**MDE Product Development Team**
**April Monthly Report – FY 2011**
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*(Compiled and edited by S. Benjamin and B. Johnson)*

## Executive Summary

**Task 11.5.1: Infrastructure support related to operational running of the RUC and NAM operational modeling systems.**

- Problems noted in two cases by RUC users about 2m temperatures. Investigations showed that this was related to excessive springtime snow cover in the RUC, and also that the Rapid Refresh was giving much improved results in these cases.

**Task 11.5.4 Develop, test, and implement Rapid Refresh configuration of the WRF modeling system.**

- *The RR run at ESRL/GSD and the real-time parallel RR at EMC continue to show improvement for the April period over RUC for precipitation, reflectivity, wind, temperature, RH, and height*
- *RUC-look-alike files from the RR continue to be produced to allow easy transition from RUC to the RR.*
- *ftp access continues for these grids from RR running at NCEP-EMC, evaluation of RR-NCEP-EMC continues.*
- *Planned date for RR implementation at NCEP - Sept 2011.*
- *Bug found, solved, and fixed (in early April) in WRF-DFI for cloud/hydrometeor/RH analysis.*

**Task 11.5.5: Develop, test, and implement 3DVARs for RR and NAM**

- Rapid Refresh testing of recently added observations (PBL profilers, Alaska Airlines aircraft reports, TAMDAR aircraft moisture observations, radial winds from WSR-88D profilers) was performed. A new QC algorithm was added for the PBL profilers. A parallel cycle showed some forecast degradation from inclusion of radial winds and it was decided to not include these observations in the operational Rapid Refresh until improved QC techniques were developed.
- Work continues to evaluate value added from radiance assimilation in RR (via GSI) including assessment of bias correction by channel for AMSU data.

**Task 11.5.15: Develop methods for improved cloud/hydrometeor analysis in RR**

- RR using GSI cloud analysis yielding significant improvement in short-range ceiling and visibility forecasts over those from the RUC.
- Testing continued with the RR with variations on specification of hydrometeors; one result was a correction to the reflectivity-snow algorithm used in GSI radar processing.

**Task 11.5.24: Development/testing of HRRR**

- On 14 April, the parent model for the HRRR was changed from the RUC (run at ESRL) to the Rapid Refresh (version also run at ESRL). Many experiments were completed from a 10-day July 2010 HRRR retrospective case study period that justified this change.
- Tests of 3-km DFI-radar assimilation in HRRR indicate forecast improvement for first hour but not beyond that, so no 3km radar assimilation will be used this summer.

**Task 11.5.1 Infrastructure Support Related to Operational running of the non-WRF Rapid Update Cycle System in NCEP Operations**

**ESRL/GSD**
Operational RUC at NCEP has continued to run at 100% reliability since coordinate fix on 17 Nov 2010.

In April, reports were received by GSD from Storm Prediction Center and NWS offices on intermittently too cold 2m temp forecasts from RUC in certain regions. These cases were investigated for both the NCEP RUC and the ESRL parallel RUCs – problems were confirmed and linked to snow cover areas. It was also found that the Rapid Refresh provided much better forecasts, related to assimilation and model differences in the RR. This is discussed more under Task 5.4. (Reported last month).

ESRL continues to monitor operational RUC (and two ESRL versions of RUC with some differences in radar and cloud assimilation). This evaluation is now especially important since it allows a benchmark for the parallel Rapid Refresh comparisons. Performance of the operational RUC is monitored at both ESRL and NCEP verification websites (see **http://ruc.noaa.gov/stats**). Inter-comparison of verification between the NCEP and ESRL versions of the RUC continue to be monitored by ESRL, also at **http://ruc.noaa.gov/stats**.

ESRL and NCEP/EMC also both tested use of a combined RUC/Rapid Refresh observational (prepBUFR) files, both successfully running the RUC pre-analysis program. These tests are preparing for eliminating one of the NCEP prepBUFR "dumps".

**NCEP**
The NRL-based aircraft QC code package was submitted to NCO on 18 March for expected implementation late in FY11. It includes quality controlled high vertical-resolution aircraft profile data near airports, with the nearest METAR report providing the surface level. Memory issues developed during testing and a solution is being worked on. Several erroneous AIREP aircraft waypoint locations were found, corrected and are currently being tested for implementation in May. Work continues on late arrival of GOES 1x1 field-of-view cloud data; bringing in new SSM/IS data from DMSP F-16, F-17 and F-18 satellites to replace discontinued SSM/I products; use of TAMDAR data from AirDAT as a MADIS alternative. The Florida and Georgia mesonet providers remained down. The Wisconsin DOT mesonet provider was down for the first half of April. The Aberdeen PG mesonet provider has been down since 24 April. There was a 5-hour outage of all mesonet data on 20 April due to a line problem. GOES-13 cloud and precipitable water retrievals have not been used since the switch to GOES-13 in April 2010. (Dennis Keyser)

No infrastructure support was needed by the operational RUC in April. (Geoff Manikin)

**Task 11.5.17 Infrastructure support for operational running of Rapid Refresh, North American Mesoscale, and HiResWindow (and future HRRR) at NCEP, including support for community WRF model**

**ESRL/GSD**
Progress in Rapid Refresh development toward operational implementation at NCEP planned for Sept 2011 can be found under Task 5.4 report.

Regarding the WRF model, ESRL is testing variations to the MYNN PBL scheme inserting the alternative Bougeault-LaCarrere mixing length formulation, including discussions with the MYNN scheme developers. It is likely that this will be submitted to the WRF repository in the next few months.

**NCEP**
The parallel test of the NEMS/NMMB model in the EMC NAM parallel system continues on the CCS. The run consists of a 12 km parent domain (same as current NAM) with all model and analysis changes that will be implemented into operations. Inside the 12 km parent domain are four high-resolution nested domains (4 km CONUS, 6 km Alaska, 3 km Hawaii, 3 km Puerto Rico) that run from 0-60 h, and a placeable fire weather nest within either the CONUS or Alaska nest at 1.33 km or 1.5 km resolution that runs from 0-36 hrs. (Eric Rogers)

During April final changes were made to add output fields needed for downstream applications. Working with Julia Zhu, in April the codes and scripts were optimized for use in production and the entire package was handed over to NCO for pre-implementation testing. (Eric Rogers)

NCEP generates experimental Rapid Refresh (RR) PrepBUFR files containing WindSat data (non-superob) and 50 km ASCAT that are copied to a private ESRL directory on the NCEP ftpprd server. These PrepBUFR files are now generated using the new NRL-based aircraft QC code and no longer flag MDCRS and TAMDAR moisture. RR dumps of Level 2 and expanded (time-window) Level 2.5/3 88D radial wind data, and GOES single-pixel cloud data from NASA/Langley (covering Alaska) are also copied to a public ftp directory. These plus early (T+0:26 minute) parallel dumps for 0000 and 1200 UTC are being tested in ESRL's experimental RR runs and the RR parallel being run at NCEP. A connection issue delayed the posting of Langley cloud data on the ftpprd server on 14 April. NAM data impact tests have been performed (Wan-Shu Wu) on Multi-Agency Profiler winds and METOP-2. Testing was also done on filling out RAOB profiles between significant levels. New VAD winds from Shun Liu's processing, RARS radiances (RARS parallel dumps are being generated) and "tcvitals" records for tropical cyclones will be tested next. EMC and GSD requested the Radar Operations Center (ROC) start their hourly processing of Level 2.5 88D data 25-30 minutes earlier for the RR, as it's the only available radial wind data for the Alaska portion of the expanded RR domain. A request for a 5th hourly ingest of Level 2 88D radar data was made to NCO. The ROC has been contacted a decrease in the amount of Level 2 and Level 2.5 (locally-generated superobs) data arriving since December 2010. A new site software build has limited Level 2.5 data collection to only 26 sites. The Level 2 data are only being collected at 140 sites (cause under investigation). A new set of Alaskan MDCRS reports were assimilated starting 8 April after ARINC removed problematic lowest level reports. (Dennis Keyser)

Most of the issues in Task 11.5.1 also affect the NAM. An instrument problem caused the loss of METOP-2 polar satellite data (all instruments) for seven hours on 1 April. Occasional gaps in GOES data around 0600 UTC from the spring eclipse season continue. GOES-13 radiances are monitored but will not be used until the next NAM update. The set points in the sounder/imager patch for GOES-12 and GOES-13 were changed by NESDIS on 7 April and 13 April, respectively, which increases their bias in the GSI. NOAA-18 has on-going gyro issues that could lead to unusable products. On 16-17 April, NESDIS engineers conducted the last 24-hour test where the corrupted navigation data was not sent to NCEP. There was a 16 hour outage of NOAA-17 AMSU-A and AMSU–B data on 20 April. NCEP will stop pulling NOAA-15 AMSU-B data from NESDIS DDS because the data is bad from an antenna problem on 28 March. The following data types are monitored by the NAM-GSI: RASS virtual temperature profiles (NPN and MAP), MAP wind profiles below 400 mb, Mesonet mass data, AIRS AMSU-A radiances, NOAA-19 HIRS-4/AMSU-A/MHS radiances, METOP IASI radiances, ASCAT and WindSAT winds, and MDCRS moisture data. All but RASS of these are being tested in Eric Rogers' NAM parallel. Ten meter wind speed from JASON-1 and -2 altimetry data will soon be monitored. NAM/NDAS and RTMA PrepBUFR files are being generated in parallel with 50 km ASCAT and WindSat scatterometer wind data (both non-superob). The NAM/NDAS PrepBUFR files are using the new NRL-based aircraft QC code. Production NAM/NDAS dumps of METOP IASI radiances, GPS-RO data and SBUV-2 data are being created and dumps of RARS 1c radiances are being created in parallel. Use of the GFS tropical cyclone relocation procedure (for medium to strong tropical cyclones) to update the global first guess fields input to NDAS is also being tested in parallel. A legacy restriction (that only surface data with a reported station or sea-level pressure is processed) will be removed to allow additional surface observations (land, marine and Mesonet) to be assimilated in the RTMA and possibly the NAM/NDAS. This is now being tested in the RTMA. (Dennis Keyser)

Debugging of the whole CIP software package has been completed and it can now run on CCS with the datasets provided by AWC. Work continues on obtaining and ingesting the equivalent datasets available at NCEP. Some WAFS mountain wave cases were run and some issues uncovered. It's most likely that there is a unit difference between the UK Met Office and NCEP in the factors used to calculate mountain wave predictors. (Yali Mao)

For the upcoming SREF implementation, the WRF version 3.3 (ARW core), was modified to be able to ingest binary files from the WRF Preprocessing System (WPS). With this change, all WRF processing can be done using binary rather than netCDF formatted data, which is preferred in NCEP operations to avoid the performance overhead associated with large netCDF files. The WRF version 3.3 release of the NMM core already included this binary ingest capability. (Matt Pyle)

**NCAR**
CURRENT EFFORTS: NCAR released WRF Version 3.3. This contains a number of new features, parameterizations, and bugfixes. A description of the release and its features may be found at **http://www.mmm.ucar.edu/wrf/users/wrfv3.3/updates-3.3.html**. WRFDA V3.3 was also released.

NCAR continued planning for the next WRF Users' Workshop, which will be held June 20-24, 2011 at NCAR. The workshop will feature the usual modeling topic areas during the week and instructional lectures on the final day. NCAR gave a WRF tutorial in Korea the week of April 11th as part of the 5th East Asia WRF Workshop and Tutorial.

Jimy Dudhia of NCAR/MMM worked with Wei Wang (NCAR/MMM) and Ming Chen (NCAR/MMM) on comparison studies of the eight cumulus schemes now available in WRF Version 3.3. The preliminary results were presented to the NCAR Convection Working Group in a seminar. The new cumulus schemes include those currently operational in HWRF (Hurricane WRF), the GFS (global) model, and the CESM (climate) model. The NCAR testing involved a 12-km US grid and a 27-km tropical western Pacific grid. No clear performance leader has emerged thus far.

PLANNED EFFORTS: The development and implementation of new physics for WRF will continue through FY11Q3.

UPDATES TO SCHEDULE: NONE

## Task 11.5.4 Develop, test, implement, and improve the Rapid Refresh

**ESRL/GSD**
The implementation of the RR at ESRL is becoming more and more locked in for the planned date in September 2011.

With the resolution of two serious intertwined issues with RR performance during the previous quarter, as reported in the MDE FY2011Q2 report, efforts this month were mainly toward continued evaluation of RR performance, both at GSD and at NCEP. These have led to some minor adjustments in the GSI cloud analysis to improve consistency in the impact of radar observations on the introduction or clearing of snow hydrometeors. These changes have been passed on to NCEP and are being evaluated there as well as at GSD.

Version 3.3 of the Weather Research and Forecast model, Advanced Research (NCAR) version (WRF-ARW) was released on 6 April. We considered switching to this newer version, but decided against this because the freeze dates for both the RR and HRRR were too close at hand, and many of the upgrades to v3.2 of relevance to the RR and HRRR had already been incorporated into our extended WRF V3.2 code. This includes the V3.2 version of the Thompson microphysics with known bugs removed.

The Request For Change (RFC) to replace the RUC code with the Rapid Refresh Code is planned for submission to NCEP Central Operations (NCO) in the first week of June (by Geoff Manikin of NCEP/EMC). We expect the RFC to be approved, with the condition of a satisfactory outcome to the evaluation of the RR by other NCEP centers (especially AWC and SPC) and the National Weather Service regional headquarters offices this summer. Accordingly, no further code transfers to NCEP are planned.

A change log on the ESRL primary and development RR 1h cycles is maintained at **http://ruc.noaa.gov/internal/RR_runs/RR_1h_info.txt**.

Two abstracts providing updates and status of RR development were submitted to the 15th Conference on Aviation, Range and Aerospace Meteorology to be held in Los Angeles in August.

***Subtasks***

**11.5.4.1 Ongoing (GSD, NCEP)**
**Ongoing evaluation of performance of real-time and retrospective runs of RR system for SAVs, AHPs**

**NCEP**
The Rapid Refresh (RR) has been running stably in an EMC parallel environment with only minor code changes since December. Final changes were made in April to improve model handling of snow cover; this had been causing some localized problems with temperatures. Statistical evaluation has shown that the Rapid Refresh is now at least comparable to the RUC for most parameters, with significant improvement shown for upper level wind and height fields. Grib1 and Grib2 as well as station time series BUFR data files have been made available to the FAA, the NCEP service centers, and other RUC users on an FTP site, and informal evaluation of the model analyses and forecasts is underway. Special work has been done with several FAA groups to ensure a seamless transition when the RR replaces the RUC, with a wide variety of test files provided. RR implementation is currently scheduled for September. (Geoff Manikin)

See extensive observation processing work by EMC's Dennis Keyser in support of RR under Tasks 11.5.1 and 11.5.17.

**11.5.4.2 1 Nov 2010 (GSD)**

**Solicit and respond to input from RR forecast users (e.g., FAA, AWC, SPC, NWS, other users), as well as AWRP RTs, on performance of Rapid Refresh.**

ESRL continues to hold RR-status telecons for FAA and AWC colleagues every 4-5 weeks (last on 5/12/2011). All feedback from the other PDTs has been positive. This evaluation has been made possible by the availability of pgrb, sgrb and bgrb files for the RR in GRIB1 from the EMC test RR cycle output.

The Storm Prediction Center has begun to evaluate BUFR sounding output from the EMC RR test cycle (from both analyses and forecasts) as compared to the RUC. The SPC forecasters use both analysis and forecast soundings extensively as part of their decision process on whether developing weather conditions warrant issuing severe thunderstorm and tornado watches.

**Task 11.5.5 Develop, test, and implement improvements to the operational data assimilation supporting Rapid Refresh and North American Mesoscale runs**

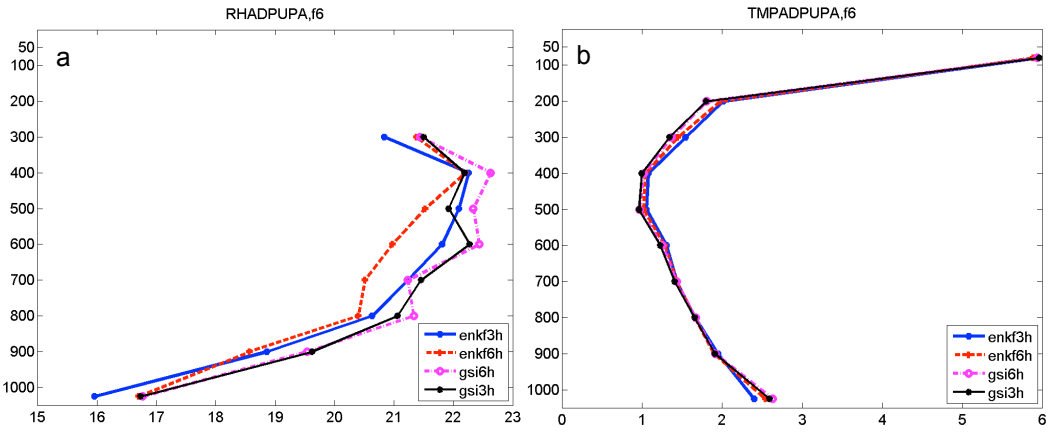
**ESRL/GSD**
A few minor additional changes were made to GSI for RR. These include adding and testing code created by Wan-Shu Wu to provide closer fit to the radiosondes in certain situation (multiple model levels bracketed by 2 raob sig levels). Based on testing in the GSD parallel RR, closer fit was seen in adjusted soundings and a slightly better overall analysis fit. This is important for the Rapid Refresh analyses detailed profile examination of analysis and short-range forecasts now being done by SPC forecasters (also under 5.4). Ming Hu also added code to compute a boundary-layer height within the analysis and is using it to place a lower elevation cutoff to the radar reflectivity-based latent heating computed in the cloud analysis and used later in the DFI-radar assimilation. In addition, code in the cloud analysis that computes snow from reflectivity was modified to use a dry snow formulation instead of a wet snow formulation, alleviation a problem of too little radar-diagnosed snow. Finally preliminary work is ongoing to code a capability to do nudging of skin temperature, based on the lowest model level air temperature increment (this will be deferred to a Rapid Refresh upgrade at NCEP late in FY12). Haidao Lin continues his satellite data assimilation work, and has obtained some modest improvement in a test with AIRS radiance data added to just conventional observations.

**CAPS**
Our earlier tests show that digital filter (the Digital Filter Launch option) is important in suppressing noise in the forecasts, especially with EnKF analyses where the noisy covariance (using 40 member ensemble) is introducing

more in-balance. The digital filter improves the surface pressure forecast especially. However, forecast instability was experienced in some of the forecast members for what we believe to be the most desirable configuration of the digital filter initialization (DFI) put into WRF by ESRL and NCAR. This problem was apparently caused by the consistency of land surface model fields with the atmospheric model in the digital filter implementation. In the previous version, atmospheric variables were filtered, but not the land surface model fields. When the forecast is re-launched from the filtered state at the center of the filter window, land surface fields from the beginning of the filter were used. Such inconsistency was the cause of instability. We made modifications so that the land surface fields at the center of the window are used and the forecasts are now stable throughout the weekly assimilation cycles and subsequent forecasts. Along with the above change, we also changed the default (as used in RR) filter cut-off period from the same length as the filter window to half of the window length so that the filter coefficients properly taper off near the ends of the filter window. The default setting places too much weight on the data at the filter window ends.

Our previous verifications were done using the diag output files from GSI and EnKF, causing the observations used by the verification to be not completely the same. We have now adapted the point-state tool available in the MET (Model Evaluation Tools) package for GSI and EnKF verifications so as to use identical observations. Observations between 1.5 hr before and after the forecast valid time are used. For sounding data, the verification is performed at 0000 and 1200 UTC only, while for other observations, average is performed for all cycles.

To understand if short 3-hour cycles are partly responsible for the noisy EnKF covariance, an experiment with 6 hourly cycles was performed. The general comparison between EnKF and GSI remain unchanged. For moisture field, the EnKF analyses are better but for other fields the GSI is better, especially for the wind fields. The largest differences between wind analyses are at the 200-hPa level (Fig. 1). The EnKF analysis errors are reduced with the 6 hourly cycles while the GSI analyses became worse, suggesting the noisier covariance due to short assimilation cycles is a factor affecting the EnKF performance. Further examination of the covariance structures in the 3 hourly and 6 hourly cases will be done. A number of additional experiments will be performed to test increased upper level localization radius, increased adaptive inflation, further investigate the QC procedures used in the GSI and EnKF and the remaining differences between the observations used (e.g., role of variational QC in GSI), and to test a larger ensemble and investigate its impact on covariance. While the results obtained so far are encouraging, especially in terms of low level and moisture fields, and the precipitation forecast (now shown), much tuning and many more experiments are still needed.



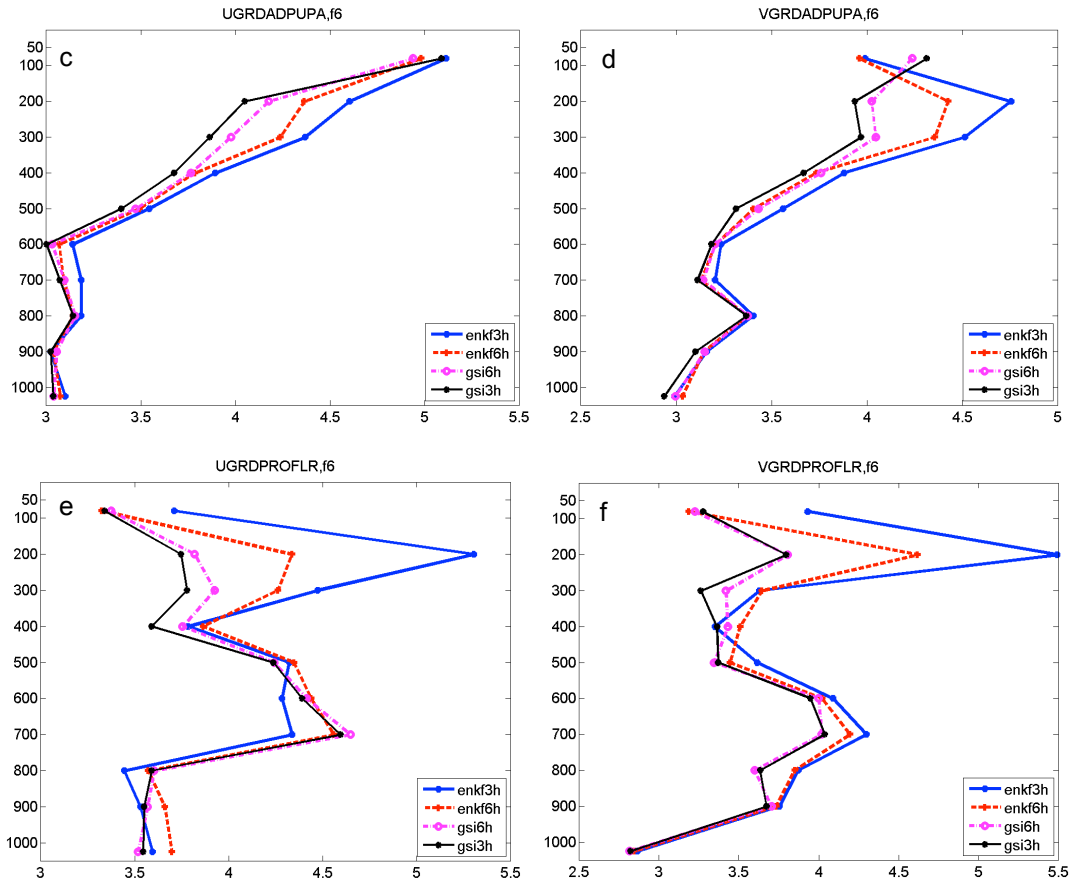



***Fig. 1. Vertical RMSE profiles of 6 hr deterministic forecasts for relative humidity (a), temperature (b), x-component wind (c and e) and y-component wind (d and f). The upper four panels are against upper air reports (ADPUPA) and the lower two panels are against the wind profiler reports (PROFLER).***

**NCEP**

Work on the 3dvar-ensemble hybrid in the regional continued. An error in ensemble wind perturbation was found and fixed, where the GSI needs rotated wind perturbations but earth wind perturbations were provided. An option was added to use the perturbation based on the regional first guess instead of on the global ensemble mean. The code was also cleaned up and unused arrays deleted to save memory. Work continues on using surface observations with no reported pressure or height, and those data files were tested in GSI to make sure the GSI can handle data without reported pressure and that nothing is degraded when using these extra observations. It will be necessary to modify the GSI code to use these data. In checking the new data, it was found that the TAMDAR data: temperatures, humidity and winds were not used in the regional parallel system. Dennis Keyser investigated and found that the new NRL aircraft QC had flagged the data not to be used. This problem was fixed in the NAM parallel. (Wan-Shu Wu)

Canadian radar data became available in the early in April, and efforts were made to verify that the data is correct. It was found that elevation angle information was missing from some of radar stations and this was reported to NCO where it was fixed. Efforts were also made to graphically display Canadian radar data. It was found the reflectivity did not match radial wind well. Reflectivity assimilation work continues but suspicions about a bug in treatment of height of obs are first being investigated. Forecast experiments were conducted with modifying temperature with latent heat using both GSD's and NRL's cloud analysis method. The hourly cycle is set up and more experiments will be performed. (Shun Liu)

A prototype 1.5-km resolution RTMA for Juneau-Alaska has been built in response to a request from NWS/Alaska forecasters, who noticed that the current Alaska RTMA failed to adequately account for the topographic

complexity of Juneau. A prototype 2.5-km resolution extended CONUS RTMA has also been built by extending the NDFD domain northward from 51N to 56N. In addition to the NDFD domain, the new system will also provide analyses over the NWRFC domain, thus eliminating the need to develop a separate RTMA system for the latter domain. The current operational CONUS RTMA is on schedule to be replaced with the extended CONUS RTMA in Q4 FY2011. (Manuel Pondeca)

Purdue University student intern Jacob Carley has begun work in using the hybrid ensemble GSI with NMMB (at 1.33km) to test assimilation of radar reflectivity in severe storm situations. This PhD thesis work could be the basis for a future real time severe storm warning system in the 1-3hr range. He is being assisted in his familiarization with the GSI code and how to run it. (Dave Parrish)

**Task 11.5.8 Improve physical processes in the WRF (RR and HRRR) and NAM models, especially including those that affect aircraft icing.**

**GSD**
Modifications to the RR version of the RUC LSM reported in the FY11Q2 report appear to be working well.

Following on to work reported in the FY11Q2 report, limited experimentation continued toward comparing the various versions of the Thompson microphysics. As noted in the earlier report, we decided to use the v3.2 version of Thompson with known bugs removed, rather than switching to Thompson v3.3 at this time. However, we anticipate upgrading to a later version of Thompson for the RR2 upgrade in late FY12.

Work on the MYNN planetary-boundary-layer (PBL) scheme continued in April, with further testing of modifications to keep the turbulence kinetic energy predicted by the scheme positive semi-definite.
The use of this modified version of the MYNN scheme is being considered for the RR2 in FY12. It is also being considered for eventual application in the HRRR.

**Task 11.5.15 Develop improved methods of cloud and moisture analysis for use in the Rapid Refresh and NAM Modeling Systems.**

**GSD**
Ming Hu made some changes minor changes to the GSI cloud analysis to improve the RR radar analysis and coordinated with Tanya Smirnova (see task 5.4) on changes to improve the RR snow cover. First, Ming created code to compute a boundary layer height within the analysis and is using it to place a lower elevation cutoff to the radar reflectivity-based latent heating computed in the cloud analysis and used later in the DFI-radar assimilation. In addition code in the cloud analysis that computes snow from reflectivity was modified to use a dry snow formulation instead of a wet snow formulation, alleviation a problem of too little radar-diagnosed snow. Finally preliminary work is ongoing to code a capability to do nudging of skin temperature, based on the lowest model level air temperature increment.

**Task 11.5.24 Develop, test, and improve the 3-km WRF-based High-Resolution Rapid Refresh**

**GSD**
A key milestone was achieved on April 14$^{th}$, 2011, when the HRRR was switched to run nested within the Rapid Refresh. Prior to this time (and since the inception of the HRRR in 2007) it had always run as nest within the RUC. A very significant amount of work preceded this important switchover. First, work to bring the RR to an NCEP operationally ready level was completed, including numerous code updates and fixes (including introduction of partial cycling, resolving issues with the rotated lat lon coordinate, and resolving issues related to DFI balance and hydrometeor reset after the DFI. Next, an extensive set of RUC-HRRR and CW PDT colleagues at NCAR completed RR-HRRR tests on summer 2010 high impact weather periods with detailed analysis of results here at GSD and. Based on this modification were made to the RR radar-DFI assimilation and changes made to the HRRR, resulting in RR-HRRR results that are generally superior to the RUC-HRRR. This work and this accomplishment would have been extremely difficult without the HRRR shadow computer system on jet and

the in-house verification package developed by Patrick Hofmann. The RR-based HRRR has been running in real-time with high reliability (and latency trimmed from ~3h last year to ~2h this year) through all the recent severe weather. Shown below is a comparison of HRRR and RUC 9-h forecasts for the April 27th Southeast U.S severe weather outbreak day (this day was also one with very significant aviation impact). As can be seen the HRRR does very well in capturing the overall character of the convection (clusters of super cells ahead of a thin squall-line). It also reproduced certain storms down to a county scale, including the devastating Tuscaloosa tornado storm indicated by the white circles.

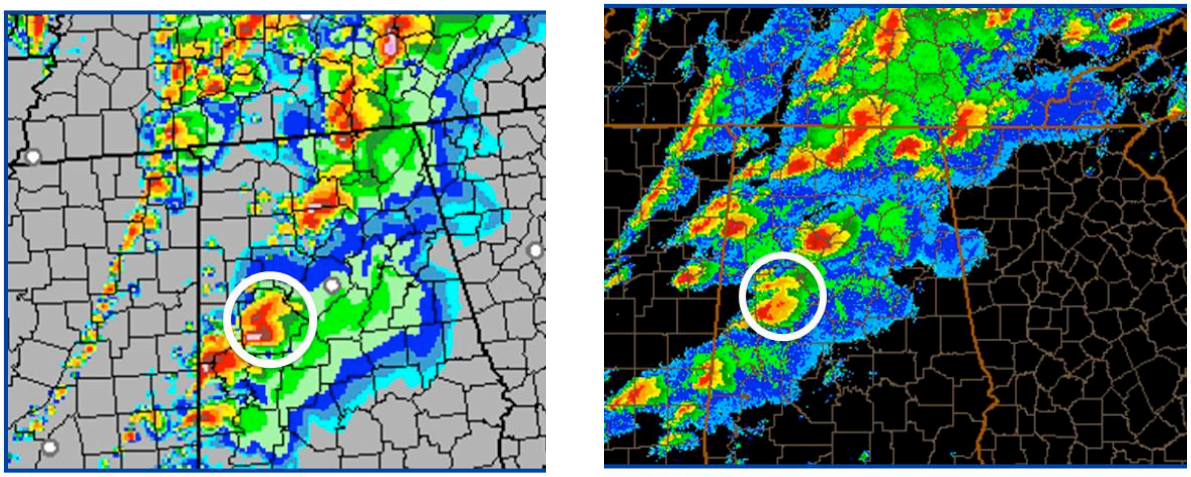


***Fig. 2: (Left) HRRR 9-h forecast thunderstorms valid 5 PM CDT for the April 27th tornado and severe weather outbreak. (Right) Observed thunderstorms at 5 PM CDT from April 27th, 2011. Overall storm character is predicted well and some storms (including the Tuscaloosa tornado storm indicated by white circles) predicted to county scale.***

**NCAR**

CURRENT EFFORTS: NCAR discussed with GSD the collaboration to analyze high-resolution ARW runs and model performance for the HRRR. NCAR and GSD agreed that NCAR will run the ARW for selected cases from the current season, based on cases seen in the HRRR runs that are being done. NCAR will simulate and analyze up to four cases, running the ARW at 3km using the HRRR for ICs and BCs. Sensitivity tests would be done as appropriate.

PLANNED EFFORTS: NCAR will collaborate with GSD on the case selection as the season progresses. NCAR will collaborate on identifying the modeling issues and testing. NCAR will deliver a write-up on the results to GSD.

UPDATES TO SCHEDULE: NONE