**MODEL DEVELOPMENT AND ENHANCEMENT RESEARCH TEAM**

**Monthly Report for August 2008**
**Submitted 15 September 2008**

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## Executive Summary

**Task 08.5.1: Infrastructure support related to operational running of the RUC and NAM operational modeling systems.**

- RUC upgrade implementation now planned for 4 Nov 2008.
- NCO/NCEP now doing testing for RUC upgrade package code (radar reflectivity assimilation, TAMDAR, radiation, Grell/Devenyi upgrade). Real-time comparisons continue in http://wwwt.emc.ncep.noaa.gov/mmb/ruc2/para.
- GOES PW 1x1 near-term change for RUC delayed by NWS-declared "critical weather" over last month, now planned for this week. Note: Higher-resolution GOES PW data to be used but only over water.

**Task 08.5.4: Develop, test, and implement Rapid Refresh configuration of the WRF modeling system.**

- Updated web-page with hourly cycled experimental RR at http://rapidrefresh.noaa.gov .
- TAMDAR data, including PenAir (Alaska), Mesaba, and Chautauqua, now being used in experimental RR. One-hour cycle using WRF version 3.0, DFI, and latest regional GSI version (March 2008) continues to run reliably at GSD.
- Cause of occasional RR 1-h cycle crashes along southern boundary found (issues related to large analysis increments along the boundary from Colombian observations), solution being tested.
- Tarball with Rapid Refresh specific elements (GSI, WPS, WRF, WRFpost) transferred to NCEP computer "vapor" to begin experimental RR work at NCEP.
- *Rapid Refresh now planned to run out to 18h duration hourly.*

**Task 08.5.5: Develop, test, and implement 3DVARs for RR and NAM**

- Further modifications incorporated in July into RR version of GSI

**Task 08.5.15: Develop improved methods of cloud and moisture analysis for use in the WRF modeling system.**

- Cloud analysis for GSI incorporating METAR cloud and GOES cloud-top data (similar to the RUC cloud analysis) continues to run regularly in a 1-h cycle with the Rapid Refresh.
- Minor modifications to cloud analysis being made to conform with EMC coding practices

**Task 08.5.24/19: Begin 3km High-Resolution Rapid Refresh testing / Improve radar assimilation**

- 15-min VIL output from hourly HRRR available at: http://ruc.noaa.gov/hrrr/vil
- New HRRR reflectivity "matrix" web-page at: http://ruc.noaa.gov/hrrr/reflectivity.cgi

**Task 08.5.1: Infrastructure Support for Operational Running of the RUC at NCEP**

**GSD**

**Updates on two change packages to operational RUC**:

**a. Small change package for GOES 1x1 PW**

**b. Larger upgrade (~September) change packages to RUC**

**a. GOES 1x1 PW change - update**

This near-term change was delayed by NWS-declared "critical weather" over last 4 weeks, will probably be implemented this week (16-19 Sept). Background: NESDIS is waiting for a RUC change to cease production of 3x3 field-of-view (FOV) precipitable water (PW) data, which the operational RUC currently assimilates. Thus, this change will be for modifications to the RUC analysis to allow use of the much denser 1x1 FOV PW data.

Background: During July and early August, it was determined that the GOES PW data has a substantial moist bias, from 2-6 mm. The effect of this bias was initially exaggerated by the introduction of the 1x1 PW data. Therefore, after tests at GSD, it was decided to use GOES 1x1 PW data only over the oceanic areas and use the GPS PW data (no bias) as the only PW observations to be assimilated over land areas. This change was introduced to the GSD devRUC13 (http://ruc.noaa.gov/pig.cgi?13km_D2) on 6 August 2008.

**b. RUC upgrade for model, assimilation, and post-processing**

The RUC upgrade code is now being tested by NCEP/NCO, transferred from NCEP/EMC. Real-time comparisons continue to be available at http://wwwt.emc.ncep.noaa.gov/mmb/ruc2/para. NOTE: the NCO version of the upgraded RUC has not been using radar reflectivity data, but that should be fixed tomorrow (9/16).

Collaborative work between EMC (Geoff Manikin and Shun Liu), GSD and NSSL overcame an issue that was holding up the beginning of a cold season retrospective test. Because there were no cold season radar reflectivity data available for the Feb 2008 test period, NSSL supplied several tar files of data and a C-based reader routine. Ming Hu (GSD) converted the C-based reader to F90, which could be compiled and run at NCEP. Collaborative work by GSD (primarily Stan Benjamin) and Geoff Manikin resolved the final issues and the retrospective test is now underway**.**

Additional TAMDAR observations (Chautauqua) now added to NCEP RUC parallel RUC, almost doubling the number of TAMDAR observations and increasing geographical coverage.

Current planned implementation date – 4 Nov 2008.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

**NCEP**

**Task 08.5.1: Infrastructure Support for Operational Running of the RUC at NCEP**

Dennis Keyser reports that the "new science" GOES cloud data continues to be plagued with two problems. First, NESDIS is encoding 1 or 2 reports at the beginning of 2-4 files per day with a missing lat/lon and bogus satellite ID. Second, the eastern GOES files arrive late and are not always available for the RUC analysis. (NESDIS has been contacted on both issues.) Tests of the RUC using GOES 1x1 f-o-v PW data are underway. An obs-processing change package (which includes turning on the 1x1 GOES and establishing a Rapid Refresh [RR] data processing system) was tested in NCO parallel production in July and will be implemented as soon as critical weather ends. Processing of new Build 10 Level II radar data (see Task 08.5.17) is affecting the generation of 88D mosaics used in the parallel RUC. NCO is testing a recombination code to make Build 8 look-alike versions. Some radiosondes are not receiving

the proper instrument type due to obsolete entries in the NCEP/NCO upper-air dictionary. NCO is ready to correct this as soon as critical weather ends. Parallel testing of TAMDAR aircraft temperature and wind data is also currently underway. At the request of ESRL/GSD, efforts are being made to get TAMDAR airframe type and company code (not included in either the ESRL MADIS or AirDAT feed) to allow for improved bias corrections. On 29 August, TAMDAR data from Chautauqua was added to the NCEP data feed from ESRL (joining Mesaba TAMDAR data in the parallel-production RUC/RR PREPBUFR files). NCEP now receives raw PenAir (Alaskan) TAMDAR data from ESRL and NCO is working on a BUFR encoder for these data. Once that is completed, the PenAir data will be present in the parallel RUC/RR PREPBUFR files. All TAMDAR data will then be restricted.

Geoff Manikin reports that in the fall of 2007 EMC began running a parallel version of the RUC model, with the primary feature of this code being the assimilation of radar reflectivity data. Geoff Manikin worked with Shun Liu to generate hourly reflectivity mosaic files to be ingested by the RUC, and the assimilation of the mosaic data is linked to the digital filter initialization to specify the 3-d profile of latent heating. Other changes include the assimilation of mesonet wind data (from a list of approved providers) and TAMDAR data, a change in the longwave radiative scheme from Dudhia to RRTM, a modification of the snow component of the land-surface model to decrease excessively cold 2-meter temperatures over fresh snow at night, another change to the snow model to allow for warmer temperatures during warm advection events over snow cover, and a modification to the convective scheme to decrease widespread coverage of light precipitation. Daily comparisons between operational and parallel forecasts and a statistical evaluation continue, and a set of cool season retrospective runs is underway. NCO has taken over the processing of the radar data, and is running it routinely in parallel (see above). Updated code for the RUC system was turned over to NCO in July, and they are now running the new RUC in parallel. Unfortunately, as of 8 September NCEP has been in critical weather mode for several weeks (due to tropical activity, political conventions and more tropical activity), preventing the start of the RUC evaluation by the NCEP centers. This delay in the evaluation process will likely delay the implementation of the updated RUC code until late October.

In addition, an operational RUC upgrade has been prepared to switch from reading 5x5 to 1x1 GOES precipitable water radiances, as NESDIS plans to shut off the 5x5 data feed. Stan Benjamin, Geoff Manikin and Dennis Keyser updated the analysis code to handle a larger volume of GOES precipitable water data. GSD and EMC discovered that the new precipitable water feed has a high moist bias, so the code was updated in August to not use this data over land. The new system was scheduled for an implementation in mid-August, but the extended critical weather also delayed this; the implementation will occur when there is a lapse in critical weather conditions, now scheduled for 4 November.

Shun Liu continued working with NCO to test generating the 3D reflectivity mosaic with new build-10 data and legacy data. He verified that the 3D reflectivity mosaic can be produced properly with new radar data. The 3D mosaic package is running as an NCO parallel test and Shun Liu's parallel run is providing 3D mosaic data for the RUC.

***Subtasks***

**08.5.1.1** Maintain hourly RUC runs and provide grids of SAV and AIV guidance products.

**08.5.1.2** Provide vendors with gridded model data via Family of Services (FOS), and the FAA Bulk Weather Data Telecommunications Gateway (FBWDTG).

**08.5.1.3** Provide full grids from RUC runs on NCEP and NWS/OPS servers.

**08.5.1.4** Maintain access to model verification data.

***Deliverables***

**08.5.1.E1** 1 October 2007 - 30 September 2008 **EMC** (Rogers, Manikin, Keyser)
Perform observation ingest, quality control, and preparation in support of the operational RUC runs.

CURRENT EFFORTS:

PLANNED EFFORTS:

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:
INTERFACE WITH OTHER ORGANIZATIONS:

UPDATES TO SCHEDULE:

**Task 08.5.4: Develop, test, and implement Rapid Refresh configuration of the WRF modeling system.**

**ESRL/GSD**
During August, work continued toward making GSD's Rapid Refresh (RR) 1-hour cycle more reliable and more efficient. As described in the FY08 Quarter 3 report, the RR is now running with major upgrades to both the WRF model component (version 3.0) and GSI analysis component (March 2008 release) of the real-time hourly cycled RR at GSD.

With assistance from Dennis Keyser and others at EMC, the problem associated with the unreliability of the real-time RR PrepBUFR (and satellite radiance) observation data feed from NCEP has been resolved. The processing to create these files for the operational RUC is now running in parallel within NCO at NCEP and PrepBUFR files are now being obtained from an NCEP ftp site.

We have also explored use of an adaptive time step option in WRF 3.0, in which the time step is increased (or decreased) during the run according to the maximum value over the domain of the Courant number in the preceding large time step. This option is now being used in the cold-start RR forecasts. However, further testing will be required to optimize the bounds on the time step before implementation in the 1-h cycle. A further modification that we see as crucial to increasing the efficiency of the model is being designed at present. This is the capability to call the Thompson microphysics less often than every large model time step. (We think that calling the microphysics every other large time step, i.e., every 2 min, will speed up the wall time of the forecast by up to 5% without degrading the forecast.) This capability exists in the RUC, but not presently in the WRF-ARW.

The causes of a sporadic model crashes due to extreme vertical velocities along the southern boundary of the domain has been identified and tests of a solution are ongoing. Ming Hu traced the problem (in which a build-up of vertical velocities over many hourly cycles would eventually lead to a crash) to large analysis increments along the southern boundary (where the main cordillera of the Andes in Colombia intersects this boundary) to Colombian observations (both METAR and aircraft observations). For these high elevation METAR observations, the problem is compounded by a significant mismatch between the observed and model terrain. We are testing a solution in which the magnitude of the analysis increments is ramped down along a 5 gridpoint wide band along the horizontal boundaries.

A tarball with Rapid Refresh (RR) specific elements (GSI, WPS, WRF, WRFpost) has been transferred to NCEP vapor machine to begin experimental RR work at NCEP. Also, with assistance from Yoshi Sato, Ming Hu has been working on a parallel track to get Yoshi's NAM retro cycle scripts running on vapor. This DTC effort also benefits the RR effort (and longer term efforts toward a more unified code structure for the 2012 ensemble Rapid Refresh) as NCEP IBM-specific elements of the NAM scripting and boundary condition processing can be incorporated into the RR cycle on vapor. In particular, Chris Harrop's workflow manager, which is used to coordinate the RR runs at GSD is not supported at NCEP and will be replaced by modified versions of similar procedures used for the NAM at NCEP.

Note: As of Tues 12 Aug, NCEP/EMC has agreed with AWC and SPC that the Rapid Refresh will run hourly out to 18h. GSD and NCEP will be working together on this new parameter, but in general, this will be very beneficial for aviation weather forecast users.

PLANNED EFFORTS: Continue to evaluate the implemented solution for the sporadic model crashes

along the southern boundary. Continue to closely monitor RR forecast performance and continue to experiment with procedures to speed up execution of both the GSI and the model.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: None

INTERFACE WITH OTHER ORGANIZATIONS: DTC, NCEP, NCAR

UPDATES TO SCHEDULE: None.

**NCEP**

***Subtasks***

**08.5.4.1** 30 December 2007 (GSD, NCEP) COMPLETE
Begin real-time hourly cycling of RR model with GSI over RR domain with availability at GSD of hourly PrepBUFR files from NCEP having begun on 12 October 07.

CURRENT WORK:
See discussion above for description of ongoing development of the Rapid Refresh real-time 1-h cycle at GSD.

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: None

INTERFACE WITH OTHER ORGANIZATIONS: NCEP, NCAR, NWS regions

UPDATES TO SCHEDULE: None

**08.5.4.2** 1 March 2008 (GSD) [COMPLETE]
Begin collaborative evaluation with planned NOAA Rapid Refresh users, including AWC, SPC, NWS in Alaska and Puerto Rico. Arrange to have GSD RR grids available to examine and solicit feedback on RR performance.

Three versions of real-time Rapid refresh grids (full RR domain -- #220, CONUS -- #130 and Alaska -- #249 sub-domains) with the correct parameter settings in the grib files are now being created and made available to FAA AWRP RTs and various NWS users.

**08.5.4.3** 1 March 2008 (GSD) [COMPLETE]
Begin collaborative evaluation of Rapid Refresh with Inflight Icing, Turbulence, National Ceiling/Visibility, and Convective Weather RTs. Arrange to have GSD RR grids available to examine and solicit feedback on RR performance.

(see discussion above). The domain parameter settings that were causing a problem for the icing team has been fixed and we are beginning real-time feeds.

**08.5.4.4** 30 May 2008 (GSD, NCAR, NCEP)
Report on status of tactical planning for making RR-WRF code for 2012 in compliance with Earth System Modeling Framework (ESMF) as specified in the Sept 2007 Rapid Refresh MOU between NCEP and GSD.

Under separate funding, Tom Henderson (formerly NCAR, now with ESRL/GSD) continues his work toward putting the ESRL FIM (Flow-following Icosahedral Model, under development, test and evaluation within GSD) into the ESMF framework, a necessary step if it is to contribute members to NCEP's Global Ensemble. In the process of doing this, Tom is working closely with Tom Black of EMC. Tom Henderson has FIM running under NCEP's flavor of ESMF version 3.1. Experience gained with this effort will strongly facilitate the process of putting the RR (and ARW dynamic core) under ESMF in the 2010-11 time period.

**08.5.4.5** Ongoing (GSD)
Further enhancement to WRFpost version for Rapid Refresh application, including modifications for generation of RUC-specific fields.

Output from the RR 1-h cycle at GSD, as well as that from the full-domain cold-start and run continue to be available. Also, real-time products are now available over an Alaska window sub-domain for both the RR 1-h cycle and cold start. They can be viewed at: http://rapidrefresh.noaa.gov/alaska/

**08.5.4.6** Ongoing (GSD, DTC later)
Ongoing evaluation of performance of real-time and retrospective runs of RR system for SAVs, AHPs.

Now that the 1-h cycle is running more consistently on wJET using version 3 of WPS and WRF and the March 2008 version of GSI, quantitative statistical validation is underway. These statistics confirmed a serious cold bias in the 1-h cycled runs (see FY08 Quarter 3 report) and helped to verify that it has been mostly resolved. Real-time products in the web displays noted above continue to permit qualitative evaluation.

**Deliverables**

**08.5.4.E1** 30 Aug 2008 (GSD)
Have available for delivery to NCEP initial 'experimental level' WRF Rapid Refresh code for start of EMC testing toward 2009 Rapid Refresh implementation.

A tarball with Rapid Refresh (RR) specific elements (GSI, WPS, WRF, WRFpost) has been transferred to NCEP vapor machine to begin experimental RR work at NCEP. Also, with assistance from EMC scientist Yoshi Sato, Ming Hu has been working on a parallel track to get Yoshi's NAM retro cycle scripts running on vapor. Yoshi has generously provided his NAM retrospective infrastructure (code, scripts, etc.), which will provide a reference framework for the NCEP computing environment. Ming's work with the NAM retro scripts benefits both DTC the RR effort (and longer term efforts toward a more unified code structure for the 2012 ensemble Rapid Refresh) as NCEP IBM-specific elements of the NAM scripting and boundary condition processing can be incorporated into the RR cycle on vapor. In particular, Chris Harrop's workflow manager, which is used to coordinate the RR runs at GSD is not supported at NCEP and will be replaced by modified versions of similar procedures used for the NAM at NCEP. Besides Ming, several GSD scientists have obtained accounts on the new NCEP research computer (vapor), where initial NCEP testing of the RR will occur.

**Task 08.5.5 Develop, test, and implement improvements to the operational 3DVAR for WRF Rapid Refresh and WRF NAM.**

**NCEP**
Wan-Shu Wu finished testing the sensitivity of the vertical grid on the forecast model. The vertical grid spacing was set to be similar to that of the global system in NCEP. The impact of where to set the transition level from constant sigma to constant pressure was also examined. Two cases were tested; one was set at 420hPa as in the current operational system and the other was at 70hPa, where the vertical grid in the global system switches to pure constant pressure levels. Even without properly tuned physics, the results from the low resolution NDAS showed that using a vertical-level spacing like that in the global system produced a significant positive impact on the free forecasts. The location of the transition level produced a secondary impact, where the transition level set at 70mb had uniformly better forecasts except for the 300hPa temperatures. The biggest difference between the current and the GFS vertical-level spacing is there are many more levels in the GFS above the jet/tropopause level than in NMM. This will be examined in future tests.

Shun Liu examined the impact of assimilating Build-10 radial wind data with a test case. It appears that the observation-minus-background of new radar data is larger than that of the Build-8 radar data. More work is needed in examining the observation error of Build-10 radial wind data.

Dave Parrish continues work on improving the regional GSI tangent linear normal mode constraint (TLNMC), and has formulated a new solution method. This is based on solving for the normal mode balance increments using a nested multi-grid technique, which in a computationally feasible manner allows any regional domain to be imbedded in a series of successively coarser grids until the coarsest grid covers the entire global domain. The solution is obtained by iterative relaxation and transfer of corrections between grids, with an exact solution obtained spectrally on the coarsest grid. Coding is in progress and should be completed in September.

Manuel Pondeca reports that he has unified the RTMA system so that the same set of executables will work for all NDFD grids of interest – CONUS, Alaska, Hawaii, Puerto Rico and eventually Guam. Operational implementation in all four current domains will be completed by next quarter. He has also started to build a 2.5-km resolution CONUS RTMA, which will someday replace the current 5-km resolution system on the next computer.

**GSD**

Work in August focused on diagnosing the cause of sporadic model crashes due to extreme vertical velocities along the southern boundary of the domain. A cause was identified and tests of a solution are ongoing. Ming Hu traced the problem (in which a build-up of vertical velocities over many hourly cycles would eventually lead to a crash) to large analysis increments along the southern boundary (where the main cordillera of the Andes in Colombia intersects this boundary) to Colombian observations (both METAR and aircraft observations). For these high elevation METAR observations, the problem is compounded by a significant mismatch between the observed and model terrain. We are testing a solution in which the magnitude of the analysis increments is ramped down along a 5 gridpoint wide band along the horizontal boundaries.

Examination of rawinsonde statistical verification for 12-h forecasts from the RR 1-h cycle vs. the operational RUC (for the month of August) continued to indicate temperatures and winds are comparable for RR than RUC except near the tropopause where the RR shows a warm bias and poorer rms difference with RAOBs. There also continues to be a cold bias in RR low-level temperature forecasts. Examination of the 00-h forecast statistics indicates that the GSI is not fitting temperature or moisture observations as closely as the RUC. The assumed errors for the background and observations have not been adjusted for the RR, and we will be considering changes to these values as we continue to monitor the performance of the real-time RR cycle. With assistance from Dennis Keyser and Jack Woolen of NCEP Dezso Devenyi and Ming Hu have completed a capability within the GSI to ingest newly available aircraft observations.

Alaskan regional PenAir TAMDAR observations have been made available for the Rapid Refresh and have been used in real-time since 11 Sept. GSD coordinated the data availability into the Rapid Refresh via MADIS through extensive discussions with NCEP/EMC and NCO over the past 3 weeks.

**08.5.5.1** 31 December 2007 (GSD and CAPS) COMPLETE

Progress report on testing and evaluation of the generalized cloud/hydrometeor assimilation (including GOES cloud-top data and METAR cloud/visibility/weather data) within a cycled GSI on the full Rapid-Refresh domain.

Based on recommendations received from John Derber and Russ Treadon (at a GSD/EMC GSI meeting at NCEP in June), Ming Hu has completed modest modifications to portions of the generalized cloud analysis to conform to specific EMC coding practices (restructuring the I/O, etc.). Following this, an extensive retro test evaluation was completed to ensure that the modified code did not impact the cloud analysis results. A tarball with these changes has been sent to Russ Treadon at EMC for possible inclusion in the next GSI release.

**08.5.5.2** 31 December 2007 (NCEP and GSD)

Report on testing of 2DVAR GSI assimilation of high spatial and temporal mesonet surface data using analysis grids with 5-km or finer resolution.

See discussion above for summary of ongoing work.

**08.5.5.3** 31 January 2008 (NCEP and CAPS)
Further refine the radial velocity analysis component of GSI in response to model resolution changes. Examine data impact at higher assimilation frequencies and higher spatial resolutions. Consider issues on data quality, super-obbing, and optimal de-correlation scales.

**08.5.5.4** 28 February 2008 (GSD)
Report on statistical evaluation of Rapid Refresh forecasts initialized with the GSI, including examination of upper-level winds, surface fields, and precipitation.

See discussion above about ongoing statistical comparisons of the RR 1-h cycle vs. the operational RUC upper-level winds (over the matched CONUS radiosondes stations).

**08.5.5.5** 31 July 2008 (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 use of WSR-88D data and satellite radiances and co-variances) to the WRF-GSI for FY2009 change package to the NAM-WRF.

**08.5.5.E1** 30 March 2008 EMC (Wu, Parrish, Pondeca, Liu)
Subject to NCEP Director approval implement upgrades to WRF-GSI used in NAM/NDAS.

**08.5.5.E2** 30 August 2008 (GSD)
A tarball with Rapid Refresh (RR) elements (including an RR specific version of GSI) has been transferred to NCEP vapor machine to begin experimental RR work at NCEP. As described in milestone 08.5.4.E1, these RR elements will be fused with NCEP IBM specific computing infrastructure (scripts, etc.) to construct the test 1-h cycle environment on the EMC vapor computer. In particular, Chris Harrop's workflow manager, which is used to coordinate the RR runs at GSD is not supported at NCEP and will be replaced by modified versions of similar procedures used for the NAM at NCEP. We are indebted to Yoshi Sato of EMC, who has generously provided his NAM retrospective infrastructure (code, scripts, etc.), which will provide a reference framework for the NCEP computing environment.

**08.5.5.E3** 30 September 2008 EMC (Liu)
Deliver enhancement package for radial velocity data analysis for further implementation testing.

CURRENT EFFORTS:

PLANNED EFFORTS

**Task 08.5.6 Develop, test, and evaluate the performance of the nonhydrostatic Weather Research and Forecasting (WRF) modeling system.**

**NCAR/MMM**
NCAR issued two minor WRF releases, 3.0.1 and 3.0.1.1. Both of these were bug fix releases. Examples of fixes were code to prevent use of the Pleim-Xiu LSM if the user has non-standard numbers of land categories code for the Lin microphysics scheme to define properly the graupel ventilation factor.

Jimy Dudhia of NCAR/MMM developed a fix for the skin temperature calculation in certain cases when using the urban canopy model. This was related to small exchange coefficients that occur in weak winds and was done in collaboration with Mukul Tewari (NCAR/RAL). For a future Noah LSM release, a time-dependent snow albedo capability was added.

Dudhia worked with visitors from the University of Tsukuba (Japan) on aspects of WRF including microphysics, developing code for budgets, and urban modeling. Dudhia also worked with Y.-H. Yang from China and Changhai Liu (NCAR/MMM) on testing WRF PBL schemes and comparison with large-

eddy simulation in idealized PBL growth situations.

These particular physics options are not planned for the Rapid Refresh or HRRR applications of WRF.

**Task 08.5.8: Improve physics in the WRF model, especially that bearing on prediction of aircraft icing.**

**GSD**
The planned 2008 RUC change bundle continues in parallel testing at NCEP (see discussion under Task 08.5.1).

**GSD and DTC**
The test of the impact of changing the vertical distribution of vertical levels in the WRF-ARW was planned and executed in a collaborative effort between GSD and DTC. The particular impacts examined were on forecasts of 2-m temperature and dew point and 10-m wind, as well as low ceiling and visibility. Of particular concern were situations having low-level warm advection over snow-covered ground, a condition that has caused systematic daytime cold biases in 2-m temperature forecasts (subtask 1, below). The hypothesis is that higher resolution in the lowest ~500m above ground will improve these forecasts beyond what has already been achieved by alterations to the RUC LSM (subtask 1). Preliminary indications are that, compared to a more standard WRF-ARW configuration in which the lowest model layer is about 40m thick, over the eastern half of the US the higher resolution near the surface (lowest layer about 15-20m thick) currently being used in the 1-h cycle RR improves the diurnal variation of 2-m temperature and 10m wind. However, the amplitude of the diurnal variation of temperature and wind speed is still too small, i.e., temperature is too cool during the daytime and too warm at night, and winds are too strong at night. Evaluation of these experiments is continuing.

***Subtasks***
**08.5.8.1 31 Dec 2007 (GSD)**

Begin systematic GSD evaluation of physics performance in GSD 1-hour RR cycle and address issues that arise in preparation for 2009 RR implementation. Particular attention will be given to microphysics and interactions between microphysics and the other parameterized physical processes.

Code modifications and testing have begun by GSD to call the microphysics parameterization in the WRF-RR-ARW less frequently, at multiples of the long (non-acoustic) time step. Initial testing in which the microphysics was called every other long time step, and the changes over the single long time step when the microphysics was called were doubled, proved to be not fully satisfactory. Efforts now are going toward computing tendencies for potential temperature and water vapor mixing ratio changes computed in the microphysics, as well as for the hydrometeor types, and saving these tendencies to be applied at each subsequent consecutive time step when the microphysics is not called. As noted under Task 4, this will save some run time (estimated at least 5%) and, based on our experience with RUC, should give similar results to the present procedure of calling microphysics at every long time step. This capability has never been available previously with the WRF-ARW dynamic core, although it has been with the WRF-NNM dynamic core.

Qualitative and quantitative evaluation of the RR cycled runs for physics effects continues. Of particular interest for this time of year is the performance of upper level winds, where similar concerns led to withdrawal of the latest version of the Grell-Devenyi convective scheme in favor of an earlier version for the upcoming RUC change package (Task 1). We will also be exploring possible sources of a remaining small low level cold bias.

Tasks

08.5.8.3 May 2008 (NCAR):

Expand the current one moment microphysical scheme to two moments and add a variable for aerosol particles in order to improve forecasts of freezing drizzle and icing. Computer storage and run time considerations will be considered as a constraint on the development. (NCAR)

A two moment scheme for rain was completed and tested on various cases. This improved scheme is available to ESRL for testing in the WRF Rapid Refresh. We participated in the WMO Cloud Modeling Workshop this July which allowed us to interact with scientists working on the some of the same microphysical modeling issues that we are. In particular, this was useful for planning the implementation of an aerosol scheme into the model. In addition, work continues on the freezing drizzle cases from Cleveland. A paper summarizing these results is in preparation. The results from this paper indicate that the use of a predictive aerosol component of the model can improve the prediction of freezing drizzle.

Deliverables
**08.5.8E3** May 2008: (NCAR)
Improved microphysics scheme to ESRL for evaluation in WRF Rapid Refresh. (NCAR

**08.5.8.5** 31 Mar 2008 (DTC, GSD)
Report on GSD-DTC RR retrospective testing of land-surface model formulations for snow, and, as appropriate, other physics.

See above discussion on the retrospective test of vertical resolution in WRF. These tests were done with a restriction to the rate of snow melt recently introduced into the RUC LSM. Tests with this modification in RUC have shown improved (though still with some cold bias) spring-season daytime temperature forecasts over snow cover

**Task 08.5.15: Develop improved methods of cloud and moisture analysis for use in the WRF Modeling System.**

***Subtasks***

**08.5.15.1** 31 October 2007 (NCEP)
Based on parallel testing and refinement of the experimental code, deliver the 'pre- implementation' code to NCO including improved diabatic initialization (e.g. nudging to analyzed precipitation and GOES cloud-top) for the March 2008 NAM change package.

**08.5.15.2** 30 Jan 2008 (GSD) COMPLETE
Develop and evaluate performance of diabatic digital filter initialization (DDFI) in the RR WRF model without use of radar data

Although this was reported as complete in previous months, we note that this work was described in a paper by Steven Peckham, Tanya Smirnova, Stan Benjamin, John Brown (all from ESRL/GSD), and NCAR/MMM colleagues at the 9th Annual WRF Workshop in late June (go to paper 1.3) . An issue with the DDFI occasionally causing the RR 1-h cycle to crash was recently isolated and resolved, by shortening the time-step in the backward integration

**08.5.15.3** 30 March 2008 (GSD and CAPS)
Further refine the generalized cloud analysis for the target RR resolution, model physics scheme and use of additional data. Perform forecast test evaluations to document the impact of the cloud analysis refinements.

Ming Hu introduced the generalized cloud analysis into the latest GSI version (March 31, 2008) and has conducted systematic tests within the RR retrospective test environment. This version is now running in the RR 1-h cycle at GSD. Ming Hu has completed modest modifications to portions of the generalized cloud analysis to conform to specific EMC coding practices (restructuring the I/O, etc.). Following this, an extensive retro test evaluation was completed to ensure that the modified code did not impact the cloud analysis results. A tarball with these changes has been sent to Russ Treadon at EMC for possible

inclusion in the next GSI release.

**08.5.15.4** 30 May 2008 (NCEP)
Based on development efforts, deliver 'research quality' diabatic initialization upgrades (e.g. initial use of Level II reflectivity) for consideration in the March 2009 change package for NAM.

**08.5.15.5** 30 Mar 2008 (GSD)
Include radar reflectivity-based latent heating within diabatic digital filter initialization (DDFI) in the RR WRF model.
The components for RR reflectivity assimilation are in place with the release of WRF version 3 including diabatic digital filter initialization and cloud analysis capability within GSI (upgraded to latest GSI version during the quarter). Testing and refinement of DDFI within 1-h cycle and of various cloud analysis options (including reflectivity assimilation) continue. An option to use a shorter time step during the DFI has been implemented to prevent sporadic crashes during the backward portion of the DFI. However, this option apparently will not be needed, as an unrelated cause for the crashes has identified (see task 08.5.4)

**08.5.15.6** 30 July 2008 (NCEP)
Based on case-study testing and refinement of the research quality code, an 'experimental' WRF code is delivered with diabatic initialization upgrades (e.g. initial use of Level II reflectivity) for the March 2008 change package for NAM.

**Deliverables**

**08.5.15.E1** 30 March 2008 (NCEP)
Subject to NCEP Director approval, the WRF-NMM code with upgraded diabatic initialization capability (e.g. nudging to analyzed precipitation and GOES cloud-top) becomes operational at NCEP as part of the March 2008 change package to NAM.

**08.5.15.E2** 30 Aug 2008 (GSD)
Complete testing of GSI generalized cloud analysis for Rapid Refresh and deliver code to NCEP as part of Rapid Refresh package delivered to EMC, pending availability of NCEP testing capability.

Ming Hu introduced the generalized cloud analysis into the latest GSI version (March 31, 2008) and has conducted systematic tests within the RR retrospective test environment. This version is now running in the RR 1-h cycle at GSD. Ming Hu has completed modest modifications to portions of the generalized cloud analysis to conform to specific EMC coding practices (restructuring the I/O, etc.). Following this, an extensive retro test evaluation was completed to ensure that the modified code did not impact the cloud analysis results. A tarball with Rapid Refresh (RR) elements (including an RR specific version of GSI with the cloud analysis code) has been transferred to NCEP vapor machine to begin experimental RR work at NCEP. In addition, a tarball with these changes has been sent to Russ Treadon at EMC for possible inclusion in the next GSI release.

**Task 08.5.17 Infrastructure support for running operational WRF model in RR, North American Mesoscale and HiResWindow modes at NCEP.**

**NCEP**
Dennis Keyser reports that there appears to be an improvement in the receipt of some of the Alaskan radiosonde data, as sites like Shemya (70414) are now usually available before the NAM data cutoff. NCEP contacted Alaska in late winter about this issue, but there is still a need for some sites to move their launch time so their data can be received in time for the NAM-GSI. This will also benefit the Rapid Refresh. Since the beginning of April, Level II reflectivity (and radial wind) data from an increasing number (at least 100) WSR-88D radar sites are unavailable due to their switch from Build 8 to Build 10 software and the inability of NSSL's qc code to deal with the super-res format of Build 10. Level 2.5 winds are used when Level 2 winds are unavailable. NCEP/NCO has submitted a Request For Change (RFC) to implement a recombination code which will ingest these data and convert them back to a Build-8 look-alike format. During at least three periods since the last half of July, some Level 2.5 radial wind

superobs have been unavailable to the NAM-GSI due to corrupted input files leading to errors in the uncompression code (NCO is investigating). Since early May, AIRS radiance data counts have been lower than average due to late posting of files associated with hardware issues with NESDIS' processing machines. This should improve later this year when NESDIS ports their AIRS system to new Linux machines. AIRS AMSU-A radiances have not been available to the NAM-GSI since mid-April when AMSU-A channel 4 went bad. Efforts are underway to modify the GSI to allow the remaining AMSU-A channel data to be used. Some radiosondes are not receiving the proper instrument type due to obsolete entries in the NCEP/NCO upper-air dictionary. NCO has filed an RFC to correct this and it should be implemented as soon as critical weather ends. The following data types are now monitored by the NAM-GSI: RASS virtual temperature profiles, QuikSCAT 0.5 deg. scatterometer wind superobs, TAMDAR (via ESRL MADIS feed) and Canadian AMDAR aircraft temperature and wind. Efforts to speed up the dump processing of NEXRAD Level II data are being explored. Cooperative Agency Profiler (CAP) and RASS data are not yet available through an alternate ESRL MADIS feed.

Eric Rogers reports that the testing of model/analysis modifications for the Fall 2008 NAM change package continues. WRF-NMM model changes being tested which address model biases include changes to the radiation parameterization (doubling the absorption coefficients for water and ice), changes to the land-surface physics, and changes to vertically mix and diffuse each hydrometeor species separately. Assimilation/analysis changes include a new version of the GSI analysis, assimilation of TAMDAR/Canadian AMDAR/METOP2 data, and "partial" cycling (using GDAS atmospheric first guess for the first GSI analysis in each NDAS cycle). Changes to the shallow convection parameterization were dropped on the advice of NCEP's Storm Prediction Center due to adverse impact on NAM forecasts of Convective Available Potential Energy. This bundle was successfully briefed to the EMC Change Control Board on 4 September and RFC's submitted the next day.

Shun Liu continued working with NCO to test radar build-10 data decoder and super-resolution data recombination algorithm and he is also working with NCO to setup and verify NCO's parallel run. It is found about ten percent of radar data are not processed in NCO's parallel. The reason is under investigation.

***Subtasks***

**08.5.17.1** Maintain four-per-day North American Mesoscale runs and provide SAV and AIV guidance.

**08.5.17.2** Maintain four-per-day HiRes Window runs and provide SAV and AIV guidance.

**08.5.17.3** Provide vendors with gridded NAM model data via Family of Services and the FAA Bulk Weather Data Telecommunications Gateway.

**08.5.17.4** Provide full grids from NAM, and the HiRes Window on NCEP and NWS/OPS servers.

**08.5.17.5** Maintain access to model verification data. (see subtask report under Task 08.5.1.4)

**08.5.17.6** Provide assistance to Inflight Icing, Turbulence, Convective Weather, Ceiling and Visibility and Oceanic Weather PDTs when their algorithms and product generation systems are ready to transition into NCEP's operational Production suite.

***Deliverables***

**08.5.17.E1** 1 October 2007 - 30 September 2008 **EMC** (Parrish, Derber, Wu, Keyser)
Perform observation ingest, quality control and preparation in support of the operational North American Mesoscale WRF runs.

CURRENT EFFORTS:

PLANNED EFFORTS:

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED:

INTERFACE WITH OTHER ORGANIZATIONS: GSD & NCO.

UPDATES TO SCHEDULE:

**08.5.17.E2** 1 October 2007 - 30 September 2008 **EMC** (Parrish, Derber, Wu, Keyser)
As requested by other PDT's, incorporate new AIV calculations into Operational WRF Model post-processor and product generator.

CURRENT EFFORTS:

PLANNED EFFORTS:

PROBLEMS / ISSUES ENCOUNTERED OR ANTICIPATED: None

INTERFACE WITH OTHER ORGANIZATIONS: NESDIS, GSD & NCO

UPDATES TO SCHEDULE:

**Task 08.5.19: Develop ability to assimilate WSR-88D radial velocity and reflectivity data through GSI and Rapid Refresh toward High-Resolution Rapid Refresh.**

**GSD**
HRRR forecasts continue to benefit from changes made in early June to initialize the HRRR directly from the RUC DFI-initialized grids. Previously, the HRRR was initialized from RUC analysis grids which resulted in the use of older reflectivity data (because the radar assimilation is applied within the DFI portion of the RUC model, which occurs after the analysis). This change has significantly improved the effective radar reflectivity assimilation for the HRRR. This was possible only after a redesign of the RUC post-processing and scripts (see 5.19.E1 text).

Currently, the RUC-DFI data is only available from the GSD "development-13" experimental RUC, not the "backup-13" RUC generally made available to outside users. A transfer to the backup RUC has started but not completed for the code and script changes required for output of the RUC-DFI grids (also valid at 00h but requiring a number of changes to avoid confusion with the different RUC analysis grids, also valid at 00h).

Ongoing monitoring of the HRRR runs with this enhancement continues to indicate that the HRRR forecasts with the direct use of the DFI-initialized RUC grids depict well the evolution of ongoing convection. Analysis of quantitative reflectivity verification statistics (produced by Barry Schwartz, see more details on 08.5.24) confirm the HRRR forecast improvement from the RUC radar assimilation and shed light on important diurnal and scale factors in the forecast improvement.

***Subtasks***

**08.5.19.1** 30 May 2008 (GSD, NCAR/RAL, CAPS)
Select initial case studies from 2007 and 2008 for 3-km HRRR data assimilation case studies.

For the summer 2008, we have initially focused on several days, including the first week of June, June 27, July 10, and 20-23 July 2008. Also, MIT/LL has compiled a comprehensive list of key days from the summer 2008 season, including a summary of the operational status of each components of the test CoSPA system.

08.5.19.2 31 August 2008 NCAR-RAL

Run case studies using 3km HRRR using different RUC-based initial conditions

- Run case studies from spring/summer 2008 using 3-km HRRR on GSD jet computer using different RUC-based initial conditions
  - Operational RUC (without radar reflectivity assimilation)
  - Radar-DFI enhanced RUC (probably from GSD)
  - Radar-DFI RUC using unsmoothed latent heating
  - Test of 3-km radar-DFI when code ready from GSD
- Use Northeast US Corridor domain for HRRR runs as used at GSD.
- Provide detailed report on case studies by 15 Sept 08

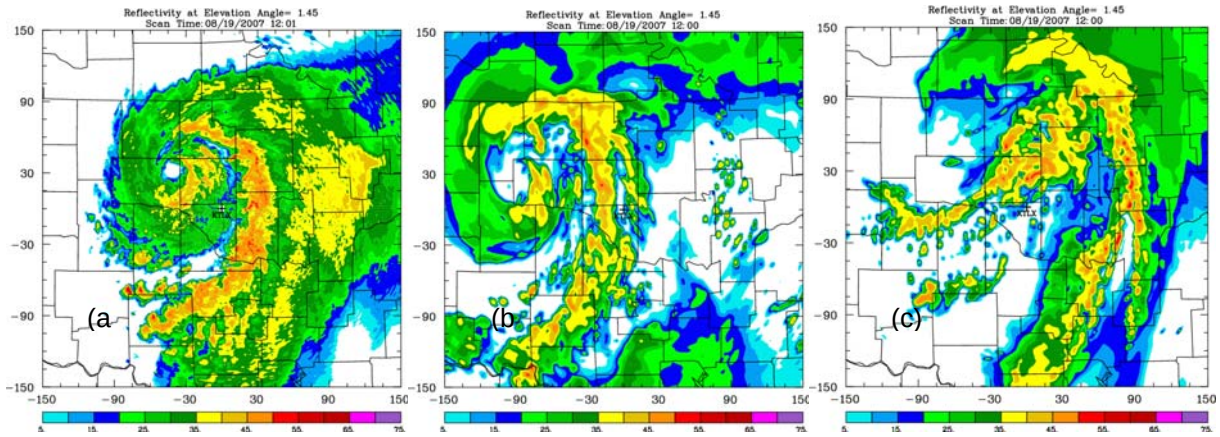
Quantitative reflectivity verification of real-time (3-hourly) runs of the HRRR from the GSD experimental RUC (with radar data assimilation) and the NCEP operational RUC (without radar data assimilation) indicate significant forecast improvement for the radar assimilating RUC-based HRRR. Based on evaluation of the verification statistics and case studies, we are beginning to understand the diurnal aspect to the forecast improvement and important characteristics relating to the spatial character of the convection.

**08.5.19** 31 August 2008 (CAPS)
Complete 3-km GSI data assimilation experiments for potential application within the HRRR assimilating radial wind. Evaluate impact using 3-km HRRR-WRF model configuration as used by GSD.

At CAPS, Dr. Aimei Shao, using WRF 2.1 and an earlier version of GSI, completed a series of 3-km assimilation and forecast experiments with 30-min assimilating cycles for up to 6 hours to evaluate the combined or individual impact of radar radial velocity and reflectivity data on the forecast of Tropical Storm Erin. The results show that both variational radial velocity assimilation and reflectivity assimilation via cloud analysis have positive impact. Radial velocity and reflectivity combined produce the best results.

One-km resolution two-way nested-grid forecasts were conducted in which 3-km analyses at 00, 02, 04, 06 UTC were used as initial condition, corresponding to 0, 2, 4 and 6-hour long assimilation windows including radar data, respectively. The predicted position and intensity of the vortex center are in general agreement with 3 km forecasts started at the same time, with the main differences being in the detailed structure of spiral rain bands. The precipitation amounts from the two grids are generally similar, and both over-predict the maximum amount, which is a common problem with explicit QPF at few kilometer resolutions.

For comparison purpose, nested 3- and 1-km forecasts are made, using the 0000 UTC NAM analysis as initial condition. Six-hour forecast from the 1 km grid valid at 1200 UTC is shown in panel (c) of Figure, which is compared to the forecast starting from the initial condition with a 6-hour assimilation window (b) and to observation (a). The reflectivity fields have been projected to the 1.45° elevation of the Oklahoma City radar for direct verification. Clearly, the forecast with radar assimilation is much better. Further quantitative verification is underway.



elevation (a), and the corresponding reflectivity from forecast with 6-hour assimilation (b) and no radar assimilation (c).

New CAPS scientist, Dr. Yi Yang, repeated the experiments of Aimei Shao with the newly released WRF version 3.0.1.1 and the latest version of GSI, and using RUC instead of NAM analyses as the analysis background and boundary conditions. Radar data are again assimilated at 30-min intervals for up to 6 hours.

The forecasts obtained are of similar quality as the NAM-based forecasts but there is a tendency for the vortex using the NAM analyses to propagate a little slower while that using RUC analyses to propagate a little faster than observed. There is also sensitivity to model microphysics. Further investigation is being made.

Remaining problems needing investigation include the apparently ineffectiveness of the analysis system in removing spurious rain bands in the forecast background, which is not surprising for the given analysis system. Efforts are being made to see if more frequent (~5 to 10 minutes) analysis cycles, over perhaps a shorter window, can prevent spurious rain bands from developing.

**08.5.19.4** 30 Sept 2008 (GSD)

- Develop new stand-alone 3-km processor from raw 3-d reflectivity tiles to 3-km HRRR domain, similar to software developed for 13-km RUC
- Develop and test code at 3-km for assimilation of radar reflectivity using observation-based specification of latent heating within WRF-DFI.

**Deliverable**

**08.5.19.E1** GSD, CAPS, NCAR-RAL 30 Sept 2008
Complete improved version of 13km/3km radar assimilation techniques for demonstration in FY09 exercises.

In the spring, GSD modified several components in the RUC processing to allow direct output and post-processing of DFI-initialized grids. While we do not advocate use of these grids as RUC analyzed fields for aviation and other user applications, it did allow tests to initialize the HRRR model with the DFI grids including the latest radar reflectivity instead of the RUC analyzed grids, which effectively does not. These tests were finally performed in early June and showed a significant improvement in 1h-6h forecasts in 3 different case studies. Based on these results, this variation in the HRRR (using RUC-DFI-radar initial conditions immediately after DFI) was implemented into the real-time HRRR runs. Thus, this new modification is now affecting HRRR grids ftp'd to NCAR and MIT/LL.

VIL output at 15-min frequency is now available from a real-time HRRR web site at http://ruc.noaa.gov/hrrr/vil. This is the first time that any RUC/RR/HRRR graphical products have been available at a 15-min output frequency.

**Task 08.5.20: Develop ensemble-based probabilistic products for aviation users.**
**UNFUNDED**

**Task 08.5.24**

***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.***

Subtasks
**08.5.24.1** 30 September 2008 (GSD, NCAR/RAL, NCAR/MMM)

Conduct HRRR summer exercise. Collaborate on analysis on HRRR tests. Draft and deliver summary of results.

Real-time ftp transfer of HRRR grids to NCAR and MIT/LL since mid April. VIL fields with 15-min output added to HRRR grids and also ftp'd to NCAR (accomplished in mid-May). Modification made to HRRR scripts to speed up processing time by 1 hour, resulting in improved HRRR guidance. In order to do this, the backup RUC was changed to run out to 13h (instead of 12h) on an hourly basis, so that each HRRR run can be started as soon as the new RUC analysis (or post-DFI) file is available, using lateral boundary conditions (BCs) from the *previous* RUC forecast. This trade-off in using older (less accurate) BCs was considered acceptable to get the new HRRR forecast out 45-60 min faster.

A second, very important change to the HRRR initialization procedure was made in June to directly use the RUC DFI-initialized grids. Previously, grids from the RUC 3DVAR (containing older radar information) were used to initialize the HRRR. This change (which required a redesign of the RUC post-processing and scripts -- see 5.19.E1 text) has significantly improved the effective radar reflectivity assimilation for the HRRR.

More recently, a new HRRR reflectivity "matrix" web-page has been created that allows the users to quickly view the HRRR reflectivity fields for multiple forecast times and multiple initialization times. The page can be found at: http://ruc.noaa.gov/hrrr/reflectivity.cgi

Additional minor changes have been made by Tanya Smirnova to make the HRRR runs more reliable and to improve the runtime. GSD continues to interact many times per week with MIT/LL and NCAR on the HRRR contribution to the CoSPA real-time 0-6h forecasts. GSD keeps the CoSPA partners abreast of changes in HRRR processing and computer availability.

Additional improvement to speed up processing of RUC radar assimilation fields used to drive the HRRR, resulting in further substantial improvement in the HRRR. Real-time verification of HRRR reflectivity forecasts is ongoing. Real-time monitoring of HRRR forecasts has revealed some issues related to the limited HRRR domain size and propagation of convective systems into the HRRR domain

Barry Schwartz coded up a reflectivity verification package, which ran for much of the summer and has provided invaluable information for diagnosing HRRR model performance and understanding aspects of the convective predictability problem. As expected, statistical verification of forecast reflectivity for the HRRR initialized with the RUC DFI fields vs. a corresponding 3-km grid initialized from the operational RUC (with no radar assimilation) indicates a significant forecast improvement in the HRRR from the radar assimilation on the parent RUC grid. Improvement is greatest for short-range forecasts (3-h and 6-h), but extends out to 12-h (even in average statistics) for certain times of the day. Analysis of the statistics continues and we are evaluating the relationship between reflectivity forecast skills, the diurnal cycle of convection and the scale of observed and assimilated convection.

**5.24.2** NCAR-MMM

Evaluate HRRR forecasts with different initializations using GSD HRRR runs

- Compare 3-km HRRR forecasts using initial conditions from 2 versions of the RUC: radar-enhanced RUC from GSD, no-radar RUC from NCEP.
- All HRRR runs performed at GSD, from spring/summer 2008
- Perform analysis of evolution of convective storm mode during first 1-3 hours of model transition from effective resolution 13-km to actual 3-km resolution.

**Deliverables**

**08.5.24.E1** 30 August 2008 (NOAA/ESRL/GSD)

Complete FY08 test with small Northeast U.S. domain with 3-km High-Resolution Rapid Refresh running every 1 h.

- Conduct real-time summer 2008 HRRR forecasts using 3-km WRF initialized with radar-enhanced RUC over Northeast US Corridor domain

- Coordinate with other AWRP users and other collaborators
- Provide project management
- Lead writing of report on summer 2008 HRRR experiments

Summer 2008 HRRR demonstration test completed successfully in collaboration with CoSPA partners (NCAR, MIT/LL). Much learned from synergistic effort. Recent work at GSD to evaluate statistical reflectivity verification leading to new insights on radar data assimilation benefits related to the diurnal cycle of convection and the horizontal scale of convection.

(See subtask 08.5.24.1)

**08.5.24.E2** 30 September 2008 (NCAR/RAP and NCAR/MMM)

Collaborate with GSD on analysis of results. Draft and deliver summary of results. Evaluate techniques for convection-resolving (e.g., 3-km) forecasting by the Rapid Refresh (ARW core) in preparation for development of high-resolution RR (HRRR). Perform and evaluate RR convection-resolving forecasts on test cases using radar-enhanced RUC or Rapid Refresh grids from GSD to identify strengths and weakness of model at high resolution. Evaluate effects of transition from 13-km parameterized convection to 3-km resolved convection in 0-3h forecasts and in lateral boundary conditions from the RUC or Rapid Refresh using the Grell-Devenyi parameterization.

See 08.5.24.E1 for discussion of preliminary analysis of results