MDE Product Development Team
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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 October 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 June 2013 after NCEP implementation moratorium is lifted.
- RAP-dev3 cycle (identical code with Jet RAPv2) running on new NOAA research high performance computing system, ZEUS, supporting a parallel 3-km HRRR on that machine, also 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

- Initial single-observation tests of EnKF hybrid for RAP using background error covariance information from 80-member GFS global ensemble. ESRL is following similar NCEP/EMC experiments for NAM data assimilation also with the GFS-ensemble-based background error covariance.
- Real-time developmental RAP in Zeus now running with similar reliability to GSD real-time RAP v2, two additional real-time developmental RAP cycles running on Zeus
- Real-time experimental HRRR-based RTMA 2D surface analysis and RUA cloud analysis running on Zeus with graphics available on web
- Code development and initial retrospective test completed for assimilation of "SatCast" IR cloud top cooling rate CI assimilation.
- Presentation on RAP satellite radiance assimilation at JCSDA workshop.

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

- 2012 warm season HRRR real-time evaluation concluded Oct. 31 with excellent HRRR verification and reliability
- Encouraging results from a series of retrospective tests to evaluate different options for 3-km cycled assimilation, including 1-h pre-forecast cycling with just radar data assimilation and fully cycled 3-km assimilation of all observations
- Presentations on latest HRRR and RAP developments at recent AMS Severe Local Storms Conference

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 October. 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. Improvement in RAPv2 over RAP-NCEP-oper over the July-Sept 2012 period is repeated in Fig. 1, showing consistent improvement for wind, temperature, and moisture at all levels. 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. An official decision on this by the NCEP director is pending, but indications are that, because of the current moratorium on new implementations due to conversion to the new Linux-based WCOSS computer, the implementation will not occur until later in 2013.

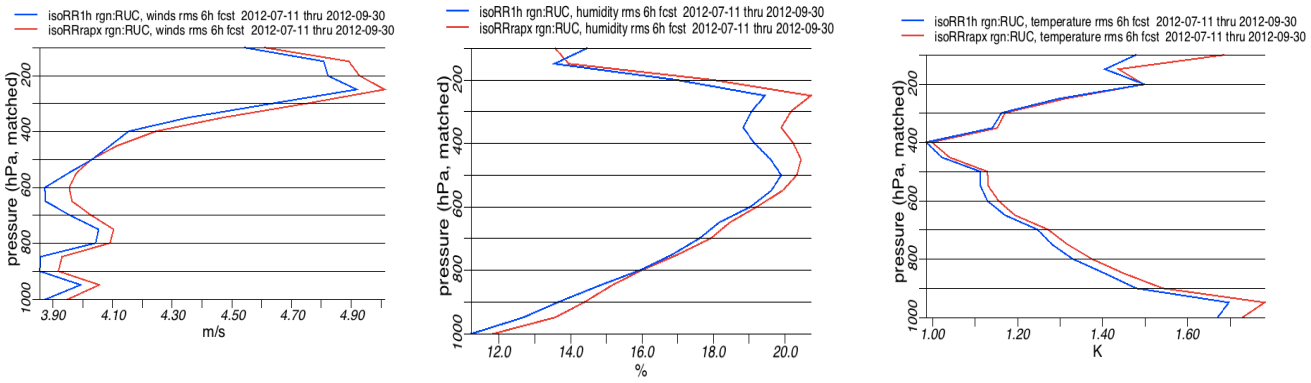

Figure 1. Last 3 months of verification of RAP upper-air 6h forecasts from RAP-ESRL (in blue) and RAP-NCEP-oper (in red) against rawinsonde observations for 20 July – 15 August 2012 on top line and for 11 July – 30 Sept 2012 on lower line. The 3 graphics are for wind (left), temperature (center), and RH (right). (repeated from last report)

The three principal thrusts of RAP work at ESRL/GSD during October were toward

1. Completing the transfer of developmental RAP cycles from the Jet computer in Boulder to the Zeus supercomputer at the NOAA Environmental Security Computing Center (NESCC) in West Virginia,
2. Further improvements to the RAP in preparation for implementation of RAPv2 in 2013, and
3. Enhancements to the HRRR in preparation for 2013's convective season.

Late in September, the capability on Zeus to use NCEP prepBUFR files containing proprietary data was achieved, finally allowing in early October a rigorous comparison of forecasts from the RAP-development1 (RAP-dev1) cycle on Zeus with the RAP primary that continues to run on Jet. This comparison showed that forecasts were very close, so now the RAP-dev1 on Zeus can be used for parallel testing, much as the dev cycles on Jet were used before that machine became unavailable for this purpose. (Only the RAP primary supporting the HRRR and the

HRRR itself are still running on Jet). Ongoing or planned near-term testing using RAP-dev1 or a new RAP cycle (RAP-dev2) that more recently became available on Zeus include the following:

- 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
- Testing of WRF version 3.4.1 released in August (with GSD enhancements), to be compared with v3.3.1+ currently in use
- Upgrades to the RUC land-surface model (LSM) from 6 levels to 9 levels (more accurate surface temperatures) 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).

The immediate goal is to arrive at the final version of the RAPv2 code so that it will be ready as soon as NCEP is in a position to begin testing it there on the new WCOSS machine in preparation for the RAPv2 implementation. (At this writing, access to "Tide", the development half of the WCOSS machine, has just been achieved.) We are also looking ahead to a likely RAPv3 implementation in 2014, 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 (1 November), we have laid plans and begun intensive testing of several possible HRRR enhancements for both assimilation and model. This includes

- HRRR direct 3km cloud analysis (instead of relying on 13km RAP cloud fields)
- A new radar assimilation procedure for the HRRR that promises improved HRRR forecasts in the first 2-4h
- 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 October.

- 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 are working with the NCAR WRF developers in validating that GSD WRF enhancements for RAP are qualified for inclusion into the WRF repository. They will likely become part of the WRFV3.5 release in spring 2013.

An added note: Tanya Smirnova has successfully run the WRF/NMM v3.4.1 on Zeus with both the default physics and the physics options used in the HRRR.

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

NCEP
The codes for the first update to the RAP, featuring new versions of the WRF-ARW and GSI analysis code, are being ported to the new WCOSS machine. Now that NCEP is in a moratorium on implementations, this upgrade won't be scheduled until mid-calendar year 2013. (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) will be made available to GSD by the end of November by NCEP Central Operations (NCO) for the 00z and 12z RAP runs at ESRL to initialize the HRRR. This is noted in a new 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**. This verification was the basis for Fig. 1 shown earlier in this report. Additional obtions for subareas of CONUS were added by Bill Moninger (+ / - 109^{o} W), chosen to gauge impact of satellite-derived Atmospheric Motion Vectors (AMVs) over the Pacific.

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 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 later in 2012 or early 2013.

12.5.4.8 31 May 2012 **(ESRL, NCEP)**
Start design of NARRE ARW and NMM model ensembles. Use of ensemble/hybrid data assimilation, likely augmented by different physics suites, provides variability for the ARW and for the NMMB. Work at ESRL, CAPS (not funded currently) and EMC on regional ensemble data assimilation (see 5.5) is critical for improved deterministic and probabilistic forecasts from the NARRE. 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)

GSD
In work initiated in May, Ming Hu reports progress toward adaptation of the GSI ensemble/variational hybrid capability toward use with the RAP. Both GSD and NCEP/EMC agree that hybrid ensemble data assimilation is critical for the NARRE. A presentation was developed on NARRE/HRRRE plans by Stan Benjamin for a DTC/NUOPC Workshop in September. 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 perhaps RAPv2 or RAPv3.

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. Stan Benjamin and Steve Weygandt made a joint presentation on the RAP / HRRR status at this review, held 6-7 December at NCEP.

COMPLETE. Available at **http://www.emc.ncep.noaa.gov/GEFS/prod-review/NCEPmodelReview-2011.html**

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)

PLANNED EFFORTS: Item is completed.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

12.5.4E3 1 Mar 2013 GSD
Final code ready for transfer to EMC for Rapid Refresh upgrade change package to be implemented in spring 2013.

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 October 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 is coming up on 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 intercompare 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.

This date was further delayed a bit given the likely RAPv2 NCEP implementation schedule, although the already-completed RAPv2 reports for the summer 2012 HRRR constitute a preliminary report.
UPDATES TO SCHEDULE: Changed from previous 30 Sept to 30 Nov.

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 help from NCEP/EMC personnel, Ming Hu completed some initial single-observations tests of application of the GSI hybrid ensemble capability to the Rapid Refresh, using background error covariance information from the 80-member global GFS ensemble DA system, obtaining encouraging results. Ming has also been applying the NCAR GEN_BE utility to sets of RAP grids to obtain improved estimates of background error covariance fields.

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]

4. Tracy Smith and colleagues at GSD completed coding within the GSI to ingest and assimilate "SatCast" IR cloud-top cooling rate data into the RAP via the RAP radar DFI procedure. Cloud-top cooling rate data are converted to a heating rate and applied within the forward model portion of the DFI). She has completed a limited

initial retrospective comparison, obtaining reasonable differences between the data assimilation run and a control. She presented results from this work at the recent Severe Local Storms Conference in Nashville.

5. 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.

6. At the recent AMS Severe Local Storms Conference in early October, Steve Weygandt presented work illustrating the improvement of the 2nd generation RAP (RAP-v2, running in real-time on the GSD JET computer) over the current RAP for both RAP analyses and forecasts and for HRRR forecasts initialized from the RAP.

Subtasks

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.

NCEP
Work continues on finalizing the new dual-pol decoder that NCO has written (see 12.5.5.12). Tests are underway on a QC algorithm for the dual-polarity radar variables, which is expected to improve the quality control procedures for radial wind, reflectivity and VAD winds. (Shun Liu)

12.5.5.6 Jan 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. Move this deadline to 31 December 2012. 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 April 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.

NCEP

A package of revisions from ESRL/GSD was committed to NCEP's GSI SubVersion trunk on April 26, 2012. This will form the basis of the RAPv2 GSI testing. 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

Changes to the MPI-implementation in the code for the RTMA post-processing have been made to reduce the code's memory usage. Work is underway to port the operational RTMA to the WCOSS machine. The code for the RTMA pre-processing has been successfully compiled and tested, and the RTMA post-processing code has been successfully compiled. Improvements to the observation blacklists and accept lists, which are created from the RTMA innovation statics, are being explored by geographically restricting 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,

In October, work continued by Patrick Hofmann in setting up real-time runs of the RTMA using 1h 3km HRRR forecasts as a background, much better than downscaled information from the 13km RAP for local-scale details.

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 31 July 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
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. David Parrish created an automatic internal endian conversion for the WRF-NMM and WRF-ARW binary input. (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
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. 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. (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
After parallel tests with neutral impact on the NOAA R&D computer, the new GPS refractivity data were turned on and included in the official NDAS parallel on CCS. It was found that the ozone channels of IASI Metop-A were used inadvertently in both the operational global and the regional assimilations. These channels were turned off in the NDAS parallels so that we could fix the error in the next implementation. It was found that the ozone field value input to the radiative forward model CRTM in the regional analysis was zero instead of undefined. If ozone were undefined, climatology values defined inside CRTM would be used. Since GSI initializes all the first guess fields with zero, 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 the correct ozone climatology or using ozone from the global system. (Wan-Shu Wu)

Yanqiu Zhu is now testing a new method for more effective use of satellite radiance data in regional models in the NDAS. The procedure is based on a newly defined temporary vertical coordinate that is used internally in GSI. The new coordinate consists of the regional model in the lower atmosphere, which is smoothly connected to the global model vertical coordinate in the upper atmosphere. In the case of the 64 level GFS and 60 level NMMB, the temporary internal coordinate has 75 levels, with the transition zone from NMMB to GFS between 150 and 79 mb. The guess is then a blend of NMMB in the lower atmosphere and GFS in the upper atmosphere. With this blended guess, it appears to be possible to significantly improve the use of satellite radiances in the NDAS. (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.

David Dowell 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

In October, main efforts were focused on tuning 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. The readjustment was needed because the additional AMSU-A data greatly reduced the spread of EnKF system, rendering the previous tuning suboptimal. Dozens of EnKF experiments with different inflation and localization parameter combinations were conducted and Fig.2 shows the forecast RMSEs verified against sounding data for the best experiment. In this experiment, the fixed inflation coefficient β was increased from 0.1 to 0.15, the vertical localization length $\ln(p_{cut})$ was set to 0.8 and the horizontal localization radius was set to 700 km for the radiance data. The GSI experiment is also rerun with the AMSU-A data included.
For the GSI experiments, the assimilation of AMSU-A reduces the forecast errors of U and V wind components (Fig.2c, d), keeps the errors of T about the same (Fig.1b), but increases the RH forecast errors by about 1% at 3 hours which decreases with time. The errors from the EnKF experiments are consistently lower than those of GSI experiments, with or without AMSU-A data. In the EnKF experiments, the assimilation of AMSU-A again reduces the U and V forecast errors noticeably, but increases the T errors slightly while reducing the RH error. This difference in the AMSU-A impact on T and RH requires further investigation. It is also surprising the radiance data has more positive impact on the wind rather than temperature or humidity forecasting.

When verified against surface station observations (not shown), for the GSI system, AMSU-A data improve the forecasts of all surface variables except for pressure. For EnKF, AMSU-A data reduce the errors in RH, temperature and the V wind component but slightly increases the error in U. Errors in surface pressure is comparable.

Given that bias correction for radiance data can significantly affect data impact, we tested two different bias correction procedures. One is based on the bias estimation produced by the GSI system, and one performs the estimation within the EnKF itself. In GSI, the bias parameters are appended to the model state vector and updated as part of the data assimilation process (Harris and Kelly 2001). In EnKF, the bias parameters are estimated through linear regression (Dee 2004). In both procedures, the bias parameters updated at the previously analysis time is used as the background estimate for the current cycle. Tests show that the EnKF-based procedure generally works better. Further testing will be needed with the bias correction to hopefully obtain consistently positive impacts of AMSU data. The results in Fig. 2 used the EnKF-based method.

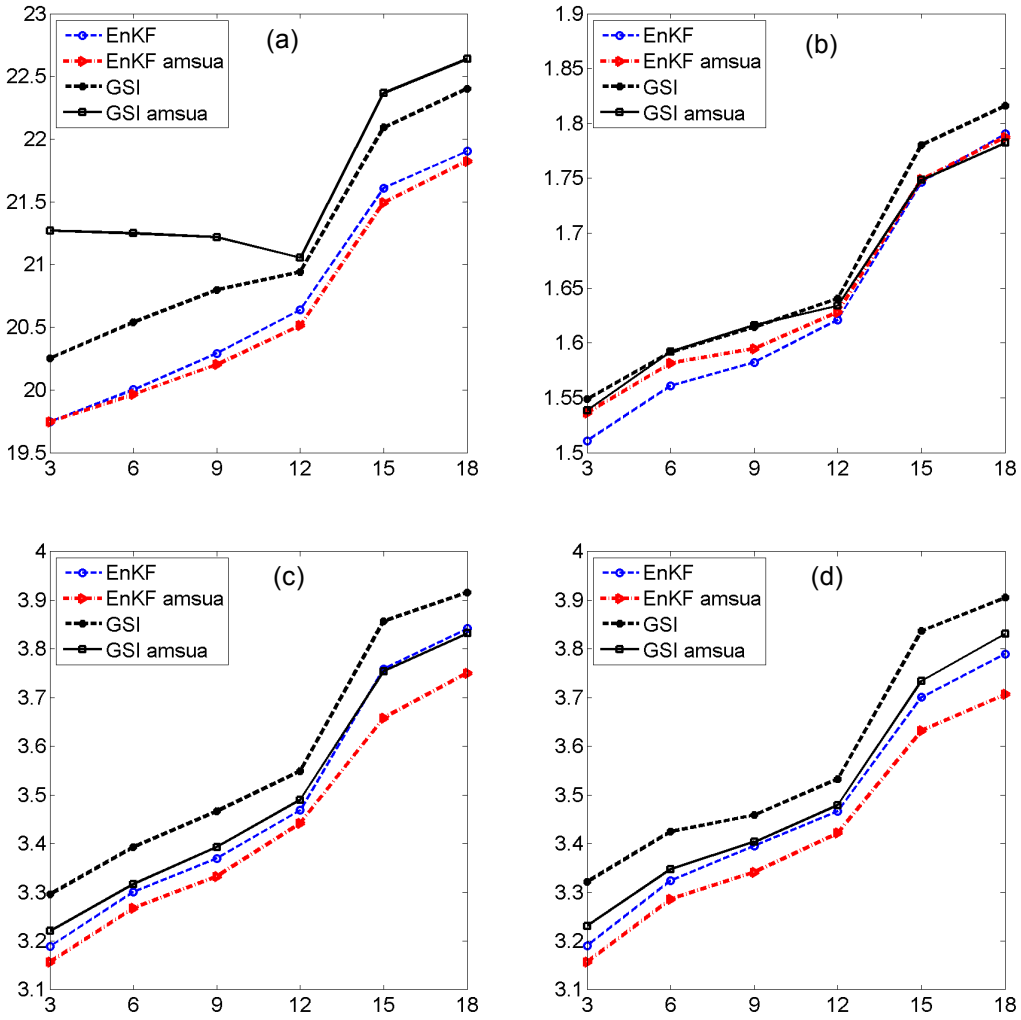

Fig.2. 9-day test for domain-averaged forecast RMSEs of experiments with and without AMSU-A data using GSI or EnKF, verified against sounding data, for (a) relative humidity, (b) temperature, (c) U wind component and (d) V wind component. The horizontal coordinate is forecast hour.

In September, EnKF and 1-way hybrid with 20 instead of 40 ensemble members were run. RMSEs of 1-way hybrid with 20 members (using half static and half ensemble-derived covariances) were close to those of hybrid with 40 members, while EnKF with 20 members gave clearly inferior results than 40. To better understand the hybrid system, a 2-way hybrid experiment with 20 members was also conducted. As in the 1-way case, results with the 2-way hybrid and 20 members were not too different from the hybrid results using 40 members and both were better than GSI. However, the RMSE differences of 2-way hybrid between 40 and 20 members were slightly larger than those of 1-way hybrid, suggesting that the ensemble size makes a larger difference in 2-way coupled hybrid.

In last month's report, we said that 1-way hybrid with full flow-dependent covariance produced higher RMSEs than pure EnKF in short range forecasts. To see if it is the observation-type-dependent localization used in EnKF made the difference, we ran the EnKF-hybrid analyses in multiple steps, with each step using only a group of observations having the same localization scales (hereafter, 3GROUPS). The observations were organized into three groups: relative humidity (RH) and temperature (T); winds (u, v); precipitation water (pw) and surface pressure (ps). The domain averaged RMSE differences ($\sum|\mathrm{RMSEs}_{hybrid} - \mathrm{RMSEs}_{EnKF}|$) from 3GROUPS hybrid

and EnKF were significantly smaller than those from 1GROUP experiments where all observations were assimilated in one step (Fig.2.). This indicates that the observation-type-dependent localization was primarily responsible for the difference between hybrid and EnKF. More recently, we re-organized observations into four groups: RH and T were first split into two groups based on the observation that RH has a smaller vertical localization scale than T in the GSI system. This change reduced temperature errors significantly in the pure EnKF while increasing wind and RH errors above 500 hPa. For the hybrid, the differences were small.
Also, in the past month, we tested the latest GSI version 3.1 release. The parallelization problem reported in August appears to have been fixed. However, compared to GSI version 3.0, the errors of all forecast variables were worse. Thus, we are sticking with GSI 3.0 for the moment.

In October, a manuscript (Zhu et al. 2012) summarizing the work of EnKF hybrid was completed for internal review.

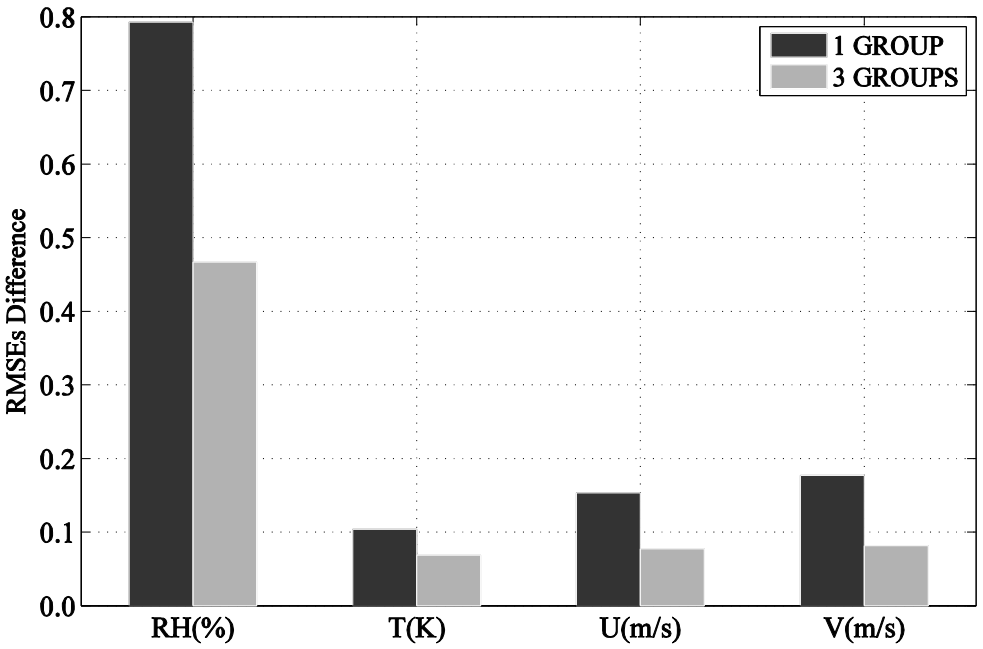

Fig 3. Results from 9-day test with domain-averaged forecast RMSEs differences ($\sum|RMSEs_{hybrid} - RMSEs_{EnKF}|$) verified sounding data (1 GROUP: observations are assimilation once a time; 3GROUPS: observations are assimilated by three steps)

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.

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.

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 most aspects of the physics receiving some attention during October. This is detailed under Subtask #1 below. Although RAP is not a primary guidance tool for hurricanes, we are happy to report that RAP forecasts for Super storm Sandy (landfall late on 29 October) were of good quality.

NCAR/RAL
CURRENT EFFORTS: During the month of October, no additional effort (or funds) was devoted to this task due to priorities on other projects.

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: Some delays were encountered due to staff working other projects. We anticipate assigning other staff to the project to regain some lost time, but this is not yet fully decided.

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).

Results of this testing for individual cases, both for the 9-level version of the RUC LSM and the land-use / land-surface properties, have shown good results. Further testing using retro periods and in real time awaits completion of validation of other RAP changes.

In September, a WRF user submitted a modification to the MYNN PBL scheme to incorporate gravitational settling of fog droplets to NCAR from Japan for consideration for inclusion in the WRF repository. Joe Olson, as the focal point for the MYNN PBL scheme in WRF, was made aware of this and has been working with the WRF developers at NCAR to test and validate this enhancement for inclusion in the WRF v3.5 release scheduled for next spring. This, together with a slight modification of the coupling between the MYNN surface layer and the RUC LSM have shown promise for eliminating the over prediction of ground fog over snow cover when the MYNN is used. If this success were confirmed through retrospective or parallel testing in RAP, it would alleviate this serious concern about the behavior of the MYNN over snow cover noted in previous MDE reports. Such tests are planned for the near future.

Georg Grell continues work on a new version of his convection parameterization, in collaboration with Saulo Freitas of Brazil. They are aiming to have this ready for inclusion in the WRFv3.5 release next spring. When this becomes available, it will be tested in RAP against the latest released version of the scheme (WRFv3.4.1) and the earlier v3.2.1 version that is currently being used in both the NCEP operational RAPv1, as well as the RAP primary on Jet and the RAP-dev1 on Zeus.

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. The announcement was sent out to the WRF mailing list in October. 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 are preparing for the next major release, which will be WRF Version 3.5. The release is planned for Spring 2013, and an announcement regarding the release has been sent out by NCAR. 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) has been collaborating with Stephanie Evan (NOAA/ESRL) on microphysical modifications for the tropical tropopause layer (TTL). This work is motivated by evidence that current schemes are deficient in ice nuclei assumptions in that region, and this can affect stratospheric water vapor.

Dudhia collaborated with Craig Mattocks (Univ. Miami) and David Nolan (Univ. Miami) on a new surface drag formulation for hurricanes. He also hosted visitor Baode Chen (Shanghai Typhoon Institute) to plan collaborations on the effects of aerosols on hurricanes.

Dudhia began a collaboration with Mukul Tewari (NCAR/RAL) on work with Greg Thompson (NCAR/RAL) and Hugh Morrison (NCAR/MMM) to separate cloud optical properties from the radiation scheme. This is aimed to allow for better future compatibility with microphysics properties.

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.

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

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 1 Sept 2012 (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.

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 2012 (NCAR/RAL)
A written report by mid September 2012 summarizing enhancements made to the model physics packages.

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. Report 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:

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.

4. As reported under task 5.5, GSD scientists now have real-time versions of the RTMA surface analysis and RUA cloud analysis running and graphical images form these runs are available on the GSD/AMB web-site.

(Intentionally repeated from last month's report)
September update – The real-time HRRR continued with very good reliability during the month of September. Reliability statistics for the first three weeks are as follows:

HRRR Jet Availability:
All missed runs: 89%
Excluding single run misses: 96%
Excluding two consecutive run misses: 97%
Excluding three consecutive run misses: 98%

HRRR Zeus Availability:
All missed runs: 77%
Excluding single run misses: 82%
Excluding two consecutive run misses: 84%
Excluding three consecutive run misses: 85%

Key progress was made on the Zeus version of HRRR, including getting the observation data feed to Zeus (there is still an issue on both JET and ZEUS with the 00z and 12z "early" data feeds, which are key for the 00z, 12z HRRR runs. The key remaining action item for enhancing ZEUS HRRR run reliability is establishing computer node reservation on ZEUS for RAP and HRRR. ZEUS IT personnel are aware of this item and working toward it.

Building upon the successful 3-km 15-min cycled radar data assimilation results shown by David Dowell at the NWP conference last May (see below – Fig 4), Curtis Alexander is undertaking a series of 3-km HRRR radar reflectivity assimilation experiments, focused on improving the storm prediction skill during the first few hours of the HRRR forecast. Our current plan is to have some version of the 3-km radar reflectivity assimilation in place in the real-time experimental HRRR for the 2013 convective season.

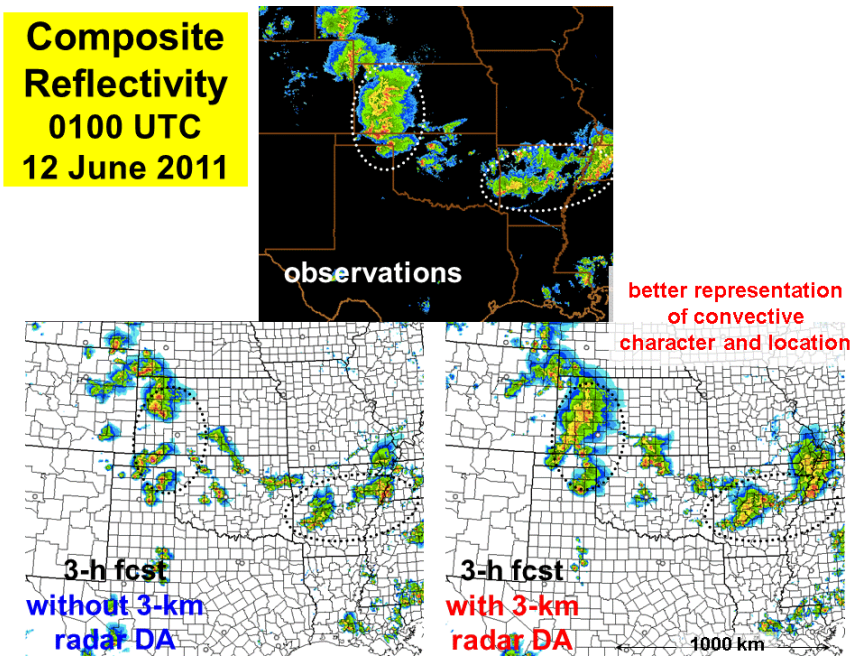

Fig. 4
3-h forecast reflectivity from case with (lower right) and without (lower left) 1-h of 3-km 15-min update pre-forecast radar reflectivity assimilation (via specification of latent heat-based temperature tendency during forward integration.) Comparison with radar observation indicates forecast with 3-km radar assimilation better captures convective clusters.
Subtasks

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**

August Summary:
Exercise ongoing with very good overall HRRR performance and reduced false alarms compared to 2011 noted. Storm structure seems to be especially well predicted with this 2012 RAP/HRRR configuration. 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. Fig. 4 shows the 12-h HRRR forecast of reflectivity and max 10m winds.

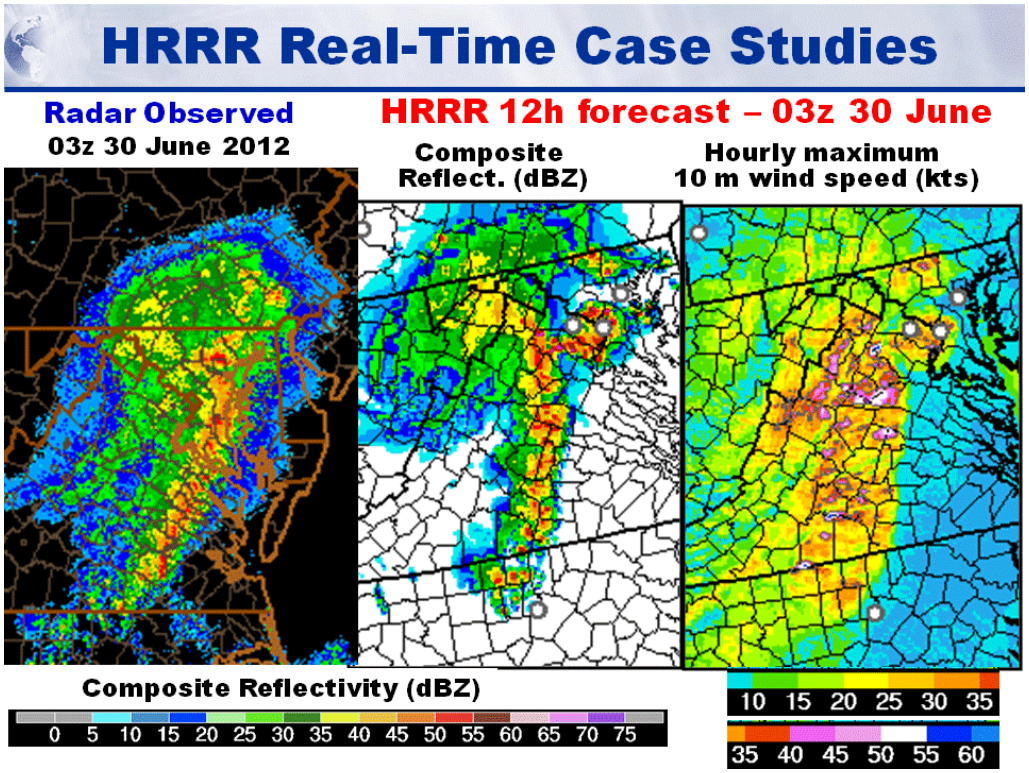

Fig. 4. Observed radar reflectivity (left) and HRRR 12h forecast reflectivity (center) and 10 m wind (right) from the extremely damaging derecho that struck Washington DC at 3z 30 June 2012.

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 Nov 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			All RAPv2 milestones are delayed until late FY12 or FY13, as noted below and in earlier monthly and quarterly reports.
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	☐	
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)	09/30/12	☐	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	☐	Date changed this month. Task is essentially complete now in ESRL RAPv2 but will keep the door open for additional physics mods until Feb 2013, given the likely RAPv2 implementation until June 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)	5/1/13	☐	
12.5.8.E4 Pending computer resources, implement RAPv2 at NCEP with new physics configuration (ESRL, NCEP))	7/01/13	☐	
12.5.8.E5 Transfer the coupled aerosol-microphysics scheme into a test version of HRRR (NCAR/RAL)	09/01/12	☐	NCAR reports that this code is not yet ready for transfer.
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)	09/15/12	☐	
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