DTC Annual Operating Plan 2012

1 March 2012 – 28 February 2013

1. Introduction

The Developmental Testbed Center (DTC) is a distributed facility with components residing at the National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL). The objectives of the DTC are to: (i) advance science research by providing the research community an environment that is functionally similar to that used in operations to test and evaluate the components of state-of-the-art numerical weather prediction (NWP) systems, without interfering with actual day-to-day operations; (ii) reduce the average time required to implement promising codes emerging from the research community by performing the early steps of extensive testing to demonstrate the potential of new science and technologies for possible use in operations; (iii) sustain scientific interoperability of the community modeling system; (iv) manage, provide and support the common baseline of end-to-end community software to users, including dynamic cores, physics and data assimilation codes, pre- and post-processors and codes that support ensemble forecasting systems; and (v) establish, maintain and support a community statistical verification system for use by the broad NWP community. The fundamental purpose of the DTC is to serve as a coordinating mechanism that acts as a bridge between research and operations thereby facilitating the activities of both communities in pursuit of their own objectives. For the DTC's AOP 2012, the Office of Oceanic and Atmospheric Research (OAR), the Air Force Weather Agency (AFWA), the National Weather Service (NWS) Hurricane Forecast Improvement Project (HFIP), NCAR, NOAA's U. S. Weather Research Program (USWRP) and the National Science Foundation (NSF) collectively provided approximately $5 M to support the activities of the DTC. The breakdown of funding by sponsor is summarized in Table 1.

The DTC currently has five major task areas (Mesoscale Modeling, Hurricanes, Data Assimilation, Ensembles, and Verification), all of which are overseen by the Director's Office. Each task has an assigned lead responsible for developing the task work plan and ensuring the successful execution of the work plan. All task areas are involved in community outreach and software management activities. The Mesoscale Modeling, Hurricanes, Data Assimilation and Ensembles tasks also undertake testing and evaluation of promising new NWP innovations from the research community that are relevant to their focus area. The Verification task provides advice on appropriate statistical methods and interpretation to ensure DTC testing activities provide reliable metrics, using the most advanced methods available to the community. In addition, the DTC collaborates with NOAA testbeds to test and evaluate current and future mesoscale NWP systems. These testbed collaborations contribute to the activities of the appropriate DTC task area(s). This document provides a description of the work that will be carried out by the DTC during this performance period, without differentiating the funding sources for each specific task. The breakdown of the funding by task is summarized in Table 2. The total funding allocated for AOP 2012 is slightly higher than the total new funding because the overall effort includes carry-over funds from AOP 2011. Tasks are carried out jointly by NCAR and ESRL staff.

Table 1: Breakdown of DTC funding by sponsor

Sponsor	Funding (in K)
OAR	$2,925
AFWA	$855
NCAR	$250
GSD	$250
NSF	$100
HFIP	$460
USWRP	$190

Table 2: Breakdown of DTC funding by task area

Task	Funding (in K)
Director's Office	$746
Visitor Program	$200
Mesoscale Modeling	$1,029
Hurricanes	$1012
Data Assimilation	$569
Verification	$915
Ensembles	$827

2. Director's Office

The Director's Office provides administrative and management support for all DTC activities. This support includes: (i) managing and coordinating all DTC tasks, (ii) conducting DTC workshops and tutorials, (iii) interacting with DTC partners [e.g., NOAA's National Centers for Environmental Prediction (NCEP) Environmental Modeling Center (EMC), the Mesoscale and Microscale Meteorology (MMM) division of the NCAR Earth System Laboratory (NESL), and AFWA] on collaborative efforts, (iv) creating and maintaining the DTC web site, and (v) providing administrative support for DTC management meetings. In addition to these basic support activities, the Director's Office hosts the DTC Visitor Program. A new activity for the Director's Office during AOP 2012 will be preparing and distributing a bi-annual DTC newsletter. Raising awareness in the community of the important testing and evaluation activities the DTC conducts each year is critical to the DTC's mission.

3. Community Interactions

Maintaining strong ties to both the research and operational NWP communities is critical to the success of the DTC's mission. Strong ties with the operational community are maintained through the DTC's interactions with our partners at the operational centers (i.e., EMC and AFWA) both at the management level and through our task lead interactions with the appropriate team leads and/or focal points at the operational centers. The DTC works towards strengthening its ties to the broader research community through workshops, tutorials and the DTC Visitor Program. Information on DTC-sponsored tutorials is provided in Section 4.2.

3.1 Community Outreach Events

During AOP 2012, the DTC will conduct or assist with two workshops and one instructional session. The first community outreach event will be the 13th Weather Research and Forecasting (WRF) Users' Workshop in June 2012, which the DTC co-hosts with NESL's MMM. The annual WRF Users' Workshop provides a forum for presentations on the use of WRF in both research and operational settings. Instructional sessions are also offered on the last day of this workshop. Acting on advice from the DTC Science Advisory Board (SAB), the DTC plans to offer an instructional session on verification methods at this event. The second community outreach event will be the 2nd DTC Ensemble Workshop in September 2012. The principal goal of this workshop is to solicit input from experts on ensemble perturbation methods to be considered for DTC testing and evaluation. The DTC will also connect with international ensemble experts who will be in Boulder 25-27 June 2012 for a Global Interactive Forecast System-THORPEX Interactive Grand Global Ensemble (GIFS-TIGGE) working group meeting

by organizing a mini-workshop on ensemble prediction systems the afternoon immediately following the working group meeting. In addition to these events that will take place during AOP 2012, the DTC will begin planning for the 2nd Gridpoint Statistical Interpolation (GSI) Data Assimilation (DA) System Workshop in collaboration with NCEP/EMC. This workshop, which is tentatively scheduled for Spring 2013 in College Park, Maryland, will serve as a forum for GSI developers and members of the GSI user community to share relevant data assimilation efforts and discuss the future direction of GSI development.

3.2 Visitor Program

The DTC Visitor Program supports visitors to work with the DTC to test new forecasting and verification techniques, models, model components, and data assimilation approaches for NWP. It also offers an opportunity for visitors to introduce new NWP and verification techniques into the community codes supported by the DTC. The goal of this program is to provide the operational weather prediction centers (i.e., NCEP and AFWA) with options for near term advances in operational weather forecasting and to provide researchers with NWP codes that represent the latest advances in technology. During AOP 2012, the DTC will be supporting five visitor projects that were selected in January 2012 (see Table 3). The DTC also plans to distribute an Announcement of Opportunity (AO) for the next round of visitor projects in July 2012 and wrap up the review/selection process by November 2012. In addition to distributing a new AO, the DTC will open its visitor program to off-cycle proposals. Off-cycle proposals will be subjected to the same review process and favorably reviewed proposals will be funded off-cycle if funding is available or they will be incorporated into the next formal cycle if no funding is available.

Table 3: List of current visitor projects. The DTC offers two types of projects: (PI) projects undertaken by the project's principle investigator and (GS) projects undertaken by a graduate student under the direction of their major professor.

PI	Institution	Type	Project Title
Jonathan Vigh	NCAR	PI	Development of an HWRF Diagnostics Module to Evaluate Intensity & Structure Using Synthetic Flight Paths Through Tropical Cyclones
Adam Clark	U. of Oklahoma	PI	Development & Application of 3-Dimensional Object Algorithms to High Resolution Forecasts
Delia Arnold & Don Morton	Technical U. of Catalonia / U. of Alaska –Fairbanks	PI	Moving The NEMS & NMM-B Into a Broader Community Resource Environment
Travis Wilson	UCLA	GS	Improvements to modeling persistent surface cold pools in WRF
Sai Ravela	MIT	PI	Deploying the MIT Field Alignment System & Test-bed (FAST) in DTC

4. Software Systems

To serve as a bridge between operations and research, the DTC provides a framework for the two communities to collaborate in order to accelerate the transition of new technology into

operational weather forecasting. This framework is based on software systems that are a shared resource with distributed development. The current operational systems are generally a subset of the capabilities contained in these software systems. Ongoing development of these systems is maintained under version control with mutually agreed upon software management plans. The DTC currently works with the following software systems:

- WRF – NWP model + pre- and post-processors
- WRF for Hurricanes (set of tools for tropical storm forecasting, including a coupled atmosphere and ocean system)
- NOAA Environmental Modeling System (NEMS)
- GSI DA System
- Modular end-to-end ensemble system
- Model Evaluation Tools (MET) – Verification package

With the exception of MET, the DTC does not contribute to the development of these software packages. Rather, the DTC contributes to the software management of all of these systems and user support for the publicly-released systems (WRF, WRF for Hurricanes, GSI and MET). All software management and user support activities are collaborative efforts with the developers, where the exact role of the DTC depends on the software package. The main developers of these packages are affiliated with EMC, ESRL, NCAR, Global Modeling and Assimilation Office (GMAO) of the National Aeronautics and Space Administration (NASA), Geophysical Fluid Dynamics Laboratory (GFDL), University of Rhode Island (URI) and the Hurricane Research Division (HRD) of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML). DTC activities are currently focused on the regional application of these software systems. In addition to working with these individual software systems, the DTC is involved in an effort to apply the GSI-Hybrid DA technique to operational hurricane forecasts, which requires linking the GSI DA system with both an ensemble system and HWRF.

4.1 Software Management

While specific software management plans differ between the various software packages, they all contain the following elements:

- Code repositories that are maintained under version control software.
- Protocols for proposing modifications to the software, whether the modifications are simply updates to current features, bug fixes or the addition of new features.
- Testing standards that proposed software modifications must pass prior to being committed to the code repository.
- Additional testing standards used to more thoroughly check the integrity of the evolving code base.

Given all these software packages continue to evolve over time, all testing standards must also be updated periodically in order to meet the maintenance requirements of the code base. The DTC will continue to collaborate with the various developer groups on these ongoing software management activities during AOP 2012. The DTC will also continue to provide a pathway for the research community to contribute to the development of these software systems. Only new

activities related to these software systems or work that goes beyond the basic maintenance will be described in this document.

4.1.1 WRF

The WRF software package contains two dynamic cores and numerous options for each type of physics parameterizations. Not all of the physics options communicate appropriately with both dynamic cores. During AOP 2012, the DTC will continue to work on increasing physics interoperability. Allowing more physics parameterizations to be run with both dynamic cores provides the research community with more options to test and additional opportunities to impact a wider range of operational configurations. This type of effort may also help support the transition of similar physics parameterizations into next generation NWP systems in future years. One key area of interest identified for AOP 2012 is the ability to use alternate microphysical parameterizations existent in the WRF software framework with HWRF. At the moment, only the Ferrier scheme can be used in HWRF. This limitation is related to advection and to boundary conditions for the moving nest. The Ferrier scheme only advects and communicates to/from the nest the total water condensate, while all other schemes employ mixing ratios and, in the case of double-moment schemes, also number concentrations. The focus for this performance period will be creating the possibility to run HWRF with the Thompson microphysics. It is expected that once the capability to run with the Thompson scheme is achieved, only minimal effort will be required to make many other microphysical schemes available to HWRF.

4.1.2 Modular End-to-End Ensemble System

The capabilities contained in the current DTC ensembles code repository correspond to NCEP's Short-Range Ensemble Forecast (SREF) system scheduled for implementation in August 2012. To carry out the research innovations testing activities planned for AOP 2012, the DTC will need to update the "cycling perturbations" technique currently in the code repository, and add a number of ensemble-based products developed by the Center for Analysis and Prediction of Storms (CAPS) that have shown promise during the Hazardous Weather Testbed's (HWT) Spring Experiments (SEs). The capability to run an ensemble based on the HWRF system will also be added. These modifications will provide the DTC with the capability to perform testing and evaluation in a functionally similar environment for both the SREF and HWRF applications. HFIP is currently funding a collaborative effort between EMC and the research community focused on improving the operational HWRF forecast skill by adding the GSI-Hybrid DA technique to its end-to-end system. The DTC will assist this rapid development process by adding the Ensemble Kalman Filter (EnKF) capability to the HWRF build system and contribute to the process of converting research capabilities to robust components of an operational system.

4.1.3 NEMS

As NOAA continues to transition their operations to NEMS, the DTC will continue to strengthen its foundation of expertise with the NEMS software and the science associated with NEMS-based models during AOP 2012. To accomplish this, one DTC staff member will continue to work at EMC to collaborate with EMC on the development of the Non-hydrostatic Multiscale Model on the B-grid (NMMB) in the NEMS framework for select areas (e.g. portability, interoperability, I/O layer capabilities). A Community NEMS repository with enhanced portability was established at the DTC during AOP 2011, making it critical to establish a code management plan over the coming year to define policies and procedures for maintaining the repository at the DTC and ensure it is kept in sync with the operational repository at NCEP. The

DTC will continue to participate in technical discussions and host a technical workshop focused on the status of NEMS development and options regarding the integration of new features or capabilities, including WRF-based physics schemes. Preliminary work to transition the Thompson microphysics scheme (available in the WRF framework) into the NEMS framework, specifically for NMMB, will also be initiated this year.

A friendly user release of NEMS/NMMB will be packaged and distributed to selected community users during AOP 2012. Preliminary documentation on running the system will be written and included with the limited distribution.

4.1.4 MET and METViewer Development

To truly serve as a bridge between research and operations, the DTC needs to make traditional as well as state-of-the-art verification tools available to the NWP community. Hence, the DTC began assembling its MET package in the fall of 2006. This package includes standard verification approaches, as well as a number of more advanced approaches recently developed by the verification community.

To maintain truly state-of-the-art verification tools, the DTC must engage the international verification community and continue to add new capabilities to MET. For AOP 2012, investigation of new methods will focus on temporal block bootstrapping and circular block bootstrapping. The DTC will also continue to investigate and implement the most useful methods for verification of cloud forecast variables. The DTC will examine different spatial verification methods and identify one operationally useful method for nearer term MET development. To stay apace with needs for verification tool enhancements, support for input in GRIB2 format will be added to MET and updates to meet compliance with the NetCDF-CF format will be implemented. Work towards integrating NASA's land surface model verification capabilities will also begin in AOP 2012. And finally, the Baldwin/Elmore field significance method[1] will be made available as a standalone package.

Testing and evaluation of ensemble forecasting is a significant effort within DTC, and new methods for verifying ensemble forecasts are needed to support this effort. The Verification task will work closely with the Ensembles task to investigate, define, develop, and test new tools to support ensemble testing and evaluation. These new tools will include the ability to produce ensemble spread-skill diagrams and enhancements to support data formats needed for ensemble verification.

Verification of tropical cyclones shares many of the challenges of traditional numerical model verification, but with very different types of forecast and observational data. MET TC (the Model Evaluation Tools Tropical Cyclone) development will be continued this year to meet many of those challenges. Initially, the MET TC capability will replicate the methods for track and intensity errors used by the National Hurricane Center (NHC) verification system. A limited initial release of this software in planned for fall of 2012.

The DTC recently developed a software package, METViewer, to build a database of verification metrics produced by MET, and to provide web-based display tools for visualization of these metrics. In addition, METViewer can produce aggregated statistics such as Receiver

[1] This stand alone tool is the outcome of a joint project undertaken by Drs. Baldwin and Elmore through the DTC Visitor Program. More information on this technique can be found in an article by Elmore, Baldwin and Schultz published in Monthly Weather Review in 2006.

Operating Characteristic (ROC) curves. METViewer will be updated to include new ensemble tools, and other tools or displays as needed to support testing and evaluation needs within the DTC. In particular, the functionality to plot confidence intervals for spatial verification methods within METViewer will be added.

4.2 Publicly-Released Systems

The DTC currently collaborates with developers on six software systems that undergo a public release process: WRF, Unified Post Processor (UPP), WRF for Hurricanes, GFDL vortex tracker, GSI and MET. These packages are on an annual or bi-annual release schedule. Prior to any public release, the DTC conducts extensive pre-release testing on several platforms using multiple compiler options and configurations of the code. Up-to-date documentation and an email helpdesk are provided for all publically-released packages. Documentation, bug fixes and code access are provided through users pages set up for each package. These websites also offer online tutorials with step-by-step instructions on how to build, setup and run each package. And finally, onsite tutorials are offered for each package in close collaboration with the code developers. During these tutorials, participants benefit from lectures given by system experts and one-on-one assistance during practical sessions. The MET tutorials also include a half-day dedicated to an introduction to general verification concepts and the MET Users Page includes numerous links to helpful instructional materials about verification. Code release and tutorial plans for AOP 2012 are summarized in Table 4. In the past, the DTC has collaborated with MMM and EMC on two Joint WRF Tutorials per year. Priorities for AOP 2012 are such that the DTC decided to only sponsor one Joint WRF Tutorial during AOP 2012. MMM will continue to offer a summer tutorial focused on the ARW dynamic core with the winter offering continuing to be a Joint WRF Tutorial. While the DTC will not be co-hosting the summer WRF Tutorial, the Hurricane task will be using this forum to provide an introduction to the HWRF system to broaden the community's awareness of this system's availability and capabilities.

Table 4: Code release and tutorial schedules.

Software Package	Public Release		Tutorial
	Version	Timing	
WRF	V3.4 V3.4.1	April 2012 August 2012	January 2013
UPP	V2.0	April 2012	
HWRF	V3.4a	August 2012	WRF Tutorial - Intro to HWRF - July 2012
GFDL Vortex Tracker	V3.4	August 2012	
GSI	V3.1	July 2012	August 2012
MET	V4.0 V4.1	July 2012 January 2013	January 2013

Anticipated major accomplishments for AOP 2012:

- Expanded capabilities for all software systems
- Code management plan and friendly user release for NEMS/NMMB
- New versions of WRF, WRF for Hurricanes, GSI, UPP and MET available to the community, including updated documentation
- WRF, GSI and MET onsite tutorials

5. Testing and Evaluation

Testing and evaluation undertaken by the developers of new NWP techniques from the research community is generally focused on case studies. However, to adequately assess these techniques, extensive testing and evaluation must be performed to ensure that these new techniques are indeed ready for operational consideration. The DTC undertakes two types of rigorous testing and evaluation (T&E) activities: 1) studies for which the DTC generates forecasts and evaluates the skill of these forecasts (end-to-end internal testing), and 2) studies for which the DTC evaluates the skill of forecasts provided by external modeling groups.

Internal DTC T&E generally focuses on extended retrospective time periods. The cases selected encapsulate a broad range of weather regimes ranging from null, to weak and strong events. The exact periods chosen vary based on the phenomenon of focus for the test. The technique to be tested must be part of the appropriate code repository to ensure the code has reached a certain level of maturity. The DTC's evaluation of these retrospective forecasts includes standard verification techniques, as well as new verification techniques when appropriate. All verification statistics also undergo a statistical significance assessment when appropriate. By conducting carefully controlled, rigorous testing, including the generation of objective verification statistics, the DTC is able to provide the operational community with guidance for selecting new NWP technologies with potential value for operational implementation. DTC testing also provides the research community with baselines against which the impacts of new techniques can be evaluated. The statistical results may also aid researchers in selecting model configurations to use for their projects.

In addition to internal testing, the DTC occasionally participates in T&E activities in which the model output is produced by a modeling group or groups. These model evaluations can consist of demonstrations of model evaluation capabilities in real-time forecast projects or long-term retrospective evaluations in which the model setup (e.g. initial conditions, resolution, other model system attributes) is well-defined in advance and the model output is provided to the DTC by the modeling group. The DTC's evaluation of these externally generated forecasts follows the same principles applied to the evaluation of the forecasts generated internally by the DTC; objective verification statistics are computed, including standard verification metrics as well as new verification techniques when appropriate. The verification statistics also undergo a statistical significance assessment when appropriate.

5.1 Mesoscale Modeling

Since its inception, the DTC has undertaken T&E activities directed at assessing the skill of WRF model configurations for mesoscale, mid-latitude applications. While the DTC will continue its WRF-based T&E activities for the foreseeable future, broadening the scope of its internal T&E activities to include new software frameworks (i.e., NEMS) utilized by the relevant operational centers (i.e., NOAA) will be necessary in order to continue to serve as a bridge between research and operations. Activities focused on both of these efforts will be described in the following sections.

Communication is a key mechanism to serving as a bridge between research and operations. One aspect of making information on DTC activities available to the community is presenting information at relevant conferences or workshops; another is posting information on the DTC website. In addition, the DTC needs to dedicate time to producing journal articles on its key activities. For AOP 2012, continued efforts on preparing relevant manuscripts describing areas such as DTC T&E methodology and results from new test activities will be ongoing.

5.1.1 DTC Testing Protocol

Early in AOP 2012, a DTC testing protocol will be written defining the general policies and procedures to engage both the research and operational communities in a streamlined step-wise testing of promising new community innovations. The first stage of testing will be conducted by the researchers on high-impact or field program case studies. To provide a common framework for researchers to demonstrate the merits of new developments, the DTC is establishing the Mesoscale Model Evaluation Testbed (MMET; see description below). If improved forecast accuracy is shown during the first stage of testing, the innovation may be recommended for the second stage of testing, where the DTC conducts more extensive T&E. During this second stage, testing may be conducted in a functionally similar environment to operations, potentially including data assimilation cycling. Along with sharing the extensive test results with the user community, information will be shared with interested operational entities. The ultimate decision to proceed to the third and final, pre-implementation testing phase would be based on a variety of factors, including forecast performance and computational resource requirements. The newly-defined protocol and procedures, along with a description of MMET, will be presented to the community-at-large during the 21st Conference on Numerical Weather Prediction / 25th Conference on Weather and Forecasting in Montreal, Canada in May 2012 and at the 13th WRF Users Workshop in Boulder, CO in June 2012.

5.1.2 Mesoscale Modeling Evaluation Testbed

As mentioned above, the Mesoscale Modeling Evaluation Testbed will be established during AOP 2012 in an effort to provide a common framework for researchers to demonstrate the merits of new developments. The MMET will consist of initialization and observation data sets that will be accessible to the entire user community. A solicitation will be announced to the community-at-large for input regarding high-impact cases of interest and/or cases with extensive field program data. These data sets will be gathered and packaged for distribution to provide the opportunity for each user to conduct their own T&E of a new technique; consistent use of the data provided by MMET allows for direct comparison between researchers' results. The DTC will utilize the MMET data sets to establish and publish baseline results for select operational configurations. These baseline results will assist the research community in demonstrating improved forecast performance with new innovations.

5.1.3 WRF-based Systems

The WRF model is a mesoscale NWP system utilized in both research and operational forecasting applications. The model has numerous options available and is highly-configurable to the users' requirements. Thus, there is a need within the WRF community for widely publicized verification results from a variety of configurations that have been extensively tested and evaluated by either the DTC or a member of the WRF community. These evaluations will ultimately support both the research and operational communities. To fill this need, the DTC conducts both model inter-comparison and Reference Configuration (RC) T&E.

To support collaborations between the research and operational communities and to facilitate the transfer of new innovations between the two, the DTC must have the capability to run a system that is functionally similar to operations. This framework was established during AOP 2011 for current operational mesoscale applications that utilize WRF-based systems. Included in the end-to-end system is a pre-processor (WPS), data assimilation [i.e., GSI or WRF data assimilation (WRFDA)], the model itself (WRF), and a post-processor (UPP). Two WRF-based tests will be

conducted within this environment during AOP 2012. One test will focus on an inter-comparison utilizing the AFWA functionally similar environment (ARW configurations utilizing a 6-hour "warm start" spin-up and WRFDA). The second test will focus on the impact of a new community innovation on a NCEP WRF-based system. The details of the NCEP relevant test to be conducted will be determined through discussions with EMC's Mesoscale Modeling Branch.

To expand the number of baselines for operational or soon-to-be operational models and build a historical record of performance over sequential model versions, the DTC will continue to designate new RCs during AOP 2012. Results of model inter-comparisons will be leveraged and each configuration will be assessed individually to designate it as a RC. Additional configurations deemed relevant to the community as a whole will be identified and extensively tested after careful consideration of several factors, including timing of the availability of the new NCAR supercomputer (Yellowstone), progress of the model inter-comparisons described above and availability of human and compute resources.

The DTC also recognizes that extensive data sets are being produced by the WRF user community and these data sets provide additional resources to leverage. Members of the university community have been invited to collaborate with the DTC to establish Community Contributed Reference Configurations (CCRCs) in order to take advantage of these data and potentially create a more extensive collection of model verification results across a broader range of forecast applications. During AOP 2012, the DTC will continue to encourage and support the research community to share their results from significant testing activities in a manner that will benefit the community as a whole.

5.1.4 NEMS-based Systems

Now that NCEP has transitioned its North American Model (NAM) to NMMB under the NEMS software framework, the DTC also needs the capability to conduct T&E for NEMS-based systems. During AOP 2012, a framework based on NEMS will be established for internal DTC testing of promising contributions from the research community. Preliminary testing of this NEMS-based system will also be conducted to assure the system is working properly.

Anticipated major accomplishments for AOP 2012:

- DTC testing protocol and MMET established and publicized to the community-at-large.
- Reports on two WRF-based model inter-comparison tests conducted using functionally similar operational environments.
- New RCs designated for WRF v3.4.
- Functionally similar NEMS-based environment established and utilized for preliminary testing.
- Manuscript(s) submitted to appropriate peer-reviewed journals.

5.2 Hurricanes

During AOP 2012, the DTC will update its operational HWRF functionally similar environment for internal testing. This work will include adopting changes to run the three-domain HWRF, adding coupling to the ocean in the eastern North Pacific basin, and upgrading to GSI v3.1. The DTC will utilize this testing environment to perform a variety of T&E activities described below. Communication of DTC activities related to Hurricanes is important. While the DTC website is

one important means of making information available to the community, this method alone is not sufficient. Hence, the DTC will also dedicate time to producing journals articles on its key activities. For AOP 2012, two manuscripts describing HWRF's sensitivity to cumulus schemes and DTC's evaluation of the High Resolution Hurricane Test that was completed in September 2009 will be prepared and submitted to the appropriate journal.

5.2.1 Sensitivity Studies

Once the capability to run HWRF with the Thompson microphysics is in place, the DTC will begin conducting sensitivity studies using the Thompson microphysical parameterization. This scheme is more sophisticated than the scheme currently used in operations, as it contains prognostic equations for the mixing ratio of five microphysical species and number concentration of ice and rain. Additionally, it includes the advection of all species, rather than just the total water condensate. Testing of this scheme was considered a high-priority at the 2011 HFIP Physics Workshop.

5.2.2 Reference Configuration

A large test of HWRF, with over 200 runs, will be conducted with the objective of assessing the skill of the operational HWRF configuration in the general WRF repository. Results will be used to designate a Reference Configuration. The primary goals of this test are to create a benchmark for a) community members to use as a control when evaluating their developments and contributions, and b) the DTC to compare forecasts created with future model versions against in order to assess the improvement of the model over time.

5.2.3 *Testing Promising New Capabilities*

Using the DTC HWRF functionally similar operational environment, the DTC will conduct two comprehensive tests of alternate HWRF configurations based on promising advances for future EMC operational implementations. As discussed with EMC and HFIP, the focus of the first test will be on the sensitivity of HWRF to various cumulus parameterization schemes. The focus of the second test has not yet been determined and will be discussed beforehand with HFIP and EMC. A DTC HWRF Test Plan will be created outlining the details.

5.2.4 *Diagnostic Studies*

In-depth large-scale diagnostic studies will be conducted to help identify the strengths and weaknesses of HWRF and to provide information for improving the model. The large-scale environmental diagnostics are directed at identifying systematic model errors that may be tied to certain regions or deficiencies in the model's handling of specific physical processes. HWRF forecasts for the basin-scale domain (planned for 2014 operational implementation) will be compared against NCEP's Global Forecast System (GFS) analyses; errors will be computed and contrasted against those of the GFS model.

Anticipated major accomplishment for AOP 2012:

- New HWRF Reference Configuration.
- Report on sensitivity of HWRF to various cumulus parameterization schemes.
- Report on comprehensive tests of impact of a promising new capability on HWRF performance.
- Report on large-scale diagnostic studies.

- Manuscript(s) submitted to appropriate peer-reviewed journals.

5.3 Data Assimilation

5.3.1 DART System

The DTC will complete the benchmark tests started during AOP 2011 of the regional EnKF data assimilation system developed by the NCAR Data Assimilation Research Testbed (DART). Tests will be conducted to assess the impacts of assimilating conventional data and satellite data using the EnKF technique compared with the WRFDA. This work is in collaboration with NCAR/MMM.

5.3.2 GSI Baseline Tests

The DTC will conduct annual GSI baseline T&E in applications of operational interest. The DTC will utilize the latest released code of WRF and GSI to conduct various data assimilation (DA) configuration tests, comparing the results to a WRF run with no DA. These tests will be designed to provide useful information on the performance of the system and examine the impact of the DA configuration setup. The aspects of the GSI system, e.g., data impacts, background error covariance study, etc, to be tested will be determined through discussions with AFWA and EMC. The DTC will utilize the results from this baseline test to provide a basis to both operational centers and the research community for the GSI development and enhancement.

5.3.3 Impact of Radio Occultation Data on HWRF Forecasts

HFIP has identified the initialization of the HWRF operational forecast system as a key area in need of improvement. A recent project funded by COSMIC looking at the impact of assimilating GPS radio occultation (RO) data into initial conditions for the operational HWRF system has produced promising results for a limited number of cases. Hence, the DTC will undertake more extensive testing to explore the potential impacts of this data type. This testing will utilize the latest hybrid DA techniques in a hurricane environment.

Anticipated major accomplishments for AOP 2012:

- Reports on EnKF benchmark tests, GSI baseline T&E, and impact of GPS RO on HWRF forecasts.

5.4 Ensembles

The Ensembles task will focus its AOP 2012 T&E activities on two forecast applications: SREF and HWRF. The testing for the SREF application will focus on providing input to EMC on potential candidates for improving aspects of the ensemble system's configuration and potential new products, whereas the testing for the HWRF application will be focused on providing input on how to best configure a GSI-Hybrid DA scheme for HWRF.

5.4.1 SREF

For AOP 2012, the DTC plans to use its SREF functionally similar testing environment to perform tests that look at the impacts of higher horizontal resolution, replacing SREF's Ensemble Transform with Rescaling (ETR) technique with a cycling perturbations technique, and modifying the representation of model perturbations by replacing the SREF physics suite with a promising physics suite from the real-time Hydrometeorology Testbed (HMT) ensemble. These tests will be performed such that the SREF system is modified in a step-wise manner in order to document the impact of each technique. A report will be prepared on the head-to-head

extended period tests for the various techniques that will be provided to EMC and posted on the DTC website so the NWP community will also have access to the results.

In addition to testing new techniques for generating the ensemble members, the Ensembles task will also be testing the utility of various ensemble-based products that have been applied to the CAPS ensembles during past HWT SEs. These tests will address the utility of these methods when applied to a coarser resolution ensemble (16 km vs 4 km), as well as fields other than the standard precipitation and radar reflectivity fields used for the HWT SEs. A separate report will be prepared for this work, which will be provided to EMC and posted on the DTC website.

5.4.2 *HWRF*

NOAA has a strong interest in advancing a regional version of the GSI-Hybrid, specifically for the HWRF model in the near term. The Ensembles team will be working with a core group formed under the auspices of HFIP to accelerate the transition of this technology into operations for the HWRF application. A number of questions need to be address in order to assemble the most effective and efficient application of this technique to the initialization of HWRF. The DTC's testing activities will first investigate the use of ensemble members from NCEP's Global Ensemble Forecast System (GEFS) to generate an ensemble-based background error covariance matrix for use in the GSI-Hybrid technique. This error covariance matrix will have cross covariances (i.e., impacts of clouds on temperature, moisture on winds, etc…). This test will address whether the inclusion of such cross-covariances will lead to improved forecasts. DTC testing will also assess how these covariances are impacted by changes in the number of ensemble members, as well as the length scale (localization radius) used in the assimilation process.

Anticipated major accomplishments for AOP 2012:

- Report on the impacts on the SREF system of higher horizontal resolution, and alternative initial and model perturbation techniques in the context of precipitation prediction.
- Report on evaluation of CAPS ensemble-based products when applied to SREF.
- Report on GSI-Hybrid testing for HWRF using GEFS for the ensemble-based portion of the data assimilation.