MDE Product Development Team
(Based on Work Plan for 12-month Period from 1 April 2014 through 31 March 2015)
December 2014 - FY15 - 1st Quarter Report
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With contributions from **Geoff DiMego and Mary Hart** (NCEP/EMC);
Stan Benjamin, John Brown, Steve Weygandt and Curtis Alexander (NOAA/ESRL/GSD);
Jordan Powers (NCAR/MMM); **Roy Rasmussen and Greg Thompson** (NCAR/RAL);
and **Ming Xue** (CAPS).

(Compiled and edited by S. Benjamin and B. Johnson)

Executive Summary

Task 1: Improve Turbulence Guidance From NWP Forecasts From RAP, HRRR, NAM, NAM-Nests and, Eventually, NARRE and HRRRE

- Substantial further updates to RAPv3/HRRRv2 code beyond the April 2014 frozen version tested in retro and parallel cycles in final testing prior to code transfer to NCEP. New model and assimilation changes to RAPv3 appear very effective to largely eliminate daytime warm-season warm/dry bias. These include better use of surface obs and physics changes reported under Task 3.
- RAPv3/HRRRv2 implementation at NCEP is planned for summer 2015.
- Real-time experiments for the 2014 warm-season exercise concluded 31 October, having used the April 2014 version of RAPv3 parent model (Task 1) and experimental HRRRv2 (Task 2 below).
- Development and testing continuing of initial pre-NARRE 8-member ensemble (4-NMMB, 4-ARW); regular real-time cycled runs started 15 November.
- Operational RAPv2 continues to run reliably at NCEP.

Task 2: Improve Quality of Convective Weather Forecasts From RAP, HRRR, NAM, NAM-Nests and, Eventually, NARRE and HRRRE

- RAPv3 / HRRRv2 change package for NCEP Q3 2015 operational implementation very nearly complete with real-time and retrospective tests indicting substantial forecast improvement, especially reduction of warm-season warm/dry bias. Summary PPT presentation at: **http://ruc.noaa.gov/pdf/RAP_HRRR_2014_report.pdf**
- HRRR summer 2014 evaluation completed, report available: **http://ruc.noaa.gov/pdf/HRRR_summer_2014_report.pdf**
- Advanced HRRR developed and tested with further upgrade to WRF-ARW version 3.6.1+ model and to a recent trunk version of GSI analysis, which will provide source code for RAPv3 and HRRRv2 to be implemented at NCEP in 2015.
- Improvements to HRRR warm / dry bias due to code refinements (primarily in planetary boundary layer scheme and land surface model – see Task 3).
- Testing and evaluation conducted successfully of assimilation in RAP and HRRR of mesonet data and radial velocity.
- Code updates for RAPv3 / HRRRv2 completed. 3-season final retrospective test period evaluation (winter, spring, summer) ongoing.
- HRRR code version of ARW provided to EMC computer experts for code optimization, GSD helping significantly.

Task 3: Improve Quality of Icing Weather Forecasts From RAP, HRRR, NAM, NAM-Nests and, Eventually, NARRE And HRRRE

- Summary of physics changes in real-time and retrospective testing completed for advanced RAPv3/HRRRv2, including those in land-surface model (snow treatment, sub-grid mosaic, wilting point), PBL scheme (shallow cumulus, effective sub-grid clouds), cloud microphysics (aerosol-aware), improved radiation effects of clouds in RRTMG radiation, modified Grell-Freitas deep/shallow convection.
- NCEP computer engineers have optimized RAP / HRRR code sufficiently to upgrade to aerosol-aware microphysics scheme from NCAR (Greg Thompson) for RAPv3 and HRRRv2 without increase in model run time.
- Final physics configuration for RAPv3 pre-implementation testing at NCEP in 2015 close to being set.

Task 4: Develop Convection-ATM-Specific Improvements To Guidance From the HRRR (and later, HRRRE) and, Interact With CoSPA (Or Other) Program Partner Labs and the FAA

- Testing of HRRR with WRFv3.6+ with WRF changes to GSD-developed model physics and assimilation underway.
- ESRL HRRR "failover" capability to use feed from Zeus instead of Jet during Jet downtime worked effectively for CoSPA and has been discontinued since 1 Nov 2014 to facilitate accelerated development of the RAP and HRRR.
- ESRL HRRR output format changes for alignment with the NCEP HRRR operational implementation will be coordinated with COSPA program partner labs after 01 November 2014.

- ESRL RAPv3 and HRRRv2 real-time upgrades have been installed in real-time and retrospective testing prior to code hand-off to NCEP near the end of January 2015.
- Continued discussion with MIT/LL regarding a capability to provide hourly updated vertically integrated liquid and echo top estimates from the ESRL RAP for oceanic regions outside of the HRRR domain.
- Initial discussion with AvMet to plan a meeting discussion for measuring potential operational ATM benefits gains associated with HRRR forecast enhancements.
- The HRRR was implemented operationally at NCEP on 30 September 2014.

Task 1: Improve Turbulence Guidance From NWP Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

Improving turbulence forecast quality involves efforts to improve initial conditions for the RAP and NAM (and HRRR and NAM Nest models) and to improve the models (WRF-Advanced Research WRF (ARW)-RAP and NOAA Environmental Modeling System (NEMS)- Nonhydrostatic Multi-scale Model – B (NMMB)).

Tasks will include:
- Continuing evaluation of RAPv3 toward 2015 implementation at NCEP, incorporating changes developed in 2013 and 2014.
- Development of RAPv4 toward 2016 implementation at ESRL and subsequent implementation at NCEP. (Note, some improvements from RAPv4 will be thoroughly tested in all seasons and included in the RAPv3/HRRRv2 package for NCEP.)
- Collaborating on developing and testing best approaches for use of hybrid/EnKF/3DVAR data assimilation within common GSI coding structure.

ESRL

Regarding the operational NCEP RAP (currently RAPv2)

The RAPv2 continues to run well in NCEP operations, without any model or post-processing issues. A webpage on RAP output grids from NCEP is at http://ruc.noaa.gov/rr/RAP-NCEP-output-grids.html.

RAPv3 model testing and evaluation

The preliminary RAPv3 configuration of 5 April 2014 continued to run reliably in the RAP-primary cycle at GSD. This cycle continued to drive the HRRR-primary running through October at GSD in support of the 2014 warm-season exercise, and will continue to support the HRRR primary, but as of 1 November was no longer constrained to run the spring 2014 version of RAPv3, but is being used as a benchmark to measure progress beyond the 5 April version. A summary of the upgrades from RAPv2 going to RAPv3 (and HRRRv2) from the December NCEP model review has been published on the web at **http://ruc.noaa.gov/pdf/NCEP_PSR_2014_HRRR_COMBINED_lite.pdf**. In the near future, this will be updated to reflect new extensions to RAPv3 and HRRRv2 codes (discussed further below and under Task 3) once they are finalized at ESRL (and implemented into ESRL versions of RAP and HRRR) prior to being ported to NCEP for implementation in summer 2015.

The RAPv3 warm-dry forecast bias noted in the FY14 Q3 report (issued 15 July) was largely eliminated by extensive model changes made and tested in the July-September quarter, as discussed in the FY14 Q4 report (issued 15 Oct). During October, GSD concentrated on test and evaluation of other likely analysis and model upgrades and the balance of the quarter was mainly devoted to intensive evaluation of the near-final configuration for RAPv3 and HRRRv2 using the RAP-dev cycles and comparing against the RAP primary, which continued to run the 5 April version. Issues that arose in this evaluation were investigated, in some cases using short retrospective runs to test candidate improvements. In mid-December, we began the first of three one-month retrospective runs from previous winter, spring and summer seasons. The winter retro from January 2013 as well as the ongoing real-time cycles showed an intermittently occurring but notable warm bias in surface temperatures over snow areas in the interior West and over Alaska, although the forecast cold bias seen in the winter of 2013-14 over snow-covered areas east of the Continental Divide was much improved.

Meanwhile, code optimization work just completed by Jim Taft and John Michalakes (both working for NCEP), has produced a notable speedup in execution time for the HRRR on WCOSS, with a large part of this coming from optimization of the Thompson aerosol-aware microphysics. Since this new executable does not produce bit-reproducible results with that being used in the long retro runs, a decision was made in early January to halt these, verify that differences in predictions are small between the new more efficient code and the older version, and restart them with the new, optimized code plus a couple additional changes to improve robustness in the GSI. This should still allow essentially final RAPv3 and HRRRv2 code to be transferred to NCEP (Deliverable 1B) in late January. The following summarizes

key changes to the RAPv3 code from the preliminary RAPv3 configuration of April 2014 that was used to support the HRRR in the 2014 warm-season exercise. Where applicable, many of these changes will be included in HRRRv2 as well.

Assimilation

- GSI new trunk code was introduced and tested and is now working.
- Use of model-derived low-level temperature and moisture directly at 2m (where observations are usually made) for computation of surface observation innovations instead of at the lowest model level or any interpolated value. This includes an improved diagnostic for the 2-m water vapor mixing ratio.
- Revised initialization of hydrometeors in GSI cloud analysis when observed reflectivity < 28 dbZ and surface temperatures are well above freezing in order to better maintain initial areas of light rain during the first few hours of the forecast.
- Improved identification of atmospheric volumes not adequately observed by radar due to beam blockage by terrain. This is intended to improve cycled snow cover in mountainous areas through more widespread reliance on the model background hydrometeors for the 0-1h precipitation that drives the RUC LSM.
- Minor revisions in GSI to accommodate cycling of cloud droplet number concentration (needed for the new Thompson aerosol-aware microphysics).

Model

- Model: After further evaluation, we have decided to continue use of the NAM SST analysis for the temperature of small lakes rather than the new lake-model option in WRFv3.6 to predict lake temperatures. There is a substantial cold bias in the latter.
- Model: The extensive physics changes are discussed under Task 3.
- Model: A very recent version of WRF approximately equivalent to WRFv3.6.1, merged with RAP / HRRR enhancements not yet in the NCAR WRF repository and further optimized for efficiency on WCOSS, replaced WRFv3.5.1, and has been carefully evaluated in the RAP-dev3 cycle (output available under **http://rapidrefresh.noaa.gov/RAP/**).
- Model: Digital filter initialization modified to account for cloud droplet number concentration.

NARRE-related activities - toward improved probabilistic aviation forecasts

GSD (led by Isidora Jankov) continues to refine a very promising set of experiments using a preliminary ensemble configuration including both ARW and NMMB models toward the North American Rapid Refresh Ensemble (NARRE). Additional interoperable physics options for both ARW and NMMB are now or will be made available for NARRE testing. Real-time testing of a preliminary NARRE 8-member ensemble (4 NMMB with different initial and lateral boundary conditions and 4 WRF-ARW, the latter with different WRF physics combinations as well) at ~13km resolution has been running on Zeus twice daily since 15 November. Work is underway to display output on the web and to verify model output at GSD. Output is also being sent to the Weather Prediction Center of NCEP, where it will be displayed and used in their winter weather forecast experiment in January and February 2015. The California-Nevada River Forecast Center in Sacramento is also developing means to display and evaluate the output later this winter. Looking back to July, GSD personnel involved in NARRE development met at GSD with Jacob Carley of NCEP to exchange ideas and outline future options and directions for NARRE development. This will include integrating the NAMRR (also toward NARRE) now under development at NCEP.

Initializing the NARRE forecast ensemble will most likely use a single regional ensemble data assimilation cycle (allowing improved cloud/radar initialization over current use GFS ensemble-based covariance) to initialize both ARW and NMMB members. Different physics configurations or possibly stochastic versions of key physics parameterizations will be used for different NARRE members. Stan Benjamin and Geoff DiMego have completed a draft report outlining the development, test and evaluation tasks needed over the next year or two to bring NARRE to fruition and how these will be partitioned between GSD and NCEP.

Subtasks

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

GSD

GSD has continued to monitor real-time-NCEP output from the RAP and the now operational HRRR, the latter having its initial implementation at NCEP at 1400 UTC 30 Sep. HRRR-OPER forecasts can now be inter-compared with ESRL-HRRR and other forecasts

NCEP

The RAP and HRRR ran in production this quarter with no issues. (Manikin, Keyser, Guastini)

14.5.1.2 28 July 2014 (NCEP, ESRL & CAPS)
Groups collaborate on developing and testing best approaches for use of hybrid/ EnKF/3DVAR and 4d-ens-var within common GSI coding structure.

ESRL

GSD: (Ming Hu) continues to prepare a new GSI/model repository from which MDE research partners (GSD, EMC, CAPS, OU, others) will check out common software for regional ensemble data assimilation development toward NARRE.

NCEP

A multi-grid method for background error correlation and ensemble localization is being developed. A working code now exists for 2-dimensional isotropic and anisotropic correlations on a single processor. A multiprocessor version is under construction. This package will provide computational scalability for the GSI analysis, to effectively use a massively parallel computer. In order to run 4DEnVar in regional mode, work was done to debug and enable the First Guess at Appropriate Time (FGAT) feature, which was only functional in global mode. A test case on Zeus revealed that the allocated arrays were not de-allocated, which would cause the program to fail when multiple first guess files were read in and the same arrays were allocated multiple times. This bug was then fixed. Time check on the ensemble files was modified to allow use of multi-time level ensembles. Changes to allow flexible input file names were included. The input parameters were also set up to dimension the 4d problem properly. (Carley, Wu, Parrish)

14.5.1.3 30 Sept 2014 (CAPS, GSD, EMC)
Test and evaluate direct radial velocity and reflectivity data assimilation within the 40-20km/13km dual resolution hybrid system. (Resolution dependent on computing resources)

CAPS

In December, for the purpose of direction assimilation of radar reflectivity in GSI, some code work had been done to use the logarithm-transformed hydrometeor mixing ratios as new control variables. Testing shows that there might still be problem when invoking the code of radar reflectivity observation forward operator and its adjoint. The background error covariance matrix for hydrometer variables is simplified for the purpose of code debugging.

EMC

No activity in December. (Liu, Carley)

14.5.1.4 1 Jan 2015 (ESRL, CAPS)
Test the 40/13 km dual-resolution system with hourly DA cycles including all observation types, including radar reflectivity data via cloud analysis and DDFI.

14.5.1.5 28 Feb 2015 (NCEP, ESRL & NCAR)
Groups collaborate on developing and testing physics schemes between WRF and NEMS' physics layer.

GSD

GSD continued to expand interoperable physics options for NARRE using ARW and NMMB. It also refined preliminary NARRE configuration testing ARW with RAP and NAM-like physics and also with NMMB using NAM physics, and will next expand the NMMB options to include the Thompson MP (microphysics) scheme and RUC land-surface model.

NCEP

Numerous bugs in the NMMB code were fixed and allowed all of the different physics to be run successfully with "traps". The SAS convection driver was changed to run with any microphysics option. The physics time step used to calculate convective temperature tendencies was corrected (made consistent with the NMMB's time-differencing scheme). The triggering of deep and shallow convection code was also made more understandable, and other unnecessary calculations were removed. The saturation tables used in the Ferrier-Aligo microphysics, also in the RRTMG radiation driver to calculate sub grid-scale cloud effects (which reduced the 2-m cold biases last winter), were properly initialized to work

with any microphysics scheme. Maximum hourly fields can now also be produced from the Thompson microphysics. A bug found by ESRL was fixed in the Ferrier microphysics; early tests indicated the fix improved the forecasts by increasing the amount of stratiform precipitation. Locally heavy rainfall amounts from 4-km NMMB microphysics experiments were reduced for most of the five warm-season retrospective cases. These preliminary results were presented at a WPC-EMC meeting to show progress being made for the next NAM upgrades to reduce locally heavy rainfall amounts from the CONUS nest (issue identified by WPC during their 2014 flash flood experiment). (Ferrier, Aligo, Jovic)

14.5.1.6 28 Feb 2015 (NCEP)
Complete testing of improved or extended 88D processing and quality control, taking advantage of dual-pol where possible.

Work has begun this quarter on NextGen funded project to connect to MRMS-processed observations and mosaic on the IDP at NCEP and getting those files to WCOSS for use in RAP and NAM. No other activity at NCEP this quarter December. (Shun Liu, Ting Lei, Kang Nei)

14.5.1.7 15 Mar 2015 (ESRL, CAPS, NCEP)
Complete readying of initial regional ensemble data assimilation capability to initialize real-time parallel RAP version and NAMRR.

GSD

No additional work this month.

NCEP

Initial NAMRR runs were made in order to test the modified cloud analysis in the NAM CONUS nest domain. (Carley, Wu, Rogers, Parrish)

14.5.1.8 28 Mar 2015 (NCEP and ESRL)
Negotiate Data Mining List priorities with NCEP Central Operations and external points of contact associated with the most desirable new sources of observations.

NCEP

Scatterometer wind estimates from the International Space Station have been added to the Data Mining List. (Keyser, Whiting, DiMego)

GSD

New agreements with energy companies for use of their proprietary tower and nacelle wind data were drafted in May by GSD and coordinated with NWS. This proprietary wind data is already on the DML.

14.5.1.9 31 March 2015 (NCEP)
Establish a pre-implementation version of the hourly updated NAMRR with a goal to use the common regional ensemble data assimilation.

General development of the NAMRR continued in partnership with DTC, and several bugs were fixed. Work has started to make the system more portable across different computing platforms, as well as to run on WCOSS in real time or for retrospective cases. (Carley)

Deliverables

All Option A unless noted otherwise.

14.5.1.E1 10 April 2014 (ESRL)
Finalize RAPv3 and HRRRv2 for summer 2014 real-time exercise.

COMPLETE. A summary of the spring 2004 RAPv3 and HRRR v2 configurations has been published on the web at **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**

14.5.1.E2 31 May 2014 (NCEP)

With approval of NCEP Director, NAMv3.1 upgrade package is implemented at NCEP.

The NAMv3.1 evaluation ended on July 30th, the NCEP director was briefed August 8th and the NAMv3.1 was implemented on August 12th. Issues associated with NAM post failures were tracked back to an issue with the digital filter in the NMMB. A fix will be submitted and implemented if failures occur again or as part of the Q4 FY15 NAM upgrade whichever comes first. (Rogers, Pyle)

14.5.1.E3 30 July 2014 (NCAR/MMM)
Deliver a WRF Users' Workshop and a WRF tutorial for the user community.

NCAR will put on the next WRF tutorial on 26 January–3 February 2015 at its Foothills Laboratory campus in Boulder. This has been announced, and registration is in progress. The program will include the basic WRF tutorial and will also cover the MET (Model Evaluation Tools) verification package.

PLANNED EFFORTS: NCAR will organize and conduct the next WRF tutorial at NCAR January 26–February 3, 2015.

UPDATES TO SCHEDULE: None.

14.5.1.E4 New date: 30 Jan 2015 (from 20 Oct 2014) (ESRL)

Code for RAPv3 and HRRRv2 finalized for transfer to NCEP/EMC for 2015 implementation.

Progress has been steady with testing having started with WRFv3.6, earlier in the year than GSD has done previously with the annual WRF release. Merger of WRFv3.6+ with RAP / HRRR enhancements was completed in July and the RAP-dev3 cycle is now running WRFv3.6+ with the Thompson-Eidhammer aerosol-aware microphysics option turned on and other physics and assimilation improvements developed by GSD. See Task 3 for more physics details.

14.5.1.E4.1 31 Mar 2015 (ESRL)
Report on wind accuracy from RAP and HRRR by quarter for previous year, strongly related to turbulence guidance.

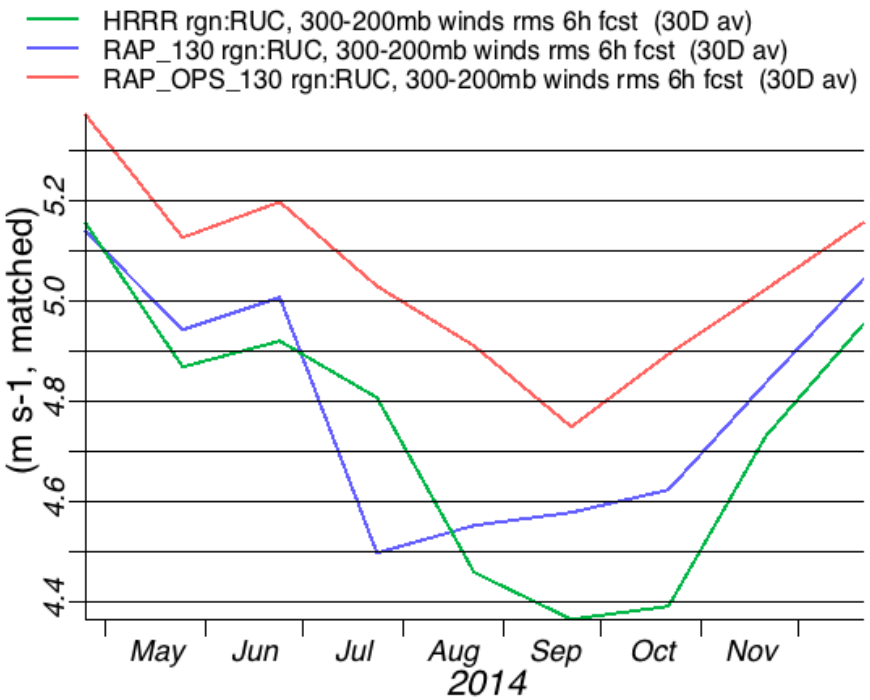

Figure 1: Upper-level (300-200 hPa) wind forecast RMS vector error vs. raobs for 6h forecasts from RAPv3 (ESRL, in blue), RAPv2 (NCEP, in red), and HRRR (ESRL, green). All scores are from native gridded data, not from isobaric coordinate data and show 30-day averages for forecasts from March through Dec 2014. Units – m/s.

A new look at upper-level 6h forecast wind accuracy during 2014 (now updated through December) shows relative wind accuracy between the operational RAP (red), ESRL RAP (blue), and ESRL HRRR (green) as shown in Fig. 1. After the introduction of RAPv3 and HRRRv2 in the ESRL runs in early April, those updated versions are showing clearly improved

wind forecast skill over that from the NCEP RAP (red). This also implies that turbulence guidance, heavily dependent on upper-level wind forecast accuracy, has also been improved from this update. Therefore, improved wind information to further improve turbulence forecasts is clearly in the pipeline with RAPv3 and HRRRv2 to be implemented at NCEP in mid-2015. Fig. 2 (below, verification against aircraft data) shows the same order for the last few months – that RAPv3 is an improvement for upper-level wind forecasts over RAPv2 (NCEP-operational), and that the HRRR provides the most accurate upper-level wind 6h forecasts.

Details on the RAP-HRRR updates in early April 2014 are described in http://ruc.noaa.gov/pdf/RAPv3-HRRR-April2014.pdf and **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**. A more recent update on RAPv3/ HRRRv2 improvements were described in December at the NCEP NOAA model review meeting: **http://ruc.noaa.gov/pdf/NCEP_PSR_2014_HRRR_COMBINED_lite.pdf**. Verification against aircraft observations is also shown in Fig. 2 but only for the ESRL RAP (changing from RAPv2 to RAPv3 in early April). In future months, results from the NCEP RAP and HRRR models will be added to allow comparison for winds vs. aircraft observations.

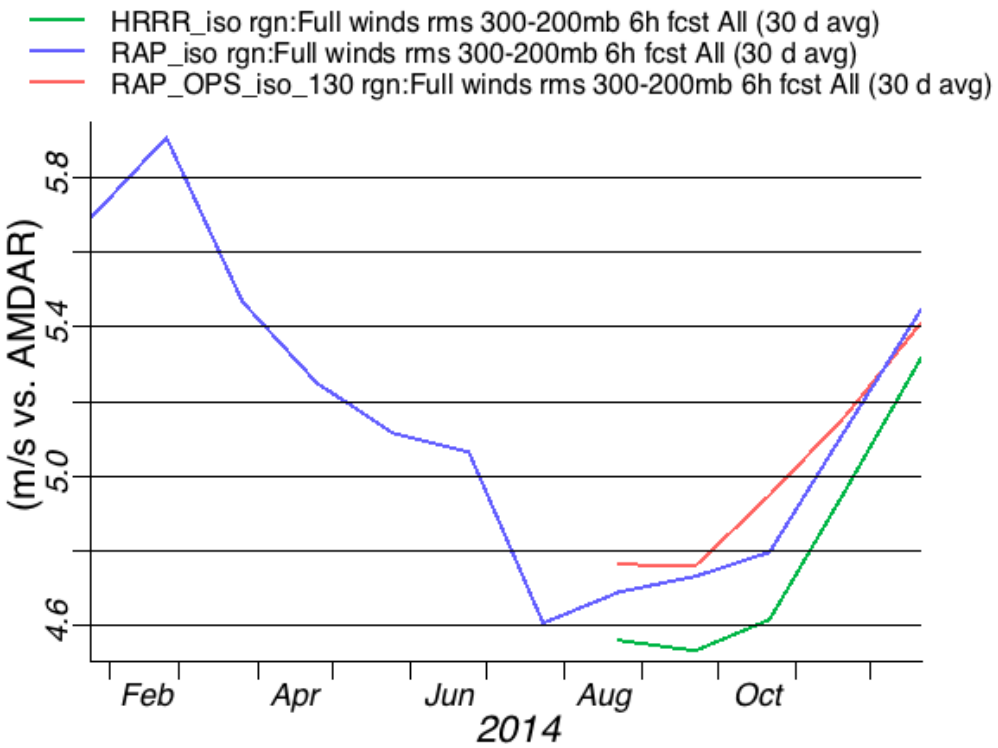

Figure 2: Upper-level (300-200 hPa) wind forecast RMS vector error vs. aircraft for 6h forecasts from the ESRL experimental RAP (blue, RAPv2 through March 2014, RAPv3 since then), also RAP-NCEP (red), and HRRR-ESRL (green). Units – m/s.

14.5.1.E5 31 Oct 2014 (ESRL, CAPS, NCEP)
Complete the testing of the 40-20/13 km dual-resolution hybrid DA system for RAP with 3-hourly cycles with conventional data.

CAPS

Most efforts at CAPS were spent on testing the reflectivity assimilation capabilities in GSI in September. Funding to CAPS for FY13 and FY14 has not arrived so CAPS was working on project with its own funding. However, strategies in this area are planned and will proceed, based on discussions with GSD.

NCEP
The NAMRR development work in 14.5.1.9 is related to this work. (Carley)

GSD

GSD has tested localization options for the GFS-ensemble-based covariances for the 40km hybrid DA system for RAP. GSD is also setting up a GSI repository for use for common GSD-NCEP-CAPS experimentation for hybrid ensemble data assimilation development.

14.5.1.E6 20 Dec 2014 (ESRL)
Report on RAPv3 model and data assimilation configuration and progress. This will include a report on wind verification and its improvements in RAPv3 vs. RAPv2.

14.5.1.E7 New date: 30 Jan 2015 (ESRL and NCEP)
Finalize code for RAPv3 to NCO for implementation at NCEP.

NCEP

Code optimizations for the RRTMG radiation and initializing the Thompson microphysics were committed to the WRF developers' repository for the WRF v3.7 release this spring. (Michalakes)

GSD

GSD has been carefully evaluating RAPv3 performance and a set of likely further changes to the ESRL RAP code before transfer to NCEP for the final NCEP-RAPv3 configuration has been established (see general discussion above under Task 1). This set includes WRFv3.6, aerosol-aware microphysics, improved coupling between parameterized shallow convection and short-wave radiation, and improvements to GSI data assimilation including treatment of surface observations and assimilation of cloud and radar data.

14.5.1.E8 15 March 2015 (ESRL, NCEP)
Pending NCEP computer readiness and EMC and NCEP initial recommendations, Requests for Change (RFCs) are filed to submit code changes as part of upgrade for RAPv3 software to NCO. RFCs now more likely to be submitted in March 2015.

NCEP

With the implementation of the HRRR at NCEP on 30 September, initial efforts have begun on the next versions (HRRRV2 and RAPV3), which will be implemented jointly in summer 2015. Preliminary efforts have ESRL and IBM and EMC personnel working to speed up the HRRR codes, as the operational run times are very tight relative to their slots. Code will be delivered by ESRL to EMC early in 2015, and parallel testing of both systems will begin soon after. (Manikin)

14.5.1.E9 31 March 2015 (NCAR/MMM)
Incorporate physics and dynamics improvements into WRF from the user community, GSD, and NCEP for use in the RAP and HRRR. Oversee code preparation and integration of these improvements into the WRF repository for future model version releases and FAA use. Assist in the implementation of bug fixes. In collaboration with GSD, assist in the development and evaluation of physics schemes for the RAP and HRRR that are contributed to the ARW.

NCAR/MMM began preparation and code review of the next major WRF release. This will be WRF Version 3.7 (V3.7) and is targeted for Spring 2015. NCAR led biweekly Release Committee meetings and oversaw WRF repository additions. Candidate features include vertical nesting, updates of the Noah and Noah-MP LSMs, a scale-aware YSU PBL scheme, the new Grell-Freitas-Olson (GSD) shallow cumulus scheme, and updated Tiedke cumulus and MYNN PBL schemes. Information on the release may be found at: **http://www.wrf-model.org/release.php**.

Dudhia obtained from Song-You Hong (KIAPS, S. Korea) updated gravity-wave drag code that includes orographic flow blocking. This was added to the repository for the V3.7 release.

Jimy Dudhia (NCAR/MMM) spent November in Korea and collaborated with scientists on WRF physics developments. One target area was WRF solar-related physics. Dudhia also worked on shallow convection simulation at very fine grid sizes (e.g., 100m) and the analysis of flux profiles in order to evaluate and improve the shallow convection schemes for WRF. This work has continued.

Jimy Dudhia (NCAR/MMM) worked with Romain Pilon (NCAR/MMM) to test the Grell-Freitas (G-F) cumulus scheme. Pilon compared fully explicit runs with ones using the G-F scheme, both on 3-km grids. Dudhia also worked with Ming Chen (NCAR/MMM) to update the PSU shallow convection scheme to WRF V3.6. The updated scheme was provided to PSU for further testing.

NCAR hosted visitor Kjetil Aas (Univ. of Oslo, Norway), who worked on sub-grid snow effects on soil and its seasonal behavior. With Dudhia, he evaluated sub-grid variability in WRF with off-line Noah LSM runs with varying snow depths. The aim was to improve the sub-grid representation of snow-pack, especially it's melting in spring. Also collaborating was Mike Barlage (RAL). The work will continue remotely with the addition of sub-grid tiling to the Noah-MP LSM.

Dudhia completed work on adding two idealized cases to WRF. The first is an LES shallow convection case that adds to the previous dry LES set-up and is designed to work at 100 m grids with the convection responding to fluxes from a warm, fixed SST. The second is a radiative-convective equilibrium case, a 1-km grid for resolved deep tropical convection responding to a fixed SST and radiation. These were committed to the repository for V3.7.

PLANNED EFFORTS: The development and incorporation of new physics and dynamics for WRF for the RAP and HRRR will continue into the next quarter.

UPDATES TO SCHEDULE: NONE

14.5.1.E10 31 March 2015 (ESRL and NCEP)
Deliver progress report on development of NARRE.

ESRL

A very preliminary NARRE configuration using both WRF-ARW and NMMB members is running twice per day at ESRL over the Rapid Refresh domain. See general discussion under Task 1.

NCEP

Discussions have been held among EMC, ESRL/GSD and DTC staff on NARRE path forward. Work on SREF in 14.5.4E2 is closely related. (Du, Ferrier, Zhou, Yang, Jovic, DiMego)

No activity in December on NARRE but work on SREF in 14.5.4E2 is closely related. (Du, Zhou, Yang, Jovic)

Deliverables Task 1: Improve Turbulence Guidance From NWP Forecasts	Delivery Schedule
A. Finalize RAPv3 and HRRRv2 for summer 2014 real-time exercise.	APR 2014 COMPLETE
B. Code for RAPv3 and HRRRv2 finalized for transfer to NCEP/EMC for 2015 implementation. Strong progress toward this at GSD through RAPv3/HRRRv2 current real-time evaluation.	New date 30 Jan 2015
C. Complete the testing of the 40-20/13 km dual-resolution hybrid DA system for RAP with 3-hourly cycles with conventional data.	New date 30 Jan 2015
D. Report on RAPv3 model and data assimilation configuration and progress. This will include a report on wind verification and its improvements in RAPv3 vs. RAPv2. Preliminary RAPv3 configuration already available in http://ruc.noaa.gov/pdf/RAPv3-HRRR-April2014.pdf.	DEC 2014
E. Finalize code for RAPv3 to NCO for implementation at NCEP.	Modified: 30 JAN 2015
F. Report on wind accuracy from RAP and HRRR by quarter for previous year strongly related to turbulence guidance. Initial evaluation on wind accuracy from RAP and HRRR vs. raobs and aircraft observations has been started and included in this monthly report.	MAR 2015
G. Requests for Change (RFCs) filed to submit code changes as part of upgrade for RAPv3 software to NCO.	MAR 2015
H. Deliver progress report on development of NARRE.	MAR 2015

<u>Task 2: Improve Quality Of Convective Weather Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE</u>

Subtasks

14.5.2.1 15 April 2014 (GSD)
Report on enhancements to RAP 13-km and HRRR 3-km radar data assimilation for beginning 2014 warm-season evaluation using the ESRL-updated version of the HRRR (i.e., HRRRv2).

COMPLETE: As reported in the April 2014 MDE report:

Following extensive testing and evaluation, a RAP/HRRR change bundle was made in late March 2014. The package includes changes to both the data assimilation and model portions of both the RAP and HRRR forecast systems and is summarized in the following report: **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2014.pdf**

14.5.2.2 New date: 31 Jan 2015 1 Dec 2014 (GSD)
Improved (optimized weight factors, and observation selection) 15-min HRRR-based RTMA.

Progress toward this goal with new researcher conducting experiments with hourly and 15-min. HRRR-based RTMA.

14.5.2.3 5 August 2014 (GSD) COMPLETE
Complete testing of updated version of 3-km sub-hourly radar assimilation within HRRR pre-forecast cycling period.

We have completed retrospective testing of an enhancement to the radar observation-based rain and snow hydrometeor specification within the HRRR pre-forecast period. The enhancement is to specify rain and snow hydrometeors from radar reflectivity observation throughout the entire column (using observed radar reflectivity for the lighter precipitation range from 15-28 dBZ). Previously, we only did full column building of precipitation hydrometeors from radar reflectivity data when the surface temperature was less then 5C (primarily building snow). When the surface temperature was greater than 5C, only a single layer of precipitation hydrometeors was added (at the level of maximum observed reflectivity). The impact from testing this radar-assimilation enhancement with 15-28 dBZ with warm-season (Tsfc > 5C) surface conditions has been successful, to reduce a low bias in short-term (0-2 hr) prediction of light to moderate precipitation in the warm season.

Additional 3-km radar assimilation work is underway to test and evaluate fully cycled 3-km HRRR runs. Preliminary tests in which the HRRR land-surface fields have been fully cycled (as opposed to just interpolated from the fully cycled RAP land surface model fields) have been successful (reasonable field evolution, indications of improved model performance) This is being followed to experiments with full data assimilation cycling. This testing has been in addition to ongoing work to reduce the afternoon warm and dry bias in the HRRR (see below and task 3).

14.5.2.4 20 Oct 2014 (GSD) COMPLETE
Complete 2014 HRRR summer evaluation using modeling and assimilation modifications determined in 2013 exercise. Collaborate on analysis of HRRR tests and deliver summary of results.

The HRRR summer evaluation has indicated expected results (improvements in 2014, clues for next refinements). Retrospective and parallel testing of RAP runs with modifications to reduce the warm/dry bias have yielding encouraging results, which lead to improvements in subsequent nested HRRR runs. These RAP changes are described in more detail under task 3 and have included: 1) the addition of a provision for sub-grid-scale cloud fraction and associated interaction with shortwave radiation and 2) adjustments to the wilting point parameters in the land-surface model, resulting in increased transpiration from the parameterized vegetation. Work is also ongoing to test and evaluate WRFv3.6.1 for RAP and HRRR.

The summer 2014 HRRR real-time evaluation exercise concluded on 31 October. Overall results indicated good performance, especially at long lead times, and good reliability. Evidence of a warm / dry bias was seen and retrospective and parallel runs with changes to address this issue have indicated improvement. Following the completion of the warm season evaluation, these changes have been incorporated into the real-time experimental RAP and HRRR and will be included in the RAPv3 / HRRRv2 upgrade at NCEP in 2015. A report summarizing the HRRR results has been prepared and is available at **http://ruc.noaa.gov/pdf/HRRR_summer_2014_report.pdf**

14.5.2.5 15 Dec 2014 (GSD)
Based on 2014 RAP and HRRR results, provide update report on development and testing of data assimilation and model enhancements important for improving forecasts of convective weather within the RAP and HRRR.

Change package very nearly complete with final retrospective results available for RAP summer retrospective. Real-time and retrospective results show significant improvement in nearly all areas, but especially reduction of the low-level warm, dry bias. An update report, composed of selected slides from various AMS RAP and HRRR related presentations from the recent AMS conferences, is provide at: **http://ruc.noaa.gov/pdf/RAP_HRRR_2014_report.pdf**
Key upgrades include enhancements to nearly all physics modules (convection, microphysics, boundary layer, land-surface model, radiation), use of new observations (mesonet, radar radial velocity, lightning), data assimilation enhancements.

14.5.2.6 5 Dec 2014 (GSD)
Single-case test of storm-scale ensemble data assimilation completed for HRRR over small Northeastern U.S. domain.

Planning and configuration work ongoing, as well as related Warn-On-Forecast tests over the SE U.S. Initial testing over the Northeastern U.S. has been deferred till after the hand-off of RAP/HRRR code to NCEP for RAP/HRRR implementation.

14.5.2.7 15 March 2015 (NCEP)
Establish routine verification of NCEP suite of convective weather guidance and begin design of calibration strategy for ensemble systems.

Ceiling heights from the HRRR, NAM, and mean SREF forecasts were added to the g2g verification using the HRRR analysis of ceiling heights as "truth". However, cloud ceiling heights from the HRRR were not converted to AGL, and clear-sky values were initialized to 13 km in the HRRR/RAP compared to 20 km in the NAM. These differences along with another processing bug, produced abnormal g2g ceiling verification statistics that will soon be fixed. Changes were made to the UPP and NMMB Launcher that allowed GSD cloud ceiling and visibility calculations to be compared against the same products generated from EMC algorithms. In one case, the GSD visibilities were reduced along the west coast and increased over the Great Lakes, while the GSD cloud ceiling heights generally increased over most areas. There was no simple, systematic pattern to the differences, because in some situations the biases reverse between the GSD and EMC algorithms. Ceiling verification is beginning to be tested in the grid-to-obs verification system but awaits a fix to an obs-decoder problem. (Shafran, Zhou, Du, Yang)

Deliverables

14.5.2.E1 Completed - 30 Sept 2014) (NCEP and ESRL)
HRRRv1 implemented at NCEP pending available computing resources.

The 3-km HRRR was successfully implemented operationally at NCEP on 30 Sept. 2014, culminating several years of development, testing, and refinement, with long-term support by FAA/AWRP and NOAA operational modeling. Key collaborating organizations with GSD include NCEP/EMC, NCEP/NCO, and NCAR (WRF/ARW). HRRR forecasts are now being distributed to many different users by NOAA/NCEP, with reduced latency (1-h forecast by ~ +50 min., 15-h forecast by ~ +90 min.) and very near 100% reliability.

NCEP

The HRRR was successfully implemented into NCEP operations on 30 September. (Manikin)

14.5.2.E2 1 April 2014 (NCEP)
Subject to NCEP Directors' approval, upgrades to HiResWindow and initial convection-allowing-scale ensemble (NSSE) becomes Operational at NCEP.

The HiResWindow version 6.0 upgrade package was implemented into NCEP Production on June 11th. Version 6.1 is being planned for FY15. That upgrade will be connected to the initial roll-out of a time-lagged HRRRE for hourly updated 12 hr forecasts, and to NCEP Convection-Allowing-Scale Ensemble (NCASE) run every 6 hours with guidance out to 36 hr including NAM-nest, HiResWindow members with some time-lagged members at least initially. (Pyle, DiMego, Zhou)

14.5.2.E3 1 April 2014 (NCEP)
With approval of NCEP Director, RTMAv6 upgrade package is implemented at NCEP.

The RTMA/URMA upgrade version 2.2.1 was implemented on January 28, 2014. Work continues on FY15 v2.3 upgrade. (Manuel Pondeca, Steve Levine, Yanqiu Zhu, Jacob Carley, Ying Lin, Jeff McQueen, Geoff Manikin, Jim Purser, Dave Parrish, Yuqiu Zhu)

14.5.2.E4 15 July 2014 (ESRL) COMPLETE
Report on status of enhancements to HRRR for 2014 version, based on retrospective and real-time testing.

Mid-term assessment indicates overall good performance for 2014 HRRR (RAPv3/HRRRv2) compared to 2013 version. In particular, reduced (improved) bias for radar reflectivity is seen in 2014 HRRR compared to 2013. CSI scores are similar overall. More details can be found in the report at:
http://ruc.noaa.gov/pdf/HRRR_midterm_evaluation_2014.pdf

Testing and evaluation of RAPv3 / HRRRv2 system is ongoing to address a warm, dry bias seen in pre-frontal southerly flow areas (see subtask 14.5.2 for details).

14.5.2.E5 15 Oct 2014 (ESRL) COMPLETE

Complete 2014-summer evaluation with revised 3-km HRRR running every 1 h.

- Conduct real-time summer 2014 HRRR forecasts using 3-km WRF with 3-km assimilation 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 2014 HRRR experiments

The summer 2014 HRRR real-time evaluation exercise concluded on 31 October and the GSD experimental versions of the RAP and HRRR that were frozen during the exercise were released for use in final real-time testing toward the next NCEP operational implementation. The HRRR performed well during the summer exercise, as evidenced by statistical skill scores, case study results, and subjective user comments. A report summarizing the HRRR results has been prepared and is available at **http://ruc.noaa.gov/pdf/HRRR_summer_2014_report.pdf**

14.5.2.E5.1 31 Mar 2015 (ESRL)
Report on convective weather forecast accuracy from HRRR by quarter for previous year.

14.5.2.E6 20 Jan 2015 (ESRL and NCEP)
Based on real-time parallel and retrospective testing, HRRRv2 code finalized and ready for transfer to NCEP/EMC

ESRL

Nov. 2014 update -- excellent progress toward this goal, with a change package being evaluated in a final set of retrospective experiments.

This date has been pushed back into Q2 (late Jan 2015, with operational implementation of RAPv3 / HRRRv2 currently scheduled Q3 FY15. ESRL will continue evaluation of the HRRRv2 code until an expected transfer in late Jan 2015. Changes from ongoing testing and evaluation to address the warm, dry bias in the RAP and HRRR have shown improvement and have been incorporated into this code upgrade package. These change have included improvement in the land-surface model (snow treatment, sub-grid mosaic, wilting point), enhancements to the PBL scheme (shallow cumulus, effective sub-grid clouds), improved radiation effects of clouds in RRTMG radiation, and modified Grell-Freitas deep convection. Additional changes being evaluated are the addition of mesonet data in the RAP and HRRR data assimilation and the addition of radar radial velocity data in the RAP assimilation. These changes, along with upgrades to latest versions of GSI and WRF (v3.6.1), will be included in the code transfer to NCEP for the RAPv3 / HRRRv2. GSD is also working with computer specialists from NCEP to provide further optimization of the HRRR code for faster runtime on fewer computer cores. Toward this goal, GSD has provided a HRRR code version to the computer specialists for optimization testing.

NCEP

With the implementation of the HRRR at NCEP on 30 September, initial efforts have begun on the next versions (HRRRV2 and RAPV3), which will be implemented jointly in summer 2015. Preliminary efforts have ESRL and IBM and EMC personnel working to speed up the HRRR codes, as the operational run times are very tight relative to their slots. Code will be delivered by ESRL to EMC early in 2015, and parallel testing of both systems will begin soon after. (Manikin)

14.5.2.E7 15 Jan 2015 (ESRL, assistance from CAPS under 5.1 support)
Report on initial retrospective test of storm-scale ensemble data assimilation for small Northeast U.S. domain.
See subtask 14.5.2.6 for details on preliminary testing work in this area.

Planning and configuration work ongoing, as well as related Warn-On-Forecast tests over the SE U.S. Initial testing over the Northeastern U.S. has been deferred till after the hand-off of RAP/HRRR code to NCEP for RAP/HRRR implementation.

14.5.2.E8 15 March 2015 (ESRL/GSD, NCEP)
Pending NCEP computer readiness and EMC and NCEP initial recommendations, Requests for Change (RFCs) are filed to submit HRRR code changes as part of upgrade for HRRR v2 software to NCO.

GSD - HRRRv2 (and RAPv3) currently scheduled for late Q3 NCEP implementation.

NCEP

With the implementation of the HRRR at NCEP on 30 September, initial efforts have begun on the next versions (HRRRV2 and RAPV3), which will be implemented jointly in summer 2015. Preliminary efforts have ESRL and IBM and EMC personnel working to speed up the HRRR codes, as the operational run times are very tight relative to their slots. Code will be delivered by ESRL to EMC early in 2015, and parallel testing of both systems will begin soon after. (Manikin)

This work awaits transfer of the RAPv3 / HRRRv2 code versions with the final changes to NCEP/EMC.

14.5.2.E9 1 Feb 2015 (ESRL and NCEP)
Provide revised 15-min RTMA surface analyses as improved alternative for frontal diagnostics and other diagnostics from surface analyses for CoSPA.

GSD - Good work toward upgrade to RTMA/URMA (scheduled for FY15Q2), which will include first use of blended HRRR / NAM-nest background. Testing and evaluation of revised 15-min HRRR-based RTMA at GSD with new research scientist.

NCEP

Work at NCEP towards a 15-min RTMA must wait for the upgrade to RTMA/URMA in FY15Q2, and the WCOSS Phase 2 computer upgrade in FY15Q2. (Manuel Pondeca, Steve Levine, Jacob Carley, Jim Purser)

14.5.2.E10 15 March 2015 (ESRL)
Finalize all changes to the HRRR for the summer 2015 exercise into a frozen version of HRRR (and parent experimental RAP). This will include latest results on reflectivity verification.

Deliverables Task 2: Improve Quality Of Convective Weather Forecasts	Delivery Schedule
HRRRv1 implemented at NCEP pending available computing resources The 3-km HRRR was successfully implemented operationally at NCEP on 30 Sept. 2014, culminating several years of development, testing, and refinement, with long-term support by FAA/AWRP and NOAA operational modeling.	SEPT 2014 COMPLETE
B. Report status of enhancements to HRRR for 2014 version, based on retrospective and real-time testing. STATUS: Preliminary mid-summer report indicates 2014 HRRR improves upon the high bias seen in 2013, especially for longer forecasts. Testing of enhancements for warm, dry bias in RAP, HRRR ongoing. Report at**: http://ruc.noaa.gov/pdf/HRRR_midterm_evaluation_2014.pdf**	JUL 2014 COMPLETE
C. Complete 2014-summer evaluation with revised 3-km HRRR running every 1 h. Conduct real-time summer 2014 HRRR forecasts using 3-km WRF with 3-km assimilation 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 2014 HRRR experiments. STATUS: Summer 2014 evaluation concluded, report available at: **http://ruc.noaa.gov/pdf/HRRR_summer_2014_report.pdf**	OCT 2014 COMPLETE
D. Based on real-time parallel and retrospective testing, HRRRv2 code finalized and ready for transfer to NCEP/EMC. (But not to be transferred until Jan 2015) -- Complete, code finalized and final set of 3 retrospective experiments (winter, spring, summer) underway; code will be transferred in Jan 2015.	Nov 2015 COMPLETE
E. Report on initial retrospective test of storm-scale ensemble data assimilation for small Northeast U.S. domain.	**DEFERRED until Apr 2015**
F. Requests for Changes (RFCs) are filed to submit HRRR code changes as part of upgrade for HRRRv2 software to NCO.	New Date: MAR 2015
G. Provide revised 15-min RTMA surface analyses as improved alternative for frontal diagnostics and other diagnostics from surface analyses for CoSPA.	FEB 2015
H. Report on convective weather forecast accuracy from HRRR by quarter for previous year.	MAR 2015
I. Finalize all changes to the HRRR for the summer 2015 exercise into a frozen version of HRRR (and parent experimental RAP). This will include latest results on reflectivity verification.	MAR 2015

Task 3: Improve Quality Of Icing Weather Forecasts From RAP, HRRR, NAM, NAM-Nests And, Eventually, NARRE And HRRRE

Subtasks

14.5.3.1 1 Apr 2014 (GSD, NCEP and NCAR/RAL)
Begin initial testing of the current version of NCAR "aerosol-aware" microphysics in RAP and HRRR models. This will use a climatological aerosol distribution for cloud-condensation nuclei and ice nuclei initially.

GSD

The WRFv3.6+ version, upgraded to be essentially equivalent to the WRFv3.6.1 release in August 2014 and to incorporate RAP / HRRR specific changes, continues to run in the real-time RAP-dev3 cycle with the Thompson-Eidhammer aerosol-aware microphysics activated. The FY14 Q4 report contains a summary under this task of our comparison between the aerosol-aware microphysics and the unaware Thompson microphysics in WRFv3.5.1.

Our current assessment is that precipitation-type predictions by the aerosol-aware microphysics are not degraded in the new scheme relative to the aerosol unaware scheme. There have not been any egregiously bad precipitation-type forecasts with the new scheme. Performance will continue to be monitored as the winter season progresses. We continue to note that the sky coverage of high (i.e., Cirrus) cloudiness is notably less with the aerosol-aware scheme. However, the actual coverage by Cirrus and Cirrostratus is also less than predicted by the aerosol-unaware scheme in WRFv3.5.1, but is usually somewhat more than produced by the aerosol-aware. Nevertheless, the aerosol-aware appears to overall have the edge in accuracy of coverage by high clouds composed predominately of ice crystals.

In earlier reports we noted that the aerosol aware scheme increases the running time of the model by more than 10%. As part of their work toward speeding up execution of WRF-ARW (see Task 1), the NCEP WCOSS experts have identified features of the aerosol-aware microphysics that can be optimized for significantly faster execution. It now appears that with their recommendations the RAP and HRRR with the aerosol aware code can be made to run as fast as the old code with the aerosol-unaware microphysics. This is good news for incorporating this important physics advance into the RAPv3 and HRRRv2 codes, but limited further testing will be necessary to ensure that the optimized version is producing forecasts comparable to the non-optimized version. We continue to be in contact with Greg Thompson regarding this and other matters.

NCEP

EMC will await the results of GSD's effort before planning physics development in 2015 or beyond. Thompson's work at NCAR on including aerosols in his microphysics scheme is also being followed with the NMMB. (Ferrier, Aligo)

14.5.3.2 1 Apr 2014 (GSD)
Continue evaluation and modification of proposed RAPv3 physics suite in preparation for submission of code to NCEP, pending NCEP readiness, later in 2014.

As noted in the FY2014 Q4 report under Task 3, major changes to the original April version of the RAPv3 scheme including to the RUC Land-Surface Model, the MYNN surface-layer and PBL schemes and the Grell-Freitas shallow cumulus schemes have largely eliminated the warm-season warm-dry bias in daytime surface conditions over the eastern CONUS. This has been confirmed by our long spring and summer retros using the near-final December 2014 RAPv3 configuration.

Upgrades to the April 2014 version of RAPv3 and HRRRv2 physics that we plan to make available to NCEP include the following. The first 3 of these were critical to alleviating the summertime warm-dry bias.

<u>Model improvements for advanced version RAPv3/HRRRv2</u>

- Activating the "boundary-layer cloud" option in the MYNN PBL, and coupling the inferred cloud cover to the RRTMG radiation.
- Activation and considerable revision to the Grell-Frietas shallow convection scheme (now sometimes referred to as the GFO scheme, owing to Joe Olson's involvement in improving the scheme), plus improving the coupling of the parameterized shallow convection with short-wave radiation.
- A modification to the RUC LSM to prevent transpiration from being totally shut down once the wilting point is reached for the cropland land-use area only. In effect, soil moisture is added to maintain conditions near the wilting point, simulating, appropriately, the effects of irrigation in cropland areas.
- Correcting a bug in the WRF model namelist in which the attenuation of solar radiation by (climatological) aerosol was inadvertently turned off. This had only a minor beneficial effect.
- Use of the aerosol-aware microphysics scheme.

- Miscellaneous changes to the MYNN surface and PBL schemes that have the effect of reducing slightly the surface heat flux and allowing for counter gradient heat flux near the top of the daytime mixed layer.
- A general upgrade to the RUC LSM, including better energetic consistency and changes to aspects of the scheme having to do with snow (e.g., albedo under conditions of partial snow cover).
- Improvements to Grell-Freitas deep-convection scheme.

14.5.3.3 1 May 2014 (GSD and NCAR/RAL)
Begin efforts toward adding aerosol species or size categories as tracers to the RAPv3 and HRRR configurations of the WRF model, including surface sources, which are highly parameterized in the first version of the new microphysics scheme. Interact with WRF-Chem experts for aerosol source datasets, surface emission inventories, and translation of specific aerosol variables into the constituents needed by the microphysics scheme.

Discussions are underway between GSD and NCAR about how to incorporate prognostic aerosol information from the RAP-Chem run, or even FIM-Chem, into experimental versions of the RAP and HRRR. A possible application would be to replace the initial climatological aerosol distribution in the current NCAR-Thompson aerosol-aware microphysics with an actual predicted initial distribution to better capture the effects of synoptic weather systems on the initial aerosol distribution.

Discussions have started between GSD and NCAR about how to incorporate prognostic aerosol information from the RAP-Chem run into experimental versions of the RAP and HRRR.

14.5.3.4 1 May 2014 (NCEP)
Perform case-study simulations of high-impact weather events in order to evaluate NMMB model running the existing and newly added Thompson et al (2008) microphysics schemes.

All of the microphysics options now work properly in the NMMB and pass all regression tests. The saturation tables used in the Ferrier-Aligo microphysics, also used in the RRTMG radiation driver to calculate sub grid-scale cloud effects (which reduced the 2-m cold biases last winter), are now being properly initialized and can be used in any microphysics scheme. Maximum hourly fields can now also be produced from the Thompson microphysics. (Ferrier, Aligo, Lin)

14.5.3.5 1 Jun 2014 (NCAR/RAL)
Test and evaluate the ice initiation mechanisms via aerosols to ensure the water-ice balance is relatively un-changed versus the prior scheme or else the updated scheme may result in significant loss of skill of aircraft icing forecasts since water is rapidly depleted by ice when too many ice crystals are supplied.

14.5.3.6 1 Sep 2014 (NCAR/RAL)
Continue to increase the complexity and interactions between the newly added aerosol variables in the microphysics with the PBL, radiation, convection, and shallow convection schemes. Particular focus will be the depletion of aerosols nucleated by sub-grid-scale eddies, the effects of which are represented by the PBL and convection schemes.

Current efforts: During the month of December 2014, G. Thompson provided a new cloud fraction scheme (icloud=3 in namelist) to NCAR-MMM WRF developers for inclusion in the next public release of WRF. The new cloud fraction scheme is entirely in conjunction with a modified RRTMG radiation scheme but has been shown to work with the Hurricane HWRF (HWRF) Ferrier physics (mp_physics=85 option). In theory, the use of the new cloud fraction scheme is available for use together with **any** microphysics option, and could relatively easily be added to other radiation scheme and into NEMS-NMMB model as well.

Future work: The ice initiation by aerosols code is being tested to resolve concerns of different upper level ice clouds as well as perform sensitivity analysis on the connections of aerosols, ice nucleation, clouds and precipitation. NCAR-RAL will assist NOAA-GSD to adopt/utilize the new scheme. This work is being performed by Trude Eidhammer and was placed on hold mostly in December as she prepared, traveled, and presented other research at the annual AGU meeting.

Problems encountered/Delays: None.

Interface with other organizations: Various DOE Solar-WRF team members including GSD

Deliverables

(All Option A unless noted otherwise)

14.5.3.E1 1 Aug 2014 (NCAR)
Submit updated cloud microphysics code to WRF repository; document changes and purpose of changes in a report.

14.5.3.E2 31 Aug 2014 (ESRL)
Complete initial evaluation of aerosol-aware microphysics in RAP/HRRR test evaluation/demonstration at GSD for its suitability for future NCEP implementation.

14.5.3.E3 15 Mar 2015 (NCAR)
Submit a report and possible journal manuscript related to the aerosol-ice sensitivity experiments including specific application to aircraft icing.

The text specifically mentions a report or journal paper by Dec 2014 regarding our work to test aerosol-ice nucleation (14.5.3.E3). We request a change to Mar 2015 for that item. It is NOT currently in the deliverable table itself, but we request a date change regardless. The work is currently being performed but will likely take longer than previously estimated.

14.5.3.E4 20 Dec 2014 (ESRL)
At the annual NCEP Product Suite Review report on RAP / HRRR physics upgrades. This will include metrics on improvement to cloud and RH forecasts from these physics upgrades.

14.5.3.E4.1 31 Mar 2015 (ESRL)
Report on RH/cloud forecast accuracy from RAPv3 and HRRRv2 by quarter for previous year, related to icing guidance.

14.5.3.E5 31 Jan 2015 (ESRL/GSD, NCEP)
Pending NCEP computer readiness and EMC and NCEP initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh v3 software to NCO.

NCEP

With the implementation of the HRRR at NCEP on 30 September, initial efforts have begun on the next versions (HRRRV2 and RAPV3), which will be implemented jointly in summer 2015. Preliminary efforts have ESRL and IBM and EMC personnel working to speed up the HRRR codes, as the operational run times are very tight relative to their slots. Code will be delivered by ESRL to EMC early in 2015, and parallel testing of both systems will begin soon after. (Manikin)

Deliverables Improve Quality Of Icing Weather Forecasts	Delivery Schedule
A. Complete initial evaluation of aerosol-aware microphysics in RAP/HRRR test evaluation/demonstration at GSD for its suitability for future NCEP implementation. ESRL/GSD: The aerosol-aware microphysics is now running and under evaluation in an experimental real-time RAP cycled run ("RAP-dev3"). See discussion under subtask 1.	AUG 2014 COMPLETE
B. At the annual NCEP Product Suite Review report on RAP/HRRR physics upgrades. This will include metrics on improvement to cloud and RH forecasts from these physics upgrades.	DEC 2014 COMPLETE
C. Requests for Change (RFCs) are files to submit WRF physics code changes as part of upgrade for Rapid Refresh v3 software to NCO.	JAN 2015
D. Report on RH/cloud forecast accuracy from RAPv3 and HRRRv2 by quarter for previous year, related to icing guidance.	MAR 2015

Task 4: Develop Convection-ATM-Specific Improvements To Guidance From The HRRR (And Later, HRRRE) And Interact with CoSPA (Or Other) Program Partner Labs and the FAA

Subtasks

14.5.4.1 15 Aug 2014 (GSD)
Initial testing toward variational/ensemble cloud analysis scheme within the GSI framework.

Several meetings have been conducted between Ming Hu, Curtis Alexander and new GSD scientist, Terra Ladwig, to plan the first steps towards the variational/ensemble cloud analysis scheme within GSI. These meetings discussed details to handle processing of satellite (NESDIS and NASA Langley) cloud and radar precipitation hydrometeors in a new framework that will handle the mapping of these observations onto the analysis grid of any model background (RAP, NAM, GFS). Ming Hu has updated the GSD GSI repository code to include recent commits to the EMC GSI repository and Terra has added the GSI I/O capability for handling cloud-ice number concentration and is now adding the cloud water number concentration. Additional discussion took place regarding the creation of observation operators to map

model cloud hydrometeors into observations of cloud base and cloud top heights for the variational minimization. Collaboration with NCAR is planned in an upcoming meeting with Tom Auligné and Gael Descombes was also discussed to obtain initial model background error covariance estimates for cloud and precipitation hydrometeors. Future planning was also discussed regarding use of the GFS ensemble including the partitioning of total water from the GFS into cloud water and ice and then how to merge analyzed cloud back to total water. Initial plans have been made to improve the analysis of cloud ice information from satellite observations by incorporating both cloud ice mixing ratio and number concentration into the cloud analysis process for use by the Thompson microphysics scheme. GSI has been modified to both read and write the cloud ice number concentration (and soon cloud water number concentration), and an evaluation is underway to determine appropriate values for these moments when building clouds in the analysis where the model background does not contain them. Terra Ladwig presented initial progress towards a variational/ensemble cloud analysis scheme at the AMS annual meeting in January 2015.

14.5.4.2 15 Nov 2014 (GSD, NCEP)
Finalize new cloud/hydrometeor analysis for 2015 RAPv3/HRRRv2

NCEP

Additional modifications were made to the RAP's cloud analysis for use in the NAM. The cloud-water mixing ratios are adjusted except when the first-guess relative humidity is too low. The first-guess rain and snow (large ice) mixing ratios were adjusted based on the reflectivity observations. (Liu, Carley)

GSD

Modifications have been completed to the WRF-ARW version 3.6 codes including the creation of a total cloud field that combines explicit, parameterized and boundary layer clouds fields for a more accurate depiction of the modeled cloud field that includes unresolved scales. Post-processing of these additional cloud fields is being tested in the cloud ceiling height diagnostic. -Testing of full-column precipitating hydrometeor building in the HRRR cloud/hydrometeor analysis has been completed. This case study was followed by a retrospective experiment to build precipitation hydrometeors only at lower observed reflectivity thresholds below 28 dBZ. Results of this test indicate an improved 3-D analysis of precipitation and an increase in 1-hr accumulated precipitation at low thresholds.

Testing of the final RAPv3 and HRRRv2 cloud and precipitation hydrometeor analysis is underway with a merging of the latest EMC GSI code into the GSD GSI repository now complete. The new GSI RAPv3/HRRRv2 cloud and precipitation hydrometeor analysis is being evaluated in three one-month retrospective periods during the winter of ~~2013~~ 2015, spring of 2013 and summer of 2014. In addition to the building of precipitation hydrometeors at lower observed reflectivity thresholds between 15 and 28 dBZ in the warm season, two additional changes were incorporated into the cloud and precipitation hydrometeor analysis including avoiding building clouds from METAR ceilometer data where satellite data indicates clear conditions, (except in the immediate vicinity of the METAR locations) and inheriting an improved 3-D radar coverage map to avoid removal of snow hydrometeors from the analysis where radar observations are not available. Experimental versions of the RAPv3 and HRRRv2 run in real-time at ESRL have been updated with these changes as of 01 January 2015. Retrospective tests are being conducted to quantify the impact of the improvements.

14.5.4.3 15 Feb. 2015 (GSD, NCEP)
Report on progress toward variational/ensemble cloud analysis

NCEP

The ability to have vertically varying localization for regional hybrid variational/ensemble analysis and several bug fixes on the cloud analysis was successfully added to the code repository in July. (Liu, Wu, Carley)

14.5.4.4 15 March 2015 (NCEP, ESRL)
Groups collaborate on initial work toward cloud analysis scheme for use in NARRE ensemble system.

NCEP

No activity in December. (Liu, Wu, Carley)

14.5.4.5 31 March 2015 (ESRL, NCEP)
Establish routine verification of NCEP suite of ceiling & visibility guidance and begin design of calibration strategy for ensemble systems.

NCEP

The radar echo top heights and hybrid-scan reflectivity (HSR) data in the GRIB2 radar mosaics were added to the grid-to-grid (g2g) verification. The operational verification codes were updated to work with GRIB2 output. Verification statistics were generated for forecasts of total cloud fractions, composite reflectivity, and visibility from most of the operational regional modeling systems. SREF forecasts of surface visibility over Alaska were added to the ensemble g2g verification. Ceiling heights from the HRRR, NAM, and mean SREF forecasts were added to the g2g verification using the HRRR analysis of ceiling heights as "truth". However, cloud-ceiling heights from the HRRR were not converted to AGL, and clear-sky values were initialized to 13 km in the HRRR/ RAP compared to 20 km in the NAM. These differences and another processing bug produced abnormal g2g ceiling verification statistics that will soon be fixed. Cloud ceiling verification is being tested in the gridtobs verification system and there are issues in some cloud observations that are being cleaned up. (Zhou, Shafran, Liu, Du, Yang)

Deliverables

14.5.4.E1 1 April 2014 (NCEP)
With approval of NCEP Director, RTMAv6 upgrade package is implemented at NCEP (including visibility).

The RTMA/URMA upgrade version 2.2.1 was implemented on January 28, 2014. (Manuel Pondeca, Steve Levine, Yanqiu Zhu, Ying Lin, Jeff McQueen, Geoff Manikin, Jim Purser, Dave Parrish, Yuqiu Zhu)

14.5.4.E2 1 June 2014 (NCEP)
With approval of NCEP Director, SREF, HiResWindow and NAM upgrade packages are implemented at NCEP (including corrections to ceiling, visibility and cloud field prediction & diagnoses).

The new SREF system continues to run in parallel test mode at EMC, and preliminary verification results are being generated. Numerous changes were made to the NMMB physics, as described above in 14.5.1.5 and 14.5.3.4, which should lead to improved performance for most of the NMMB members. (Du, Zhou, Yang, Jovic, Pyle, Rogers)

14.5.4.E3 15 Dec 2014 (ESRL/GSD)
Finalize cloud/hydrometeor assimilation for RAPv3 and transfer code to NCEP.

Testing of the final RAPv3 and HRRRv2 cloud and precipitation hydrometeor analysis is underway including three one-month retrospective periods. Upgrades to the real-time ESRL RAPv3 and HRRRv2 were completed on about 01 January 2015. Initial RAPv3/HRRRv2 code transfer to NCEP is scheduled for the last week of January 2015.

14.5.4.E4 15 Feb 2015 (ESRL/GSD)
Report on variational / ensemble/hybrid cloud analysis development for RAP and NARRE

14.5.4.E5 31 March 2015 (NCEP)
Subject to NCEP Directors' approval, upgrades to RTMA/URMA (addition of total cloud and cloud base height [ceiling]) become operational at NCEP.

The assimilation of total sky cover from the GOES imager was added to the RTMA/URMA upgrade. The upgrade package was submitted to NCO for operational implementation, and it was also committed to the EMC GSI trunk repository. The RTMA/URMA parallel webpages were also maintained. (Pondeca, Carley, Levine)

Deliverables Task 4: Develop Convection-ATM-Specific Improvements	Delivery Schedule
A. Report on ATM impact related to skill of HRRR forecast.	FEB 2015
B. Complete implementation of new microphysics scheme and associated reflectivity and ET diagnostics in real-time ESRL/GSD RAP and HRRR prior to code freeze for 2015-exercise release.	MAR 2015
C. Report on baseline testing of the early 2015 HRRR version.	MAR 2015
D. Report on evaluation of revised Thompson aerosol-aware microphysics for RAP/HRRR for its effects on echo-top and reflectivity in ESRL RAP/HRRR.	MAR 2015