

**Quarterly Report
of the WRF Program Coordinator
to
Executive Oversight Board**

April-July 2006

1. WRF Model Implementation:

- **WRF operational implementations:**

- (a) **NCEP** – The **WRF-NMM** became **operational** on June 21, 2006 in the North American Mesoscale (NAM) domain. WRF-NMM was developed and prepared for implementation by a 20-member team at NCEP's Environmental Modeling Center (EMC), including Dr. Zavisla Janjic, the original model developer. The NMM science code runs within the WRF common modeling infrastructure. WRF-NMM has improved NCEP's upper-air guidance in the 12-36 h forecast range, reduced biases for most surface variables compared to Eta, and provided more realistic mesoscale structure, especially for oceanic and tropical cyclones. EMC immediately began working on improvements to model physics, numerics and code structure to further improve the model's accuracy and performance.
- (b) **AFWA** – The **WRF-ARW** became **operational** on July 25, 2006, for AFWA's Southwest Asia domains. The WRF-ARW was developed as a community model, with contributions from the National Center for Atmospheric Research (NCAR), NOAA, the Department of Defense, the Federal Aviation Administration, the Center for the Analysis and Prediction of Storms, and many other additional participants. By late 2007 WRF-ARW will replace all remaining Pennsylvania State University/NCAR Mesoscale Model 5 (MM5) windows at AFWA. WRF-ARW has been thoroughly evaluated, both subjectively and objectively, and was generally found to produce superior forecasting results over the MM5. The WRF-ARW routinely outperformed the MM5 in aerial extent of severe weather, produced smaller root mean square errors (RMSEs) and biases with respect to stability indices, and depicted more accurate surface winds and visibility. Subsequent findings of on-going WRF-ARW evaluations will be documented and provided to the AFWA and WRF communities.

2. Community Support and Outreach:

- **Release of WRF Reference Code:** The next WRF code release, **Version 2.2**, is planned for September 2006, succeeding version 2.1.2. This release will include

the **new WRF Preprocessing System** (replacement for old Standard Initialization) and a **one-way nested-grid capability for WRF-NMM**.

- **WRF tutorials:** NCAR/MMM conducted a **WRF-ARW tutorial** on July 24-28, with approximately 50 persons attending. The DTC will be conducting a **WRF-NMM tutorial** on August 8-11, with 27 persons registered.
- **7th WRF Users Workshop:** NCAR hosted the 7th WRF Users' Workshop on June 19-22. The workshop included presentations on **technical and scientific developments**, a poster session, panel discussion on WRF development planning, plenary discussions on WRF organizational issues, and breakout sessions and subgroup reports on long-range (5-10 y) WRF science priorities. Attendance was 203, representing 101 institutions and 17 countries.

3. WRF Software Development and Model Evaluations

- **NCEP Hurricane-WRF: Pre-implementation testing** and evaluation of the HWRF for this hurricane season began on June 1. The HWRF is run over the Atlantic and East Pacific basins **4 times per day** in near real time. The model uses a movable (vortex following) **two-way nested grid** with a 27-km outer domain extending over a 75X75 degree area and a 9-km inner domain. In preparation for operational implementation in 2007, the HWRF system uses an advanced vortex initialization that assimilates **airborne Doppler radar winds** from NOAA's P-3. This pre-implementation system will be upgraded by the end of August to include coupling to the advanced **HYCOM** ocean model. The HYCOM capability includes initialization of circulation features important for hurricanes (e.g., G. of Mex. loop current) and features an **ocean data assimilation system** that takes advantage of *in situ* data (e.g., AXBTs).
- **NCAR Hurricane-ARW:** NCAR/MMM has been running a 12-km grid of its Hurricane ARW over the Atlantic basin since July 1. When storms form, **4-km and 1.3-km nested grids** are spawned to provide convection-resolving simulations.
- **COAMPS and WRF:** The **first phase of physics integration** in COAMPS and WRF has been completed by NRL and committed into the COAMPS configuration management. Additional work is needed in COAMPS to address efficiency issues introduced by the WRF physics merger and to perform new timing tests. Modifications to the WRF microphysics schemes will be required to output accumulated snow field, which is needed by the COAMPS surface module. Benchmark tests have been performed with several different physics suites and different physics combinations for both models. Additionally, **common input/output (I/O) interfaces** for WRF and COAMPS are being developed. An **I/O post-processor** is under development to enable direct

comparisons between COAMPS and WRF dynamic cores using the same physics suite.

- **T-REX:** NRL is evaluating **COAMPS real-time forecasts** performed in support of the Terrain-Induced Rotor Experiment (T-REX) Special Observing Period. During T-REX, COAMPS was run twice daily at a horizontal resolution of 2 km on the finest grid mesh and using 40 vertical levels. The initial analysis indicates that the real-time forecasts were in reasonable agreement with the observed mountain wave activity as measured by the NSF/NCAR GV. The model forecasts successfully identified the Intensive Observation Periods with the observed largest-amplitude waves and provided reasonable guidance regarding wave characteristics. Future verification will be conducted using observations from the ground based network as well as other research aircraft.
- **WRF Preprocessing System:** NCAR/MMM has completed the **new front-end initialization** WRF Preprocessing System (WPS) as a replacement for the old WRF Standard Initialization (SI). WPS encompasses functions of static/terrestrial field generation (geogrid), input data degribbing (ungrib), and met field gridding (metgrid), and can process data for both the ARW and NMM cores. WPS provides overall **faster processing and better memory usage** than SI by running distributed-memory parallel processing for geogrid and metgrid programs, yielding up to two orders of magnitude speedup in static field generation.
- **WRF CMI and Grib2:** NCAR/MMM has completed integration of **I/O** packages for the common modeling infrastructure, developed by Todd Hutchinson of WSI, that allow WRF to both read and write Grib1 and **Grib2** datasets.
- **WRF-ESMF convergence:** In response to WRF ExOB's Action Item 6.2-2006, a request has been made to NCAR/MMM to **estimate cost and time** necessary to implement nine recommendations for **streamlining the WRF CMI**. These recommendations were contained in the final report emerging from the Technical Workshop on WRF-ESMF Convergence, held in Boulder, CO, on 9-10 February 2006. MMM has promised to provide the requested estimates.

4. WRF Management

- The **next meeting of the WRF Executive Oversight Board** has been scheduled for October 4, 2006, at the Global Sciences Division of NOAA/OAR in Boulder, CO. Logistical information for meeting attendees will be distributed as the meeting approaches.
- In accordance with ExOB **Action Item 6.1-2006**, the WRF Program Manager and DTC Director have begun contacting ExOB members to further discuss options to establish **management, staffing and resourcing** for the DTC.

5. DTC – OTC Activities

- **WRF Core Intercomparisons:** The Boulder DTC recently completed its planned set of dynamical core inter-comparison experiments to support the development of the **Rapid Refresh WRF** that will replace the RUC model in 2008. For this purpose WRF-ARW and WRF-NMM runs focused on the short range (0-24 h) using a **13-km full-CONUS domain** (slightly smaller than the operational RUC domain). Two sets of uncycled runs were made for four months of historic cases (one month per season): one using the NCEP physics suite and the other using the RUC suite. To the extent possible, the carefully controlled experiment design used identical initial and lateral boundary conditions and the same physics suites.

Statistical evaluations showed only minor differences in solutions using the two cores. ARW tended to have slightly better RMSEs near the tropopause, where it has somewhat greater vertical resolution than NMM. Conversely, NMM tended to have slightly smaller biases, especially in the lower troposphere, where it has somewhat greater vertical resolution than ARW. Overall, ARW appeared to do better in diagnosing conditions supporting turbulence, while NMM soundings retained somewhat more vertical detail. Subjective evaluations indicate ARW tended to produce more intense short-wave troughs in the mid-to-upper atmosphere.

Tests of statistical significance are underway. Limited additional experiments are planned to gain better understanding of the causes for the mostly small differences in accuracy found in these experiment results. Based on analysis of the test results, several Rapid Refresh (RR) product development teams will make a recommendation to NCEP on a preferred core for the new RR system.

6. WRF and COPC

- Agreement on text for a **WRF Joint Implementation Plan** between AFWA and NCEP was reached in June. The WJIP will govern packaging and transmission of NCEP operational WRF-NMM datasets to AFWA for use over its North American domains. The document will go into effect upon signing by the respective agency directors.

7. WRF and Air Quality Forecasting

- **CMAQ-WRF-NMM:** The operational CMAQ air-quality forecast model built in partnership by NOAA and EPA was **switched over to using WRF-NMM meteorological inputs** in June 2006. The operational system produces forecasts

of 8-h and maximum 1-h surface-layer ozone out to +48 h over the eastern U.S. Ozone forecast biases have decreased following implementation of WRF-NMM, mostly due to reduced surface temperature biases in the new meteorological model, plus better treatment of chemistry boundary conditions and cloud mixing processes.

A parallel experimental version of the air-quality forecast system to extend ozone forecasts over the full CONUS has been running daily since June 2006. The CONUS domain CMAQ-WRF is scheduled for operational implementation by June 2007. A version to extend the air-quality forecast capability to include aerosols is now undergoing early developmental testing.

Glossary of WRF Acronyms
6 June 2005

AFWA	Air Force Weather Agency
AIP	Agreement In Principle
AO	Announcement of Opportunity
ARL	Army Research Laboratory
AWRP	FAA's Aviation Weather Research Program
BAMEX	Bow Echo And MCV Experiment
COAMPS	Coupled Ocean-Atmosphere Mesoscale Prediction System™
COMET	Cooperative Program for Operational Meteorology, Education and Training
CONUS	CONTinental United States
COPC	Committee for Operational Processing Centers
DTC	Development Testbed Center
DWFE	DTC Winter Forecast Experiment
ESMF	Earth System Modeling Framework
ESRL	Earth System Research Laboratory
ExOB	Executive Oversight Board
FSL	Forecast Systems Laboratory
FTE	Full-Time Equivalent
FNMOCC	Fleet Numerical Meteorology and Oceanography Center
GFS	NCEP Global Forecast System
GSD	Global Systems Division of ESRL, formerly FSL
GSI	Gridpoint Statistical Interpolation
JCSDA	Joint Center for Satellite Data Assimilation
MCV	Mesoscale Convective Vortex
MMM	NCAR Mesoscale and Microscale Meteorology division
NAM	NCEP North American Mesoscale domain
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Predictions
NCOM	Navy Coupled Ocean Model
NOGAPS	Navy Operational Global Atmospheric Prediction System
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
OAR	NOAA/Office of Oceanic and Atmospheric Research
OST	NWS/Office of Science and Technology
OTC	Operational Testbed Center
POP	Princeton Ocean Prediction model
QPF	Quantitative Precipitation Forecast
RAMS	Colorado State University Regional Atmospheric Modeling System
RR	Rapid Refresh version of WRF
RUC	Rapid Update Cycle
RTVS	Real Time Verification System

SPC NCEP Storm Prediction Center
SREF Short Range Ensemble Forecast
TOR Terms of Reference
USWRP US Weather Research Program
WRF Weather Research and Forecast modeling system and program
WRF-ARW WRF Advanced Research WRF dynamical core
WJIP WRF Joint Implementation Plan of COPC
WRF-NMM WRF Nonhydrostatic Mesoscale Model dynamical core
WRF-SI WRF Standard Initialization