MDE Product Development Team
March 2nd Quarter Report – FY 2012
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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)

- Continued progress toward RAP implementation at NCEP to replace the RUC, now planned for 1 March. After discovery that no radar reflectivity data has been assimilated since January due to a script error, a new limited 30-day evaluation was started in late March, which has been going well. No additional
- A presentation on the RAP implementation for a 3/12 briefing to NCEP management is available at **http://ruc.noaa.gov/pdf/RAPbrief.NCEP-Dir-20Mar2012.pdf**.
- Further upgrades to ESRL RAP implemented at ESRL in February through early March, including data assimilation and modeling improvements. All of these will be included in Rapid Refresh v2 (RAPv2) with implementation at NCEP, proposed for early FY13.

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

- Recent short-range upper-air verification continues to show strong improvement of NCO parallel RAP over NOAA operational RUC, indicating good performance by the RAP GSI analysis package.
- Merge of ESRL/GSD GSI trunk with recent NCEP (r16882) / community (r719) version. Benchmarking of this updated GSI version, followed by use for all ESRL/GSD real-time runs. With this merge, the RAPv2 inherits other GSI community improvements from NCEP, NASA and others.
- Further enhancements to GSI cloud analysis added to the ESRL/GSD RAP version 2, including provision for partial cloud building and building of marine stratus at a level consistent with the background marine boundary layer. These changes are being merged back to the NCEP/EMC subversion trunk of GSI via a Trac ticket system.
- Addition of GLD360 lightning data to GSI analysis for real-time ESRL/GSD RAP cycle runs.
- Continued testing and evaluation of impact from assimilation of energy observations (nacelle, tower, sodar).
- Inclusion of level-2 radial wind assimilation in GSD real-time parallel RAP based on near-neutral impact from real-time parallel tests.
- RAP 13-km and 3-km GSI running on new Zeus supercomputer
- Initial work to run RTMA 2DVAR using 3-km HRRR CONUS grid as input (collaboration with M. Pondeca)
- Discussions with AK NWS personnel on arctic surface temperature and cloud analysis issues

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

- Updated version of WRFv3.3.1 implemented in RAP-primary at ESRL using options tested at ESRL for optimal RAP performance, especially for clouds.
- Updated Thompson v3.3.1 microphysics and MYJ boundary layer and RUC land-surface schemes implemented in RAP-primary at ESRL on 15 Feb.
- ESRL RAP updated to use MODIS land-use and fractional sub-grid-scale data – 15 Feb.
- Testing continues of GSD/Olson version of MYNN PBL scheme with some excellent results but testing was insufficient to include MYNN PBL in the frozen summer 2012 RAP/HRRR system.

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

- HRRR system frozen on 9 March 2012 for the 2012 real-time evaluation season.
- HRRR Program Review presented at ESRL/GSD – see **http://ruc.noaa.gov/pdf/HRRRProgramReview-13mar2012.pdf**. This is an excellent summary of recent progress with the HRRR and the ESRL version of the Rapid Refresh from which the HRRR is initialized.
- Completed extensive real-time and retrospective testing / evaluation of numerous candidate changes for RAP/HRRR system arriving at substantially improved convection, surface, and precipitation forecasts

from the now-frozen system for 2012 CoSPA real-time evaluation.

- Main RAP / HRRR enhancements for 2012 CoSPA evaluation include: 1) upgrade/code merge to recent community versions of both GSI (for RAP) and WRF for RAP and HRRR, 2) several enhancements to RAP analysis to reduce moist bias in RAP, 3) several WRF model enhancements for both ESRL/GSD RAP and HRRR, 3) upgrade to reflectivity diagnostic calculation that is consistent with the new Thompson microphysics (for both ESRL/GSD RAP and HRRR)
- Completion of 9-day Aug. 2011 retrospective test using frozen RAP version, followed by 9 days of HRRR runs with dissemination of grids to NCAR/RAP and MIT/LL. Verification comparison to 2011 HRRR shows substantial reduction in high reflectivity bias in first few hours while maintaining similar CSI scores.
- 9-day June 2011 RAP retrospective run nearly complete on Zeus. Work to run June 2011 HRRR cases on Zeus ongoing.
- Good real-time reliability and performance for HRRR since 9 March code freeze
- Tests of 3-km GSI cloud analysis on both the ESRL JET supercomputer and the ZEUS supercomputer.

NOTE to all RUC/RAP users: **Now** is the overlap period with ***both*** RUC and RAP data available from NCEP for any users to sort out any transition issues. When the RAP changes status to operational, planned for 20 March or shortly thereafter, there will be no RUC grids available after this date.

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 Rapid Refresh (RAP) implementation was delayed yet again by computer issues starting 15 March culminating in the discovery that the NCO RAP was not using the 3-d mosaic radar reflectivity data. For those ftp'ing RAP data from NCEP, the absence of radar reflectivity data started in early January, but was not a problem with NCEP RAP data from Geoff Manikin in NCEP/EMC before that. This came just days after the 11 March RAP Evaluation Review (reported on in the February MDE report) led by Louis Uccellini, director of NCEP, resulted in a recommendation for implementation. This review included participation by personnel from the Aviation Weather Center (AWC), the Hydrometeorological Prediction Center (HPC), the Storm Prediction Center (SPC) and the National Weather Service Eastern Region, in addition to personnel from the Environmental Modeling Center (EMC). Stan Benjamin of GSD and Geoff Manikin of EMC made presentations at this review on RAP content and performance (available at **http://ruc.noaa.gov/pdf/RAPbrief.NCEP-Dir-20Mar2012.pdf**). These were well received, with the only reservations being expressed by the Storm Prediction Center out of concern that there haven't been enough severe weather episodes yet to fully evaluate the RAP, particularly its ability to describe and predict vertical sounding structures important for severe weather. The discovery that the RAP was not being properly initialized necessitated resetting the clock for a more limited RAP field evaluation involving primarily the SPC and AWC that will be completed in late April. Assuming no further problems, the implementation is now scheduled for 1 May 2012. (As noted in our January and February monthly reports, earlier in the quarter there had been two Unipost crashes that were quickly diagnosed by EMC and GSD. However, in each case, once the fixes were made and tested, NCO made the decision to restart the clock on the 4-week field test.)

After intensive effort during the first half of the quarter, the RAPv2 upgrade was brought to a point where retrospective testing on the August 2011 retro period was showing great improvement in alleviating the low level moist bias and the high precipitation bias that has been of much concern. Retrospective testing of the HRRR initialized with this version of the RAPv2 also clearly benefited the HRRR forecasts (see Task 5.24). The GSD RAP primary incorporating these enhancements was frozen on 9 March to support the HRRR for this warm

season's CoSPA exercise. Our subjective evaluation of HRRR forecasts since the 9 March code freeze has confirmed that improved HRRR initial conditions from the RAP2 upgrade improves HRRR convection forecasts, with fewer false alarms in particular.

The following is a cursory list of the most important RAPv2 enhancements now in the RAP primary cycle at GSD *beyond* the initial RAP code that will be implemented into NCEP operations in May. These have all been noted in recent MDE reports.

- GSI analysis
  - Radar assimilation change to use temperature-dependent hydrometeor specification that is particularly important in reducing warm-season moist bias.
  - Water-vapor pseudo-observations derived in the estimated boundary-layer depth from actual surface observations
  - Soil moisture/temperature adjustment from near-surface atmospheric analysis increment fields.
  - Adjustment of integrated precipitable water vapor observations to account for model-observation ground height differences
  - Use of radar radial velocities as well as limited low-level 50-80m wind observations (available through a DOE project) in the analysis
  - Extensive upgrades to cloud analysis, including
    - Constrain addition of snow hydrometeors from radar reflectivity to prevent excessive 1h precipitation and overall moist bias from subsequent excessive soil moisture.
    - Restrict cloud building into dry layers having a steep lapse rate
    - Various other changes to reduce moistening related to cloud building
- WRF model
  - WRF version 3.3.1 (released August 2011) instead of version 3.2.1 (released August 2010)
    - V3.3.1 of Thompson microphysics
    - Kept v3.2.1 of Grell G3 parameterized convection
    - 5th order accurate (replacing 3rd order) vertical advection—better retention of initial cloud layers in forecast
- UniPost
  - Radar reflectivity output now consistent with V3.3.1 Thompson microphysics

These other changes of slightly less but still notable importance for improving forecast skill have been in development and testing:

- The latest parallel testing on assimilation of radar radial winds has shown approximately neutral impacts, based on our objective verification.
- Other work toward improving the physical parameterizations in RAP continues (Task 5.8).
- Assimilation of low-level winds from towers, anemometers on wind-generator nacelles, and sodars (winds in lowest 100-300m). These proprietary data have been made available via NCEP through leveraging from the Department of Energy-funded Wind Forecast Improvement Project (WFIP). They are available in the upper Midwest of the US and some locations in Texas. Evaluation of the wind tower and nacelle data over the past 2 months has resulted in modification of the quality control for admitting use of the tower data and in deciding to use the wind speed only for the (superobbed) nacelle data. With these conditions, the wind tower and nacelle wind data, along with the sodar data, are now being assimilated within GSI.
- Efforts to improve the analysis fit of rawinsonde temperature and humidity data through reducing the vertical error correlation and lower observation errors are being made to address SPC concerns that RAP more faithfully replicate smaller-scale details of the temperature and moisture stratification that can be important for prediction of initiation of convection (see Task 5) with somewhat encouraging results. Data collection for use in generating new background error covariances specific to the RAP continues.
- Evaluation of use of Vaisala GLD360 lightning data as a proxy for reflectivity in DFI radar initialization. It was decided to also use lightning data from GLD360 and NLDN in the frozen 2012 confirmation.

An important development during the quarter: the new supercomputer, Zeus, at NOAA's new National Environmental Security Supercomputer Center (NESSC), Fairmont WV, successfully completed acceptance testing and became available for general users. This machine, which is shared between parts of NOAA Research

and NCEP / EMC model developers, and is a Linux cluster similar in overall configuration to Jet, but larger, with roughly 26,000 compute nodes. We expect to move most of our test and evaluation RAP activity to this machine over the next few months, as the hJet computer at ESRL will be decommissioned later this year. Ming Hu has been running a new RAP cycle, RAP-dev3 on Zeus for over a month, and considerable effort has gone toward establishing timely access to the requisite data files with help from the Zeus management team. The HRRR will also be run on Zeus in addition to the current nJet computer at ESRL. (See further discussion under Task 24.)

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

NCEP
The implementation of the RAP (now mostly referred to herein as RAPv1), which was targeted for March, hit a delay. Problems with the assimilation of radar data required a restart of the NCEP 30-day evaluation period. All issues have been resolved, and the new target date for the implementation is 1 May. Grids matching the RUC domain and content have been made available at 13, 20, and 40 km for output on pressure levels, and at 13 and 20 km for output on native levels. A 32 km full domain grid (#221) as well as an ~11 km Alaska grid (#242) and a 16 km Puerto Rico grid have also been generated and made available during the evaluation. Statistical analysis shows that the RAPv1 quality matches or exceeds the RUC for most parameters. Work is already underway to develop the second version of the RAP (referred to herein as RAPv2), which will feature updates to both the model (WRF-ARW) and the analysis code (GSI). (Manikin)

An RFC was implemented on 17 January to allow the (NASA Langley) LaRC GOES cloud product ingest used by RAPv1 to automatically switch to LaRC's backup server in the event their primary server goes down. Improved operational Vaisala Global Lightning Data (GLD) 360 data need to be decoded to replace the experimental long-range lightning data from Vaisala, which was terminated in September 2011. About 80% of the SODARs are not getting into the parallel RAPv1 because they do not get into NCEP in time for the RAP dumps. Consideration is being given to a dump time change or some other means to get the data into NCEP in time. (Keyser)

GSD
GSD continues to make pgrb and bgrb files available from the ESRL/GSD RAP-primary real-time 1-h cycle available from its FTP site. RAP grids from the pre-operational NCEP/NCO cycle continued to be available during the quarter.

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 maintained real-time availability of SAV and AIV guidance to all vendors from the operational hourly RUC on pressure surfaces on the 80-km AWIPS grid #211 via the NWS Family of Services (FOS) data feed and via the FAA Bulk Weather Data Telecommunications Gateway (FBWDTG). (EMC and NCO)

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

The RAPv1 implementation has been delayed to 1 May, so NCEP maintained real-time availability of full resolution gridded data from the operational RUC runs via anonymous ftp access via the NCEP server site at **ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/ruc/prod/** and at the NWS/OPS site at **ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/** in hourly directories named MT.ruc_CY.00 through MT.ruc_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**. A limited set of fields from the RUC runs (and other NCEP models) can also be viewed at **http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller**. (EMC and NCO)

NOTE to all RUC/RAP users: **Now** is the overlap period with ***both*** RUC and RAP data available from NCEP for any users to sort out any transition issues. When the RAP changes status to operational planned for 1 May, there will be no RUC grids available after this date.

12.5.4.4 Ongoing (NCEP, GSD)
Maintain access to model verification data.
GSD maintains its verification web site for RAP and RUC versions at **http://ruc.noaa.gov/stats/**
Statistics are available from the three RAP real-time cycles. Verification of the NCO pre-operational RAP is now available at this web site. This verification will continue with the official RAP implementation scheduled for 20 March.

The RAPv1 implementation has been delayed to 1 May, so NCEP maintained its capability and provided access to routine verifications of the operational RUC 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 (MMB) website:

http://www.emc.ncep.noaa.gov/mmb/research/meso.verf.html (EMC/MMB)

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

The implementation of the RAPv1, targeted for March, hit a delay. Problems with the assimilation of radar data required a restart of the NCEP 30-day evaluation period. All issues have been resolved, and the new target date for the implementation is 1 May. (Manikin)

12.5.4.6 changed to June-Sept 2012 **(ESRL, NCEP)**
Initial software for RAPv2 changes ready for porting to EMC.

Delays in the initial RAPv1 implementation will delay the RAPv2 upgrade until after the moratorium, likely no sooner than May 2013. (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 (RAP2) at NCEP near end of 2012.
COMPLETE - The configuration of the Rapid Refresh (RAP-primary at ESRL) for the summer 2012 is now fully set. This version of the RAP will be nearly equivalent to the RAPv2 version envisioned for NCEP by late 2012. 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.

12.5.4.8 31 May 2012 **(ESRL, NCEP)**
Start design of NARRE ARW and NMM model ensembles.

Using different physics suites will derive these. 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)

The NARRE-TL system has been sent to NCEP Central Operations for operational implementation. It is expected to be implemented along with RAPv1 in early May. (Binbin Zhou)

Physics were adjusted for the NMMB members in the SREF to reduce its warm bias. Tests to fix a surface temperature cold bias problem in WRF_NMM and WRF_ARW were performed with the new 16km SREF. Based on the test results, physics options in the radiation and surface physics schemes were adjusted to reduce the cold bias in the SREF WRF_NMM and WRF_ARW members. A "backscatter stochastic physics scheme" option was

added to the 16km SREF ARW members. In a test run, this backscatter scheme ran too slow and therefore wasn't practical for real time operations yet. Judith Berner is working to speed up the code. (Jun Du)

12.5.4.9 28 May 2012 (ESRL, NCEP)
Complete testing at EMC of RAPv2 code, pending NCEP readiness.

Delays in the initial RAPv1 implementation will delay the RAPv2 upgrade until after the moratorium, likely no sooner than May 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)

Delays in the initial RAPv1 implementation will likely delay the RAPv2 upgrade until after the moratorium, likely no sooner than May 2013. (Manikin)

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

Work on this project will begin after RAPv1 model is implemented at NCEP. (Tom Black)

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

ESRL continues to work primarily on bringing the FIM global model into NEMS compliance and working with NCEP to make further modifications to NEMS. (S. Benjamin)

ESRL did not start work on the ARW plan during the last quarter. (Tom Black)

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 RR / HRRR status at this review, held 6-7 December at NCEP. Presentations will be made available on the web.

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

12.5.4.E2 1 Feb 2012 (ESRL, NCEP)
Update documentation for operational Rapid Refresh.

NCEP and ESRL
CURRENT EFFORTS: A National Weather Service Technical Implementation Notice (TIN) concerning the RUC to Rapid Refresh transition was posted on 30 November 2011. It can be found at **http://www.nws.noaa.gov/os/notification/tin11-53ructorap.htm**. The document contains an overview of the model and explanation of the differences between the RUC and RAPv1. (Manikin)

PLANNED EFFORTS: Implement the RAPv1 in May 2012.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

12.5.4.E3 1 Oct 2012 (modified) (ESRL, NCEP)
Final code ready for transfer to EMC for Rapid Refresh 2 (RAPv2) package to be implemented in early FY13 (modified)

NCEP
CURRENT EFFORTS: Work will begin on RAPv2 after the RAPv1 is implemented in May 2012. (Manikin)

GSD – RAPv2 code is essentially now ready for testing at EMC. Discussion has taken place about the possibility of starting some testing of RAPv2 at NCEP this summer.

PLANNED EFFORTS:

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.

12.5.4.E4 30 March 2012 (ESRL)
Report on testing of RAP assimilation/model improvements toward planned RAPv2 upgrade.

Extensive testing complete or underway … see above.

12.5.4.E5 31 July 2012 (request change to FY13) (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RAP at NCEP.

NCEP
CURRENT EFFORTS: Work will begin on RAPv2 after the RAPv1 is implemented in May 2012. (Manikin)

PLANNED EFFORTS:

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 June 2013.

12.5.4.E6 Ongoing (ESRL, NCEP)
Perform configuration management for Rapid Refresh, including thorough documentation, and respond promptly to any code malfunctions or performance issues.

NCEP
CURRENT EFFORTS: A total of 25 RFCs directly related to Rapid Refresh (RAPv1) codes and scripts were submitted to NCO during the last week of October in preparation for the implementation. Twenty additional RFCs covering related systems and verification codes were also submitted. A thorough documentation of the Rapid Refresh codes and downstream dependencies is found in the Technical Implementation Notice found at http://www.nws.noaa.gov/os/notification/tin11-53ructorap.htm. (Manikin)

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

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

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

ESRL and NCEP
CURRENT EFFORTS: The Rapid Refresh (RAPv1) had been running stably in parallel for over a year before a series of crashes occurred in late December in the vicinity of a strong mountain wave generated by an intense jet stream over Greenland. Tests were made with a slightly different model configuration (i.e., the wave damping option was modified), and all cases which experienced crashes were run to successful completion. This new configuration was given to NCO at the end of December to update the RAP parallel code. (Manikin)

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

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

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

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

ESRL/GSD

NCEP operational implementation is now planned for 1 May 2012. Recent short-range (+3 hr) upper-air verification continues to show strong improvement for the NCO parallel RAP compared to the operational RUC, as indicated in Fig. 1. This indicates good performance by GSI analysis as configured for the RAP.

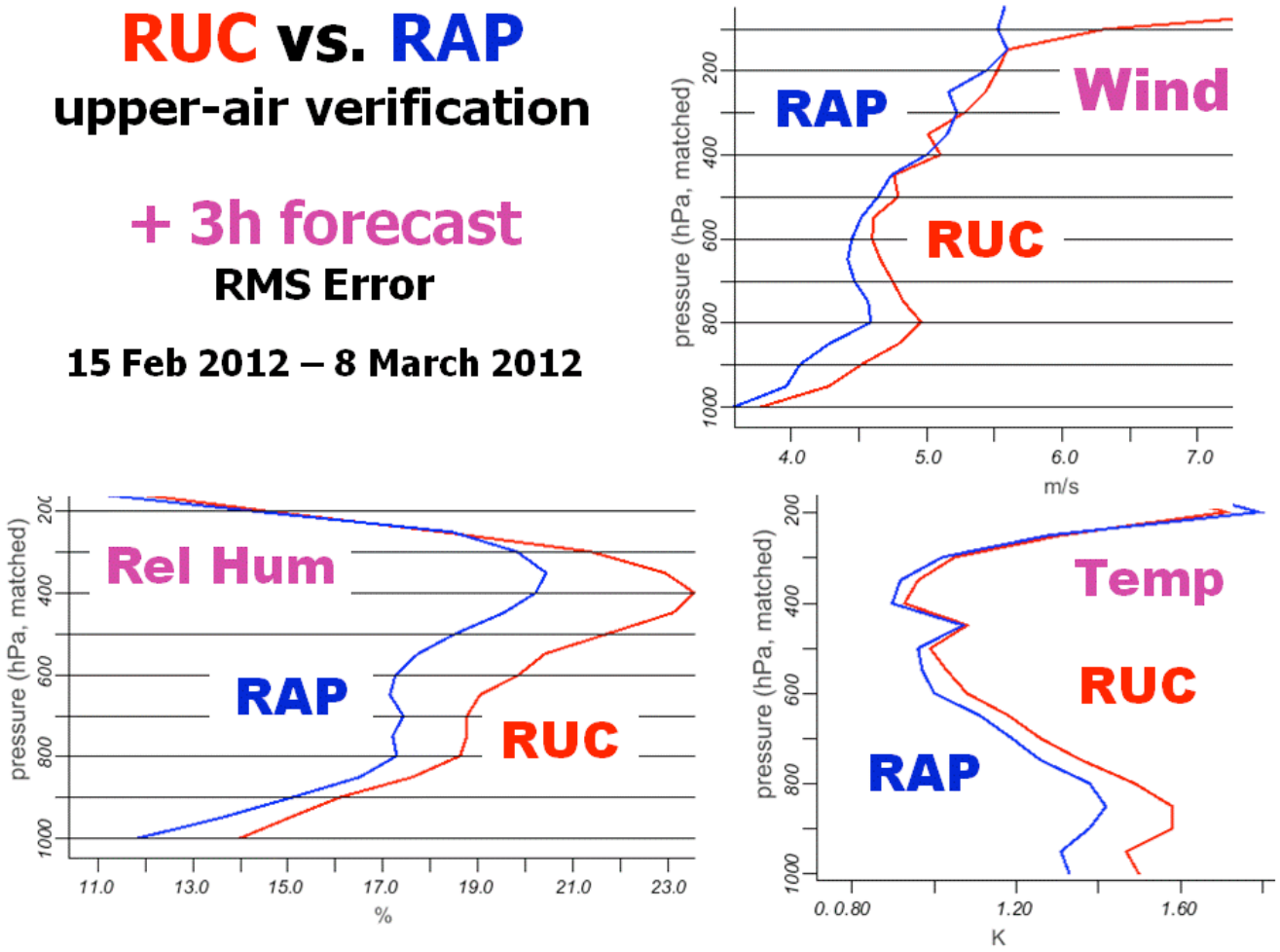

Fig. 1. Vertical profile of +3h forecast RMS errors for the NCEP Central Operations (NCO) parallel version of the RAP vs. the NCAP operational RUC for wind, temperature and moisture.

Work was completed to freeze a real-time ESRL/GSD version of the RAP to drive the HRRR for the 2012 CoSPA real-time evaluation. Additional changes beyond those implemented in Dec. / Jan. have included several items. 1) The treatment of cloud building was improved, so that the background cloud hydrometeor states of the individual grid columns within the search region of each observation are better preserved. The practical result of this enhancement is a reduction in the extent of artificial cloud "disks" from the cloud building. 2) The building of low-level marine cloudiness was modified to build at levels that are consistent with background marine boundary layer. 3) Assimilation of GLD360 extended range lightning data was added to the GSI, using a similar algorithm to that used for the NLDN lightning data (mapping the lightning to proxy reflectivity, use in the radar-DFI technique). 4) Assimilation of energy sector related observations (nacelle, tower, and sodar) and monitoring of forecast impact.

The impact of these changes (along with earlier set of changes listed below) was evaluated in both real-time and a retrospective run (for the 11-18 Aug. high weather impact period). Results indicate improvement in nearly all aspects of the model forecast. Specifically, a reduction in the high precipitation bias in the first hour of the RAP, improved upper-level skill scores (likely due to the reduction of spurious parameterized convective precipitation systems), and improved surface dew point forecasts. These changes will be part next version of the RAP at NCEP (RAP-version2) and of the RAP version frozen in March 2012 for the CoSPA exercise.

Previous changes implemented in ESRL/GSD RAP v2 system in Dec. 2011 / Jan. 2012:
(1) Added soil adjustment for moisture and temperature based upon near-surface temperature and moisture analysis increments
(2) Switched planetary boundary layer pseudo-observations to moisture only (remove temperature pseudo-observations)
(3) Modified GSI forward model for GPS-met PW observations to account for difference in terrain height between observations and model and to limit large PW innovations.
(4) Modified GSI cloud analysis to reduce relative humidity for cloud clearing and to preserve virtual potential temperature when adjusting water vapor for cloud building/clearing
(5) Incorporated new temperature-dependent specification of hydrometeor specification from 3-d radar reflectivity that significantly reduces excessive precipitation during first 1-2h of RAP model forecasts. This modified technique appears to be particularly important in reducing RAP and HRRR moist bias.

Work to evaluate impacts from real-time parallel testing of assimilation of low-level winds data from towers, wind-generator nacelles, and sodars is still ongoing. These data are available and being evaluated for RR assimilation through leveraging from the Department of Energy-funded Wind Forecast Improvement Project.

Ming Hu completed work to update the ESRL RAP-version 2 GSI to the latest EMC trunk (NCEP r16, 882, community r719). He is also working to merge recent RAP GSI changes back to the EMC GSI SVN repository via the track ticket system.

Patrick Hofmann has evaluated GSI parameter changes (most notably in radiosonde observation error specification) to obtain closer RAOP analysis fit to radiosonde vertical structure. This will be followed up by a retrospective or real-time parallel test to evaluate possible adverse impacts on forecast skill. With assistance from Manuel Pondeca at EMC, Patrick has also begun testing (on Zeus) application of the GSI RTMA 2DVAR code using a CONUS 3-km HRRR grid as input.

Cloud analysis – new software was developed to re-introduce GOES cloud building but only within 1200m of surface. This software was tested first in the development RUC and then tested within the GSI for the RAP. Additional work will continue in this area both before and after the RAP freeze. Curtis Alexander and Ming Hu have also recently run the GSI at 3-km to create detailed cloud analysis fields.

GSD contributors to RAP/HRRR effort under FAA and NOAA funding: Ming Hu, Curtis Alexander, Stan Benjamin, John Brown, Tanya Smirnova, David Dowell, Haidao Lin, Joe Olson, Patrick Hofmann, Eric James, Brian Jamison, Xue Wei, and Bill Moninger.

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.

12.5.5.1a 31 Jan 2012 (ESRL, NCEP)
Complete preparation of initial GSI changes for RAPv2 changes ported to EMC.

Work will begin on RAPv2 after the RAPv1 is implemented in May 2012. (Wu, Parrish)

NCEP
Delays in the initial Rapid Refresh implementation will delay the Rapid Refresh upgrade to 2013. Move deadline to 31 Jan 13. (Wu, Parrish)

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.

Ongoing retrospective and real-time testing led by Haidao Lin in this area. Improvements for AIRS data from selective channel removal shown in retrospective tests.

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

Scripts for off-line NDAS parallel tests were set up to compare using the GEFS ensemble versus the ENKF ensemble in the regional hybrid analysis. The impact test could only be performed when the ENKF was produced routinely in the global pre-implementation parallel tests. Due to resource constraints only 2 cycles per day were used. The results from the limited cases that ran to completion show that using the global ENKF ensemble improved the short term (3-hour) regional forecasts over using the GEFS ensemble and that the resulting hybrid variation-ensemble analysis significantly reduced the error of subsequent regional forecasts. Once the ENKF is implemented in the operational global in mid-May, this will be put into a NAM parallel. (Wu)

12.5.5.4 1 April 2012 (change to 31 July) (ESRL)
Complete testing of GSI changes for RR2 at ESRL.
Delays in the initial Rapid Refresh implementation will delay the Rapid Refresh upgrade to FY2013. Move this deadline to 31 July 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.

12.5.5.5 1 Feb 2012 (GSD, NCEP)
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
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 application 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).

In late March, Stan Benjamin noted the absence of data from the Langley Hill radar from western Washington State getting into the RAP at NCEP or ESRL and getting into the HRRR. The Langley Hill data was only installed last fall. Stan started a sequence of emails started resulting in changes at NCEP (Shun Liu) and NSSL to accelerate moving Langley Hill data into full usage in the US radar mosaics and therefore, getting into the RAP and HRRR models.

NCEP
Checks were done on the conv_vol Canadian radar data, which are used to generate the reflectivity BUFR tank. The ring discontinuity problem was resolved by using conv_vol reflectivity. Checks on the new VAD winds were begun. To use this new VAD, which has higher vertical resolution, the GSI code was modified to thin and super-ob the new VAD wind. Co-located data from new VAD winds and operational VAD wind were compared with NMMB background. RMS of the new VAD wind is smaller than that of the operational VAD wind while BIAS of the new VAD wind is larger than that of the operational VAD wind. Performance of CQC bird control for both new

VAD wind and operational VAD wind were compared, but the impact is small since the level-2 radar data QC already rejects most of bird contaminated scans before generating the new VAD wind. Only very few CQC bird events were found in new VAD wind. Checks were done on status of new radar at Langley Hill (KLGX) on the Pacific coast of Washington and single radar Cartesian grid files were generated so this radar will be included in the national reflectivity mosaic. (Shun Liu)

12.5.5.6 Moved to later in 2012 (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 15 June 2012 (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.

NCEP

Work will begin on RAPv2 after the RAPv1 is implemented in May 2012. (Manikin, Wu)

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

An improved first guess that blends the downscaled RAPv1 and NAM-nest forecasts has been tested and will be used with the new RTMA Alaska-3.0km. The capability to analyze cloud amount and cloud base height has been added to the GSI, so that an RTMA-GSI field of cloud ceiling can be diagnosed in the next RTMA. The GSI code has also been enhanced to handle the use of diurnal station blacklists for surface temperature and moisture observations, and direction-stratified station accept lists for mesonet wind observations. (Pondeca, Yanqiu Zhu, Levine)

GSD

Manuel Pondeca has provided the 2DVAR configured GSI code, scripts, etc. to Patrick Hofmann, who has started to run the code on Zeus and conduct initial test runs toward evaluating use of the 3-km HRRR as a background for the RTMA.

12.5.5.10 1 July 2012 (CAPS, ESRL)

Develop dual-resolution capabilities of EnKF and test it for RR configurations.

12.5.5.11 31 July 2012 (CAPS, EMC, ESRL)

Complete initial comparison of 13km EnKF/hybrid results using background error covariance fields derived from a global model ensemble vs. those derived from a regional ensemble.

GSD

Ming Hu has begun initial work to test a 13-km EnKF system on Zeus (collaboration with Kefeng Zhu and Yujie pan at OU/CAPS).

NCEP
Contributions and changes from several applications of the hybrid-ensemble analysis were combined and tested in each application before being committed to the GSI trunk on 29 March. Included are (1) the regional dual resolution option (Parrish); (2) the use of a switch to allow an ensemble member to be perturbed on the regional first guess instead of on the global ensemble mean, vertical weighting of static and ensemble background errors, and vertical weighting of the surface pressure contribution from ensemble (Wu); (3) HWRF additions (Tong); (4) NEMS-NMMB format ensemble input (Carley); and (5) several new 4d-var ensemble options that currently only work for global model (Kleist). (Parrish, 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
Forecasts with reflectivity assimilation from 20111219 to 20120116 were verified with the 3h STAGE2 precipitation and 24 STAGE4 precipitation. A lower precipitation bias was found with radar data assimilation. A bug in cloud analysis package for updating NMMB background was fixed. Cloud ice in the cloud analysis package was modified to be small cloud ice crystals rather than total ice for the NMMB background. (Liu)

Some corrections were made to the NMMB code's digital filtering to properly handle filtering of non-zero hour restart files. Previously in Shun Liu's radar assimilation work, his restarting of the model at 1 h to ingest more radar data would zero out the precipitation field and thus make the first 3 h precipitation total erroneously small. Adding the accumulated precipitation array to the list of physics fields to be restored to their pre-filtered state corrected the problem. Other changes were made to the logic deciding when boundary information needs to be read, as the wrong boundary information occasionally was read after filtering in the case of non-zero hour restarts. (Pyle)

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
The working version of the GSI was modified to include the radiosonde level enhancement, which was tested in the official NDAS parallel. A bug fix for the grid definition of the first guess fields was also included. This new version was tested with the off-line parallel and a neutral impact was found. This version was then used as the basis for new enhancements. Work on porting the analysis code on to the new NOAA R&D machine (Zeus) was successfully completed. The background error variance for the normalized relative humidity was tuned to study the character of the NDAS humidity analysis. The relative humidity distributions before and after the analysis procedure were compared as well as those before and after the model forecast. A lot more grid points were found to become saturated between 600mb and 200mb during the 3-hour forecast of the NDAS cycling while the analysis procedure produced acceptable changes to the relative humidity distribution. The background error variance for the normalized relative humidity was tuned and a bug related to using the normalized relative humidity as a control variable in GSI was fixed. The impact of these changes will be tested in an off-line parallel. (Wu)

Some preliminary results were obtained for the use of GDAS derived satellite channel bias correction coefficients directly in the NDAS GSI. A comparison for a single case was made between the operational regional GSI and the test version using GDAS sat bias, an extended vertical coordinate, and GDAS stratosphere. More high peaking channels were assimilated and overall statistics were better. However, switching from NMMB to GFS in the stratosphere adversely impacted many moisture channels. This was caused by a bug in the NDAS cold-start,

by which the specific humidity was 1 to 2 orders of magnitude too large in the top layers of the NMMB. This was due to setting a minimum value of RH to 1%, which, in retrospect, should have been more like .001%. In any event, instead of using relative humidity, specific humidity is now being used. Possible impact on the operational NDAS will be reported in the next monthly report (Parrish, Pyle, Rogers).

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.

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

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

NCEP
Work will begin on RAPv2 after the RAPv1 is implemented in May 2012. (Wu, Parrish, Liu)

Deliverables - All Option A unless noted otherwise.

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

12.5.5E3 (28 Feb 12) (NCEP)

Final GSI code transfer complete to EMC for Rapid Refresh upgrade change package to be implemented in spring 2012. (Combined with 12.5.5E1) (Manikin, Wu)

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

PLANNED EFFORTS: Implement the RAPv1 on 1 May 2012.

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 15 June 2012 (GSD, NCEP)
Pending EMC, and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit GSI code as part of spring 2012 upgrade for Rapid Refresh 2 software to NCO, pending NCEP readiness.

ESRL
Request for change to early FY13.

NCEP
Pending EMC, and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit GSI code as part of spring 2012 upgrade for Rapid Refresh 2 software to NCO, pending NCEP readiness.

CURRENT EFFORTS: Work will begin on RAPv2 after the RAPv1 is implemented on 1 May 2012.

PLANNED EFFORTS: Implement the RAPv1 on 1 May 2012.

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 May 2013.

12.5.5.E5 31 July 2012 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RR at NCEP.

ESRL
Request for date change to early FY13.

NCEP
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RAP at NCEP.

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

PLANNED EFFORTS: Implement the RAPv1 on 1 May 2012.

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 July 2013.

12.5.5.E6 30 Sept 2012 (CAPS, EMC, ESRL)
Report on the results of EnKF and hybrid DA systems for the RR configuration.

NCEP
CURRENT EFFORTS: Work will begin after the RAPv1 is implemented in May 2012.

PLANNED EFFORTS: Implement the RAPv1 in May 2012.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS: Delays in the initial RAPv1 implementation will delay the RAPv2 upgrade until after the moratorium, likely no sooner than May 2013.

UPDATES TO SCHEDULE: None

12.5.5.E7 30 Sept 2012 (NCEP)
Subject to NCEP Director approval, implement NEMS/NMMB version of GSI (e.g. strong constraint, revised bkg+obs errors) in NAM/NDAS.

CURRENT EFFORTS: Porting of the GSI into NEMS has been put on hold while it completes its transition to EnKF especially for regional applications. Tests with hourly updated NAM will help determine of having model and GSI in a single executable will be worth the effort. Some 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)

A new satellite data feed created by direct read-out stations and corrected more quickly than the standard feed were tested and included in the package for the next implementation. In order to use the GOES15 radiances in the analysis, a new version of GSI was checked out from the GSI trunk. The parallel tests indicated the new version produced slightly larger forecast error than the control. Work was done to find out the reason. (Wu)

PLANNED EFFORTS: Continue testing the hybrid variation-ensemble analysis and the new data, i.e., VAD winds, GPSRO bending angles, and surface observations without pressure. If the new components pass the parallel tests with at least a neutral impact, the components will be included in the package for official regional parallel. Move work to the NOAA R&D computer (Zeus). (Wu)

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: The development computer in NCEP is at its full capacity and the off-line parallel does not run to completion often.

INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE: None.

12.5.5.E8 30 Sept 2012 (CAPS and GSD)
Report on initial results of dual-resolution EnKF for RR configuration.

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

UPDATE TO DELIVERABLE:
Change to early FY13 due to late implementation of initial RAP.

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

GSD
Improvements to radar and moisture assimilation in GSI finalized in January-February 2012 have greatly improved the WRF moist precipitation bias at least for RAPv2. We expect some continued moist precipitation bias in the NCEP RAP until the RAPv2 assimilation changes are implemented there.

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).

WRF V3.3.1 versions of the Thompson microphysics and RUC-Smirnova land-surface model were implemented into RAPv2 in February, resulting in improved precipitation, cloud, and near-surface forecasts. In collaboration with Greg Thompson of NCAR, we also eliminated problematic surface accumulation of very small amounts of frozen precipitation when surface temperatures are will above freezing.

The MYNN PBL and surface-layer scheme has been running in the RAP-development-2 cycle at GSD since mid February. Although it improves upon the MYJ scheme running in parallel in the RAP-primary by some measures, there continue to be areas of deficiency compared to the MYJ as well. In particular, the Yang surface-layer scheme, part of the current MYNN package, has proved a bit problematic for the evening transition in the RAP-dev2 cycle. Accordingly, it was decided not to elevate the MYNN to the RAP-primary at this time or into the operational HRRR for spring/summer 2012. Despite these concerns, a version of the MYNN that is regarded as superior to the one released with v3.3.1 was submitted to NCAR and is part of the WRFV3.4 release by NCAR on

6 April. Because we still consider the MYNN to have promise for improved boundary-layer performance in both RAP and HRRR, effort to refine the MYNN PBL by eliminating specific problem areas will continue.

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.

12.5.8.7 1 July 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.

12.5.8.8 1 June 2012 (GSD)
Based on RR experience and recent WRF physics progress, begin development and testing of physics enhancements for RR3 implementation planned for FY13 and for future versions of the HRRR.

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

NCAR conducted a WRF tutorial January 24–28. This covered the basic WRF system and consisted of series of lectures and practice sessions. Attendance was approximately 60.

NCAR is organizing the 13th WRF Users' Workshop, to be held at NCAR's Center Green facility on June 25–29. As in the past couple of years, the first day will provide lectures on a focused area of mesoscale modeling. This year's topic will be convective parameterization. On June 29th there will be mini-tutorials on visualization packages, regional climate modeling, and verification. The workshop web page may be found at: **http://www.mmm.ucar.edu/events/2012_wrfusers** .

PLANNED EFFORTS: NCAR will host and deliver the next WRF tutorial in FY12Q4. The dates are July 16–20. NCAR will host the 13th WRF Users' Workshop on June 25–29.

UPDATES TO SCHEDULE: NONE

12.5.8.14 30 Sept 2012 (NCAR/MMM)
Task 12.5.8.14 Incorporate Physics and Dynamics Improvements into WRF

NCAR continued overseeing major WRF release, WRF V3.4, which is targeted for April 2012. Candidate features include new/improved physics (including the Noah MP LSM, the UCLA SSiB LSM, and a new surface

layer scheme), software framework improvements, and a parallelized 4DVAR in WRFDA. NCAR conducted regular Release Committee meetings and issued two friendly-user (beta) releases, in January and February. Information on the release may be found at: **http://www.wrf-model.org/users/release.php**.

Jimy Dudhia of NCAR/MMM was involved in testing a number of the new features for the V3.4 release. He obtained updated code from Joe Olson (NOAA) for the MYNN PBL scheme that is being tested in Rapid Refresh. This code was added to the repository for V3.4. Dudhia developed a modification to the YSU PBL scheme for the boundary-layer Prandtl number treatment, which was added to the repository.
Dudhia also tested code for the ACM2 PBL scheme and the PX LSM scheme from developer Rob Gilliam of the EPA. This was added to the repository.

Dudhia also worked Prof. Y. Xue and Dr. F. DeSales (UCLA) on getting the new SSiB LSM ready for the V3.4 release. Ming Chen of MMM tested the code and SSIB landuse data in WPS. In the area of microphysics, Dudhia and Chen examined the Morrison-Gettelman scheme, from the CAM physics package.

Dudhia helped with the addition of aerosol and ozone effects to prepare WRF for the upcoming high-resolution, real-time hurricane forecasts at NCAR. This is a collaboration with Ryan Torn of SUNY-Albany and Wei Wang (NCAR/MMM). Dudhia continued testing convective-radiative equilibrium code, running to equilibrium after 15–20 days. The latest test included a Coriolis force to maintain the geostrophy of upper-level winds. Dudhia worked with Ming Chen to resolve problems in UCLA radiation code, which will now be released in V3.4.

Dudhia worked with visitors Roanne Bakker (Wageningen University, Netherlands) and Pedro Jimenez (CIEMAT, Spain) on evaluating and testing WRF against CASES99 tower data for stable conditions. Ongoing tests are focusing on the vertical mixing strength.

PLANNED EFFORTS: The development and incorporation of new physics and dynamics for WRF for the RR will continue into FY12Q3.

UPDATES TO SCHEDULE: NONE

12.5.8.15 Ongoing (GSD)
Continue development of the RUC LSM for application to both RR (RR2 in FY12 and RR3 in FY13) 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).

The upgraded WRFv3.3.1 RUC-Smirnova scheme in RAPv2 and HRRR as of February 2012 now uses updated MODIS land-use information, and also uses fractional land-use within each RAP and HRRR grid area. We have also upgraded to use of a daily-updated 4-km resolution snow cover and sea ice product from NESDIS that daily assists in trimming areas of snow cover (over land) and ice cover (water) where snow and ice are present in the ongoing RAP cycles including at NCEP, but are absent in the NESDIS product. This required introducing, in collaboration with NCEP, additional quality-control safeguards against spurious ice points in this field.

Deliverables

12.5.8.E1 28 Mar 2012 (defer to July 2012) (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.

12.5.8.E2 15 June 2012 (defer to Nov 2012) (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 early FY13 due to late implementation of initial RAP.

12.5.8.E4 15 July 2012 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RR at NCEP.

UPDATE TO DELIVERABLE:
Change to early FY13 due to late implementation of initial RAP.

12.5.8.E5 1 Sept 2012 (NCAR/RAL and GSD)
Transfer the coupled aerosol-microphysics scheme into a test version of HRRR.

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

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.

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 RR 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.

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.

On March 9, the HRRR system (including the parent GSD RAP-primary) was frozen for the 2012 real-time CoSPA evaluation. The set of changes within the RAP system that serves as the parent for the HRRR is basically the set of changes for version 2 of the RAP at NCEP (implementation hopefully before spring 2013). The large set of modifications, especially to the RAP analysis, but also the RAP and HRRR model system, including a crucial upgrade to a reflectivity diagnostic that is compatible with the current Thompson microphysics version, has resulted in a significant improvement in the HRRR. Foremost among the HRRR improvements is a reduction of the false alarm / high bias noted in the 2011 evaluation. Overall location of storms, and especially predicted storm structure is better. Sample real-time HRRR forecast (from the frozen 2012 configuration) for the devastating 3 April 2012 Dallas-Ft. Worth tornado outbreak (and wide-spread convection which significantly affected aviation travel) are shown below (Fig. 2). We are seeing numerous positive references to the HRRR in various NWS forecast discussions.

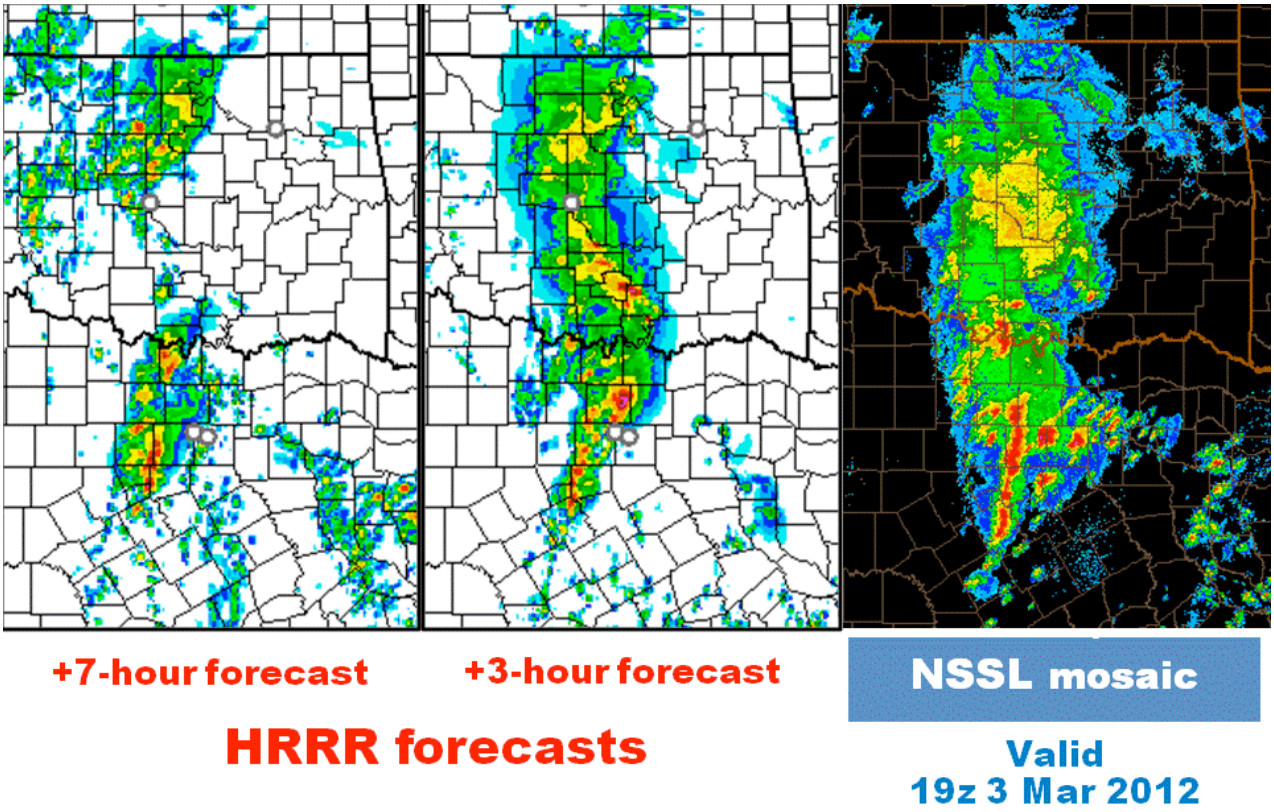

Fig. 2. HRRR 7-h forecast and 3-h forecast and observed reflectivity at 19z March 3, 2012 the time of the Dallas-Ft. Worth tornado outbreak.

As part of the preparation for the code freeze, a coordinated 9-day Aug. 20122 RAP and HRRR retro was completed and output grids verified and transferred top NCAR/RAL and MIT/LL. We have completed a 2nd 9-day RAP retro for June 2011 (on Zeus) and are working on the associated HRRR retro runs for June 2011. The real-time HRRR system has shown good run reliability with > 97% for outrages 3h or under and greater than 90% for all outages. David Dowell, Ming Hu, Curtis Alexander, and Patrick Hofmann are continuing with 3-km cloud analysis and 3-km cycled radar reflectivity assimilation experiments, in preparation for future upgrades.

A summary of the changes is included here. Work has been completed on an extensive set of upgrades to the GSD/ESRL RAP/HRRR analysis/forecast system for the 2012 CoSPA real-time evaluation. The work included coding, testing, and evaluating a large number of candidate analysis and model upgrades, utilizing both real-time and retrospective test configurations and with rapid verification feedback for upper-air, surface, ceiling and visibility, precipitation and reflectivity. The overall goal was to improve the accuracy of HRRR forecasts, especially targeting the high reflectivity bias (especially in the +1-4 h forecast range) and occurrences of spurious convection noted in the 2011 CoSPA evaluation.

Several significant enhancements were made to the RAP data assimilation including:

1. Assimilation of surface moisture pseudo-obs in PBL,
2. Soil adjustment based on near-surface temperature / moisture increments
3. Elevation correction for precipitable water assimilation and limits to PW innovations
4. Conservation of virtual potential temperature for cloud building
5. Fractional cloudiness and improves marine stratus building
6. Building of low-level clouds from GOES data (without instruction of a moist bias)
7. Temperature-dependent hydrometeor specification from 3D radar reflectivity (less 1h precip bias)
8. Assimilation of tower/nacelle/sodar observations
9. Assimilation of GLD360 lightning observations
10. GSI merge with recent NCEP/EMC trunk

In additional several enhancements were made to the ARW model and post-processing (benefitting both RAP and HRRR) including:

1. Upgrade to WRFv3.3.1+ (+ indicates with RAP specific enhancements)
2. Enhancements to PBL, land-surface (MODIS land use, and Thompson microphysics (two moment rain), more frequent call to short-wave radiation
3. Enhancements to model numeric (vertical velocity damping upper bound conditions, 5th-order vertical advection)
4. Improvements to model post-processing especially use of a new reflectivity diagnostic that is consistent with the new Thompson microphysics.

Extensive verification of real-time and retrospective RAP runs has confirmed the benefits of these changes to the RAP (see task 5.5). A key RAP improvement for the HRRR has been the reduction on the high bias for RAP forecast moisture and precipitation. Following the completion of a RAP retrospective run for the Aug. 11-18, 2011 period a series of HRRR forecasts were launched from this RAP retrospective. We have currently completed over 5 days of even hour HRRR runs (> 60 runs). Verification of these runs has confirmed that the RAP improvements have yielded a significant reduction in the high reflectivity bias during the first few hours of the HRRR runs. This can be seen in Fig. 2, HRRR CSI and bias plots from the few days of these HRRR.

An excellent summary of recent HRRR and related RAP progress was presented on 13 March 2012 at an ESRL/GSD program review, available at **http://ruc.noaa.gov/pdf/HRRRProgramReview-13mar2012.pdf**.

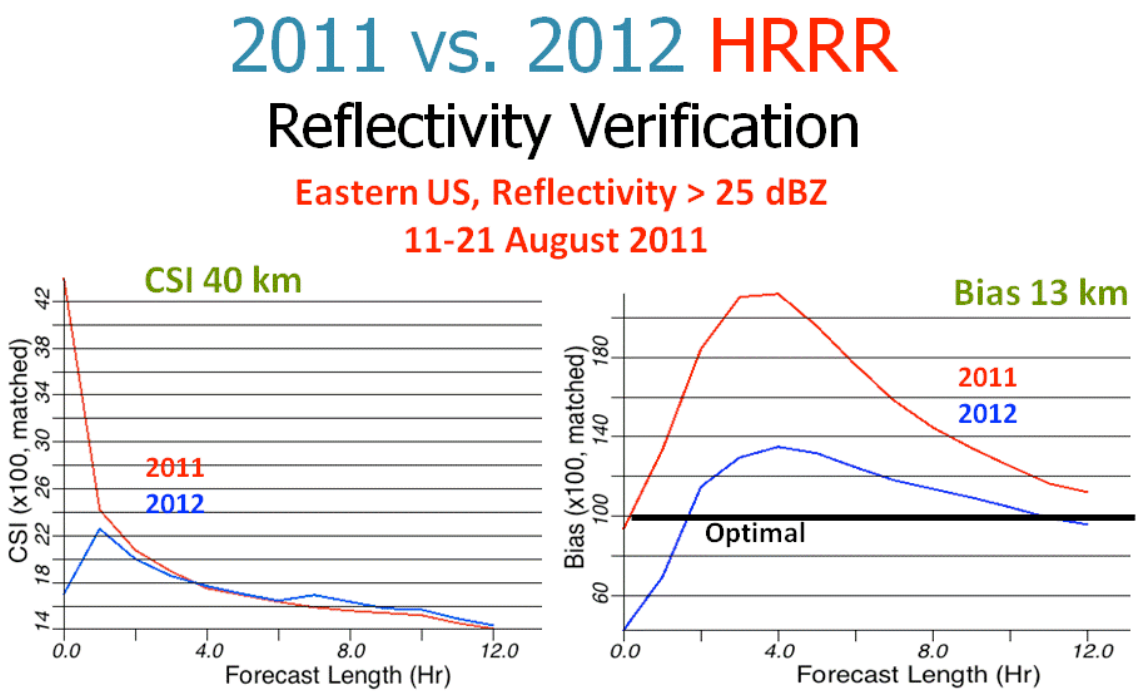

Fig. 3. Comparison of categorical skill scores for 5+ days of HRRRs (HRRR run for all even hours) run from the 11-21 August 2011 high impact weather period. Blue (2012) curves are for retrospective HRRRs run with all the analysis and model changes incorporated into the frozen code for the 2012 CoSPA evaluation. Red (2011) curves are from the 2011 real-time runs.

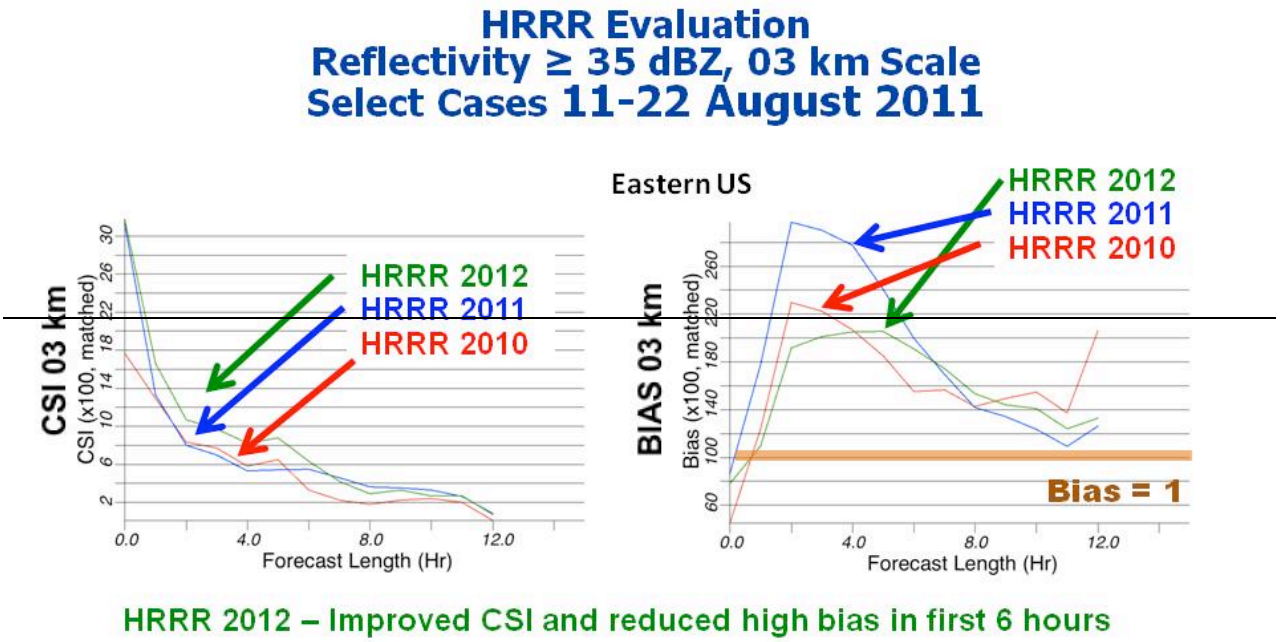

Fig. 4. CSI and bias for reflectivity above for HRRR/RAP versions from 2010, 2011, and 2012 versions for a common testing period from 11-22 August 2011.

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 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.
Deliverables

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.

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**

Real-time project ongoing with good results so far.

12.5.24.E2a 1 June 2012 (NCEP, ESRL/GSD)
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.

With an experimental version of the RAP now running on zeus and HRRR case testing also running there, it appears that there will be a dual HRRR capability. On the other hand, due to NWS funding decreases, it has been decided that NCEP cannot help with the dual HRRR configuration or with distribution of HRRR grids.