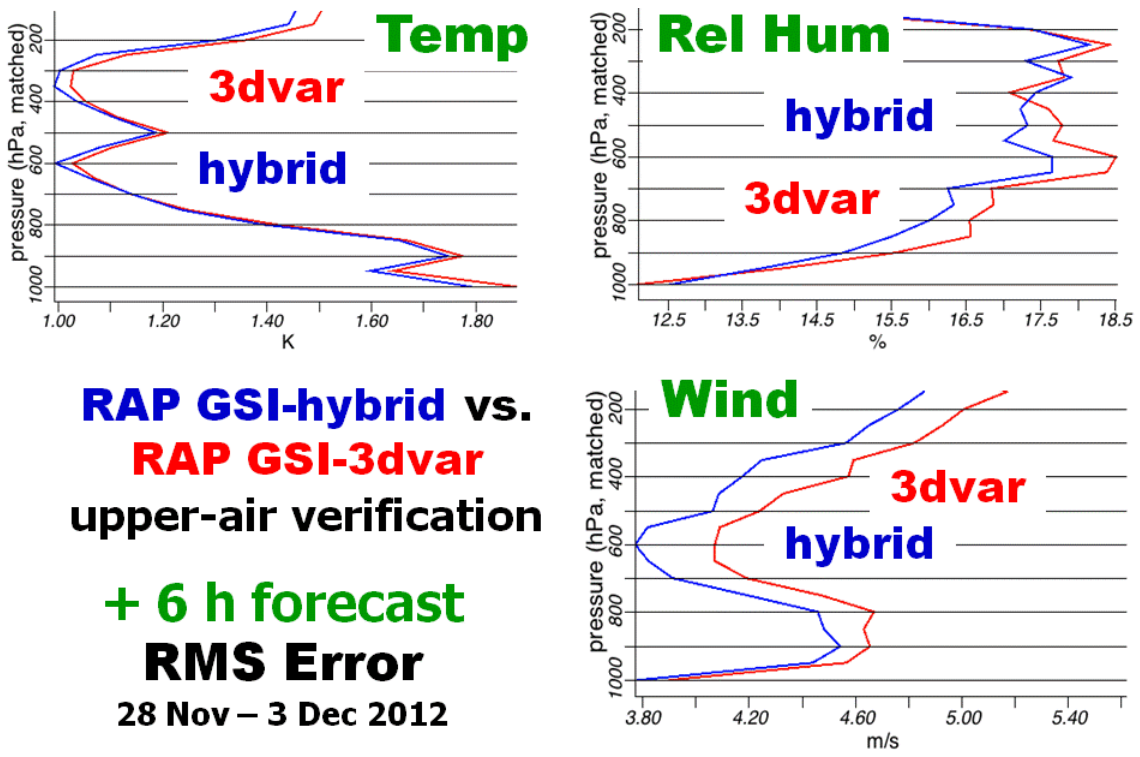

Fig. 1. Comparison of +6 hr upper forecast skill (verified against radiosonde data) for a real-time parallel cycle using the hybrid EnKF data assimilation (with ensemble information from the 80-member global ensemble DA system)[blue curve, "hybrid"] against the primary RAP v2 real-time cycle using a standard GSI 3DVAR configuration [red curve, "3dvar]

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]. 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 recent Joint Center for Satellite Data Assimilation (JCSDA) workshop.

5. Several AMB personnel recently visited the NCEP Environmental Modeling Center 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 this 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**

Subtasks

NOTE (11 Dec 2012) – Many of these 5.5 subtask reports below are retained from the Oct 12 report since they are still relevant.)

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

Results from inclusion of radial velocity data assimilation in parallel versions of the RAP are still generally neutral, resulting in its inclusion in the early March frozen version of the RAP. Some further bird-QC refinement may yet be needed – will report more next month.

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.

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 previously completed with forecast improvement noted. 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
Now the EnKF has been implemented in the operational global, the EnKF members are being used in the NAM parallels on CCS and on zeus which take advantage of the simple hybrid approach for background error covariance specification in the GSI. Testing a full-blown 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 spring to early summer 2013, ESRL will continue to test additional RAPv2 enhancements into fall, and will incorporate well-tested additions as they become available this fall.

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, 4 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 times (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
The GSI code was modified to handle both new VAD wind and current operational VAD wind. The GSI will differentiate between new and old VAD winds based on the vertical resolution of the VAD wind profile. Multiple versions of GSI code were modified and tested for the CCS parallel and zues parallel. Efforts were made to

ensure the modified codes run correctly on both machines, and the differences between CCS and Zeus versions were examined and found to be acceptably small. The modified codes will be added to the GSI SubVersion code repository. (Shun Liu and Wan-Shu Wu)

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 FY2013. 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.

12.5.5.7 *changed to August 2013* (NCEP, ESRL)
Submit Request for Change (RFC) and modified GSI code for RAPv2 from EMC to NCO, pending NCEP readiness.
Delays in the initial Rapid Refresh implementation will delay the Rapid Refresh upgrade to 2013 – note current estimated date.

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
As part of the WCOSS transition, GSI test runs were successfully performed on WCOSS for all six operational RTMA grids. Work on porting the RTMA postcode has begun. Work continues to enhance the observation reject lists and accept lists generated from the RTMA innovation statistics by geographically restricting the METAR observations used to compute the baseline statistics as part of the 'buddy check'. Previously, a single whole domain average had been used for this, but now an average of just the local METARS is being used in the test version. (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.

12.5.5.10 1 Jan 2013 (CAPS, ESRL)
Develop dual-resolution capabilities of EnKF and test it for RAP configurations.

No new information this month.

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 started testing of the 13km RAP in an EnKF mode using the background error covariance derived from the 80-member GFS ensemble and the GFS EnKF assimilation system. Results look very promising from this single initial test. This result will be compared from 3 other options:

1. Current fixed background error covariance
2. New fixed background error covariance derived from RAP forecasts over a 6+-month period using the GEN_BE (i.e., GENerate Background Error).

3. Evolving background error covariance from a regional 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.

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
Some initial planning has been done on how to use SREF ensemble members in combination with the Global ENKF (or GEFS) members already included in the NDAS hybrid ensemble GSI parallel. Some useful code already exists inside GSI to do general interpolation between different model grids, where the only information needed is the earth latitude-longitude coordinates of each grid point. (David Parrish)

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
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)

12.5.5.13 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
Off-line parallels were set up to test the impact of using ozone from the global system in the CRTM radiative calculation in NDAS, and this fix produced no impact on the NDAS forecasts. The possible reason why the system works with unrealistic ozone input to the CRTM might be that the ozone contribution was taken into account through the satellite channel bias correction. 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 (top of the SubVersion trunk) produced very different analysis results from the operational NDAS running on CCS. Different numbers of observations were used as opposed to ops for many conventional observation types and different types & mixes of observations were used. These differences will preclude use of this code in the NDAS/NAM on WCOSS. While this global GSI used the same number of observations as the operational GDAS on CCS, its results are too different to be used for initial WCOSS implementation. It 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 and used identical numbers of conventional observations. Both versions ran successfully on WCOSS. (Wan-Shu Wu)

Testing of enhancements to the use of satellite radiance data in the NDAS continues. With a focus on satellite channel bias corrections, Yanqiu Zhu has completed an initial evaluation of cycling (without running the extended 84hr forecasts). It has been concluded that the global-regional model vertical blending is effective in improving the use of radiance data in the NDAS. Parallel tests with 84-hr forecasts & verification are being prepared for running on Zeus. (David Parrish, Yanqiu Zhu)

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. 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)

NCEP
Work will begin on this now that the RAPv1 was implemented in May 2012. (Binbin Zhou & Wan-Shu Wu)

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 28 Feb 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: Work with ESRL/GSD will begin on RAPv2 after the RAPv1 is implemented in May 2012.

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

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

Efforts on tuning the configuration of assimilating satellite radiance AMSU-A within EnKF framework continued. In earlier tests with conventional data only, it was found the height-dependent localization scheme improves the forecast accuracy of surface variables and as well as upper air wind components. In October, to find out the optimal localization length, we ran a serial of tests with constant localization for the assimilation of AMSU-A data. The vertical localization length $\ln(p_{cut}) = 0.8$ and the horizontal localization radius $r = 700\ km$ were recommended based on the forecast RMSEs. During this month, we further applied the height-dependent localization scheme to

the radiance observations. The same monotonically increasing localization function $r_1 - r_2 * taper(|\ln(p_{ob}) - \ln(1020)| / 2.0)$ as conventional observations were employed but for satellite radiance data, we are using different coefficients r_1 and r_2. Here the 'taper' function is given by Eq. (4.10) of Gaspari and Cohn (1999), which is commonly used to define spatial localization functions. Until now, compared with constant localization, the best height-dependent localization setting slightly improves the surface variables. It also slightly improves upper air relative humidity for the forecast after 9 hours. However, for other upper air variables, no improvements were found.

In November, we started tuning the configuration for assimilating satellite radiance AMSU-A within the hybrid framework also. When assimilating satellite radiance data along with conventional data within EnKF framework, the ensemble tended to be under-dispersive with the same inflation and localization parameters as the configurations used for assimilating conventional data only. To reduce the adverse effect related to this problem, we assimilated satellite data AMSU-A and conventional data within hybrid 1-way framework based on the present optimized EnKF ensemble that assimilated conventional data only. We ran a serial of tests with different flow-dependent covariance weighting factor and bias coefficients. The same as the convention data assimilation, hybrid 1way with half static covariance got significant smaller RMSEs than tests with full flow-dependent covariance. However, compared to the results assimilating conventional data only, satellite data have negative impact on hybrid performance. Further investigations and configuration tuning are still needed in future.

Dual-resolution 1-way and 2-way capabilities within the EnKF code (not GSI-hybrid yet) were implemented and tested in the second quarter this year. Forecasts on the 13 km RAP grid, starting from dual-resolution and interpolated 40-km EnKF were compared. Their precipitation forecasts were verified against the NCEP Stage IV precipitation data. Precipitation forecasts from dual-resolution were more intense and closer to observations, but pattern and locations were not. The localization lengths for coarse domain might be too long for the fine domain. We reduced the horizontal and vertical localization scales for fine domain analyses in dual-resolution EnKF this month and tested it with single observation experiments. Further investigation will be done in the coming month.

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 May 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 May 2013. Move this deadline to 1 May 2013.

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

ESRL
Request for date change to mid 2013

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 May 2013. Move this deadline to 1 July 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).

NCEP
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 RAPv2 consider using this technique which is readily available now in the GSI. As noted above, this has been done and yielding very good results.

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 May 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 idea of porting GSI into NEMS was put on hold while the global implementation of EnKF 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 incorporated into the regional parallel system. The satellite angle bias correction program was also updated to be compatible with the upgraded GSI code. Impact studies of new VAD winds and GPSRO bending angles were performed. (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. (Wu)

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: Although the new analysis package is ready to be implemented, it is waiting for the arranged schedule to pass the 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

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 emphasis on the land-surface model (LSM), boundary layer and convection during November. 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 RR 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 are continuing. The motivation for this work is twofold:

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

2) To improve 10m wind forecasts, particularly at night. As described in the FY12Q4 report, Tanya Smirnova has 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. Tanya has also tested the following modifications to land-use and land-surface properties:

- 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).

Parallel testing in the RAP-dev1 cycle on Zeus is confirming earlier results for 10-m wind—an example is shown in Fig 2. We also note improvement in the positive temperature bias during the evening transition from daytime to nighttime conditions.

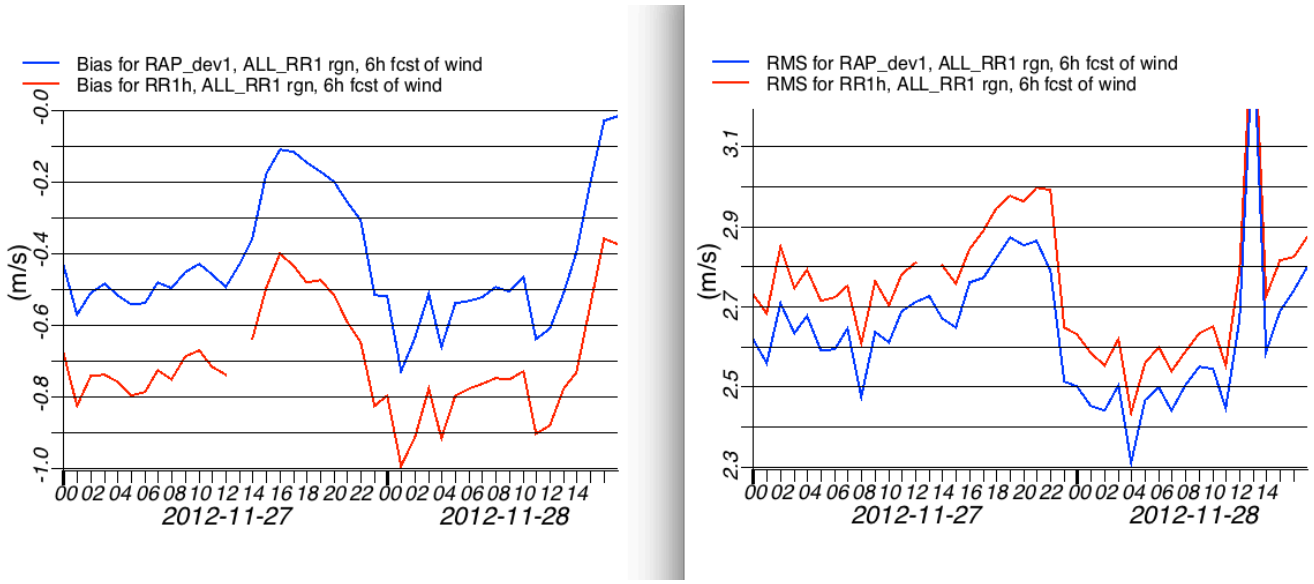

Fig. 2. Wind-speed bias (left, negative values mean high wind speed bias) and root-mean-square vector error (right) comparison for 10-m wind as verified against METAR observations over the RAP domain. Red curve is from RAP-primary cycle using 6-layer version of RUC LSM and old surface roughness formulation. Blue curve is using the 9-level version of the LSM and the new surface roughness described under 12.5.8.1.

We are continuing to investigate the problem with excessive nighttime fog formation with the MYNN PBL and surface layers in conjunction with the RUC LSM. Although accounting for gravitational settling of fog droplets helps reduce this, we also see what we believe is too much latent heat flux from the surface at night.

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. The latest version of the Grell convective parameterization (known as the Grell-Frietas scheme after Saulo Freitas of Brazil) is nearly ready for testing in RAP and fixes some bugs in v3.4.1. We will test this as soon as the code is made available to us.

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

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.

In his discussion with GSD in August, Greg Thompson advocated for further testing of this scheme before releasing it to GSD for implementation in RAP and HRRR.

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. AS reported in the previous month, the announcement has been sent out to the WRF user community. There will be a basic 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 on the tutorial 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. The deadline for outside contributions was in November, and the code free will be next month. Candidate features include software framework improvements, new physics options, new observations available in WRFDA, and WRF-Chem additions. Details may be found at: **http://www.wrf-model.org/release.php**.

Jimy Dudhia (NCAR/MMM) continued collaborating with Stephanie Evan (NOAA/ESRL) on microphysical modifications for the tropical tropopause layer (TTL). The results show that improvements can 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 is to allow for better future compatibility with microphysics properties. A choice is now provided for the microphysics to specify its own effective radius for radiation.

Dudhia worked on the preparation for inclusion into the WRF repository of various developer-supplied WRF physics updated codes for the next release (V3.5). These include the MYNN and Boulac PBL schemes and the PX LSM. Dudhia also obtained the CLM4 and CAM microphysics code for addition to the WRF repository.
PLANNED EFFORTS: The development and incorporation of new physics and dynamics for WRF for the RAP will continue through FY13Q1.

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 May 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 spring 2013 due to NCEP implementation forcing delay for overall RAPv2 implementation.

12.5.8.E4 1 July 2013 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RAP at NCEP.

UPDATE TO DELIVERABLE:
Change to spring 2013 due to NCEP 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-November:

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 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

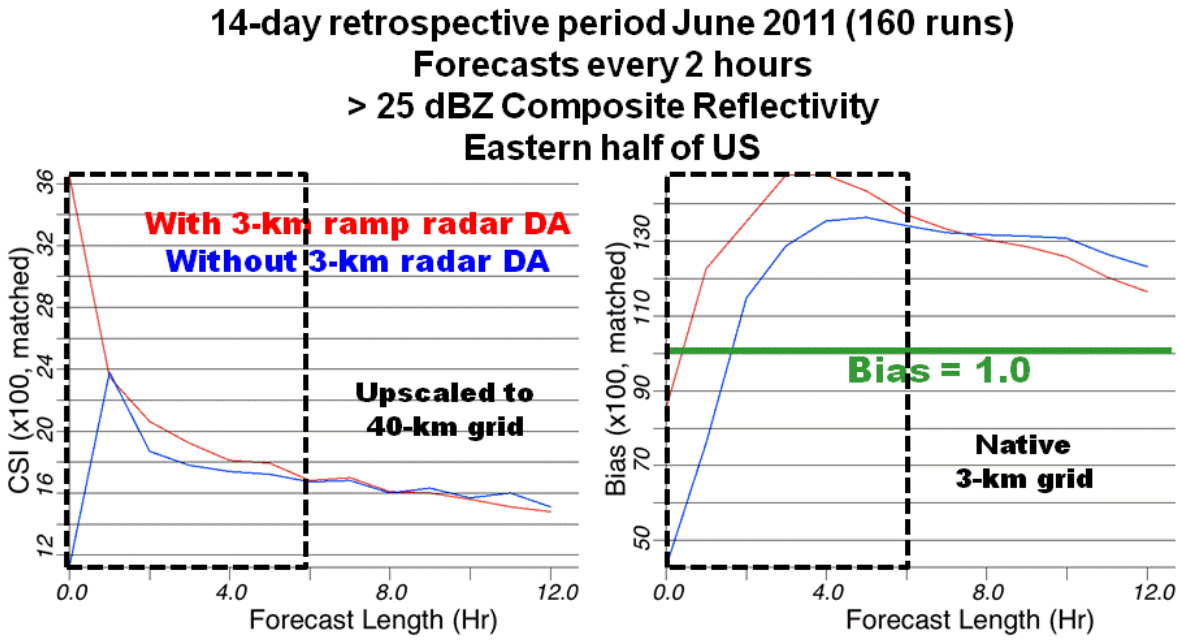

Fig. 3. Comparison of reflectivity forecast skill (measured by CSI) and bias as a function of forecast length for 14-day retrospective cycles with and without the 3-km 15-min cycled hour pre-forecast reflectivity data assimilation period. The red curve ("with 3-km radar DA") shows improvement relative 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 – 12 Dec 2012

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 11 Dec 2012: All RAPv2 milestones are now further delayed until late FY13 or early FY14, 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)	5/31/13	☐	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	05/01/13	☐	NCEP plans a moratorium that may delay this implementation, although ESRL and NCEP will try to

readiness (NCEP, ESRL)			implement RAPv2 before it since code is essentially ready as of spring 2012.
12.5.5.E5 Pending computer resources, implement RAPv2 at NCEP (NCEP, ESRL)	07/01/13	☐	
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.
12.5.5.E9 Report on planned GSI changes for the RAPv2 upgrade to the Rapid Refresh (ESRL)	09/30/12	☑	
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)	2/01/13	☐	Task is essentially complete now in ESRL RAPv2 but will keep the door open for additional physics mods until Feb-Mar 2013, given the likely RAPv2 implementation until late 2013.
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)	8/1/13	☐	Changed Nov 12 with further NCEP delays on RAPv2.
12.5.8.E4 Pending computer resources, implement RAPv2 at NCEP with new physics configuration (ESRL, NCEP))	10/01/13	☐	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