Developmental Testbed Center Annual Operating Plan
1 April 2015 – 31 March 2016

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 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. The DTC Annual Operating Plan (AOP) for 2015 was developed based on recommendations from the DTC's Science Advisory Board (SAB) and the priorities of NCEP's Environmental Modeling Center (EMC) as articulated by the EMC team leads, as well as the priorities expressed by the DTC sponsors through their DTC Management Board (MB) members.

Director's Office Staff and Non-Salary Expenses

Motivation

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). In addition to a distributed staff, all DTC activities involve extensive interactions with external partners in both the research and operational communities. The DTC Director is responsible for the overall coordination of DTC activities and maintaining strong ties with the community. The DTC Assistant Director helps the DTC Director with this overall coordination. Due to the distributed nature of the DTC, the Director must rely on staff at the respective institutions to oversee the staffing, budgets and reporting to assure accountability. The DTC external management structure also requires administrative support for external meetings that goes beyond the day-to-day administrative support for staff contributing to DTC activities.

Project Description

The DTC Director's Office provides administrative and management support for all DTC activities. This support includes: (i) overseeing and coordinating the annual planning process (both internally and externally), (ii) managing and coordinating all DTC tasks, (iii) conducting DTC workshops and tutorials, (iv) 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, (v) creating and maintaining the DTC web site, (vi) coordinating the preparation and distribution of a quarterly DTC newsletter, and (vii) providing administrative support for DTC management meetings.

Project Deliverables

- Quarterly reports to EC
- Reports to sponsors
- Quarterly DTC newsletter

DTC Visitor Program

Motivation

Maintaining strong ties to both the research and operational NWP communities is critical to the success of the DTC's mission. The DTC Visitor Program provides an opportunity for the DTC, as well as our operational partners, to develop stronger ties with the research community, as well as serving as a mechanism to make research innovations available for considering by the DTC's operational partners.

Project Description

The DTC Visitor Program supports visitors to work with the DTC to test new forecasting and verification techniques, models, model components, and DA approaches for NWP and to perform diagnostic evaluations of the current operational systems. 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. The DTC offers the opportunity for two types of projects: 1) projects undertaken by the Principal Investigator (PI), and 2) projects undertaken by a graduate student under the direction of the PI. Successful applicants for the first type of project were offered up to two months of salary compensation, and travel and per diem, where the two months could be distributed over several weeks during a one-year period. Successful applicants for the second type of project were offered up to one year of temporary living per diem stipend and travel expenses for the graduate student to work with the DTC in Boulder, Colorado, or with DTC operational partners, and travel and per diem for up to two two-week visits to the DTC by the project PI. Researchers have a year to complete their project.

Project Deliverables

- Visitor project reports and transition of new NWP technology to community codes, as appropriate

WRF Users Workshop

Motivation

Maintaining strong ties to both the research and operational NWP communities is critical to the success of the DTC's mission. Workshops are one mechanism for bringing together a broad range of people working on a similar problem together to share information and ideas. The annual WRF Users Workshop is a forum that brings together researchers from around the world to share ideas and discuss future NWP development.

Project Description

The DTC proposes to continue to provide funding to MMM to invest in the organization of the 2015 WRF Users Workshop. This funding provides salary support for staff tasked with organizing the workshop. Expenses related to food and beverages provided at the workshop are covered by the workshop registration fee. In the past, this workshop has provided a productive forum for bringing together researchers and the operational community to discuss model strengths/weaknesses and potential new innovations for operational consideration. Topics discussed at this workshop include from model physics, data assimilation, ensembles systems and verification techniques.

Project Deliverables

- Co-host WRF Users Workshop

NWP Information Technology Environment (NITE)

Motivation

For scientists outside of the NWS to contribute relevant research and development, it is important that they work with the current operational codes, workflows, and input datasets. However, obtaining such codes and inputs, and configuring the system to run with data assimilation and cycling workflows identical to the ones used in operations, can be a daunting task for the research community. To facilitate the use of operational NWP systems by the R&D community, NOAA partnered with the DTC during the DTC's 2014 AOP to create the design of the NWP Information Technology Environment (NITE). The next step in this process is to make this design a reality. While the development of such an infrastructure will be NCEP's responsibility, the DTC can serve as a resource for assuring the end product will deliver on its ultimate goal: providing a framework for the research and operational communities to effectively and efficient work together towards improving the operational forecast systems.

Project Description

The DTC is proposing to allocate time for key staff members involved in its AOP 2014 NITE activity to continue their interactions with contacts at NCEP as NCEP takes on the task of implementing NITE. This allocation will allow NCEP to tap into the DTC expertise gathered through extensive review of practices used at NCEP, ECMWF, and UKMO to provide insight and guidance onto the implementation of NITE. The DTC can also provide a continued perspective of the broader community to this project.

Project Deliverables

- Contribution to NITE implementation through transfer of knowledge in model systems, particularly regarding connections with the external community

Data Assimilation System Code Management and User Support

Background

In July 2014, the EnKF and GSI operational repositories were merged into a single repository at EMC. Correspondingly, the GSI Committee Review Committee was expanded to include EnKF development teams and is now referred to as the joint DA Review Committee (DRC). These endeavors have laid the foundation for transitioning the EnKF package to a community-based system, benefiting the existing GSI community framework.

Project Description

For AOP 2015, the DTC is proposing to continue its DA system code management and user support activities. This work touches on three areas: chair and member of the DRC, maintenance of the DA Community Repository, and community support. GSI community support covered under this activity includes assistance provided to the DTC's operational partners, in particular AFW.

As the chair of the DRC, the DTC coordinates the meetings and code review procedures, as well as fulfilling the basic committee member duties, such as reviewing proposed code changes, testing proposed changes, and providing suggestions and advice on code development and support.

The DTC is also responsible for maintaining the DA Community Repository. This is necessary because of the restricted access and lack of the community support in the design of the EMC Operational Repository. The DTC will continue to synchronize the community repository with the EMC repository. The DTC will also maintain additional files required for community code releases through the DTC community repository. These files include libraries for running GSI and EnKF, a user-interactive multiple-platform configuration/compilation utility, and other community-based tools (e.g., BUFR format converter, diagnostic reading code and display scripts, etc.). These are essential for general users, especially those who do not have access to NOAA computers, to compile and run GSI.

The DTC is responsible for providing community support for the GSI system through code releases, tutorials, and the helpdesk service. A joint GSI and EnKF code release is planned for early summer 2015, with updated documentation followed by a joint DA tutorial at the NCAR Foothills Laboratory, Boulder, Colorado. This release and tutorial will mark the first official start for the EnKF system being a supported community code. Following this release, the current helpdesk capabilities will be expanded to include user support for EnKF. The DTC will continue to promote research community involvement through community outreach events, conferences and meetings.

Project Deliverables

- Joint DA code release and update documentation and DA Users' Page
- Joint DA tutorial
- Documented AFWA GSI support

Regional Ensemble-based (and hybrid) Data Assimilation T&E

Motivation

As highlighted by the DTC SAB, an effort needs to be made to build capability and support for ensemble-based (including hybrid) data assimilation for regional applications. This work addresses future operational data assimilation systems and complements the use of covariances from global models in current regional systems at NCEP. The SAB recommends that the DTC emphasize convective-scale NWP and ensembles, focusing on the next generation Ensemble-Variational (EnVar) DA and the challenge of using dual dynamic cores. It is also of interest to EMC and ESRL to advance such a system through objective testing and evaluation. In response to this feedback, the DTC DA team proposes building capabilities and performing regional ensemble-based DA tests in the context of NCEP's regional applications. This project will lead to transitions of research to operations in this area.

Project Description

The DTC proposes to test and evaluate EnVar capabilities for regional applications. This work will examine existing capabilities of this newly developed technique inside GSI and perform preliminary tests for regional cases. The DTC will start with ARW-based forecast systems in the regional tests, due to existing testing experience and capabilities. Such tests will help the DTC to apply the EnVar technique to NMMB-based forecast systems in the future. The goal of these tests are to examine the readiness of the GSI EnVar system for regional applications and provide an assessment of potential working areas for further improvement. The DTC will verify the results against the current operational configuration for regional applications (e.g., RAP configuration). The DTC will discuss the results with system developers and provide feedback for further code development, if required.

Project Deliverables

- Project report
- Presentation of results at conferences and workshops

NEMS software support & community engagement

Motivation

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 scientific techniques into operational weather forecasting. This framework is based on software systems that are a shared resource with distributed development. The current operational systems are 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 NOAA Earth Modeling System (NEMS) Nonhydrostatic Multiscale Model on the B-grid (NMMB) is one such system the DTC proposes to support to the community to facilitate operations to research (O2R) and research to operations (R2O) transitions.

Project Description

The critical elements undertaken for the NEMS software support and community engagement include maintaining the NEMS repository and external libraries, enhancing portability of the software system, enhancing physics options for NMMB, and offering user support through a variety of mediums. Each aspect is briefly described below.

The DTC will be responsible for maintaining a community NEMS repository, which will be kept in sync with the operational NEMS package (O2R). Community users may contribute modifications and enhancements to the community NEMS package; these modifications will be tested and made available to the operational community (R2O), as appropriate. In addition, the DTC will maintain a version of each of the external libraries required for NEMS-NMMB and these libraries will be shared among other DTC supported software packages to the greatest extent possible. Focus will be placed on ensuring the NEMS-NMMB software system is portable to the NCAR supercomputer, Yellowstone, and the NOAA supercomputer, Zeus, to facilitate additional community use.

To facilitate future multi-physics ensemble systems (specifically, NARRE) and future testing and evaluation (T&E) activities, work will be undertaken to port new or enhanced techniques into the NEMS repository for use with NMMB. Initial focus will be placed on enhancements to the RRTMG radiation scheme and inclusion of the Thompson aerosol-aware microphysics scheme.

An updated tag of the NEMS-NMMB code repository will be packaged and distributed broadly to the user community in AOP 2015. Prior to the code release, regression testing will be conducted on Yellowstone and Zeus to ensure the code is robust and portable. Ongoing support to maintain the Users' Guide and NEMS-NMMB webpage will be continued and the tutorial will be held on an annual basis. In conjunction with the tutorial, a one-day workshop will be held to discuss active research conducted with NEMS-NMMB. Once a core user base is identified, an email helpdesk will be established to more effectively support community users.

All NEMS software management and user support activities are collaborative efforts with the developers. Through this work, the DTC provides a pathway for the research community to contribute to the development of this operational software system.

Project Deliverables

- NEMS-NMMB code release and updated documentation
- In-person NEMS-NMMB tutorial at NCWCP

ARW software support and community engagement

Motivation

MM2a: Enhance the contributions to general WRF support for tasks that are traditionally under-funded. WRF is a community code with distributed development and centralized support. Though MMM contributes to the WRF modeling system for the community in many areas (including dynamics and physics development, WRF framework development, modeling system testing, and user support) additional activities are not well funded yet are critical to the overall success of the WRF package and offer great benefits to WRF users around the world. Hence, DTC funding is an important source to enable these additional support and development tasks.

MM2b: The ARW has a basic terrain-following vertical coordinate. Even though the coordinate surfaces do flatten with increasing height, the impact of terrain can still be seen even at the top of the model. The influence of terrain on model coordinate surfaces is reflected in the calculation of the pressure gradient force term as well as transport and dissipation terms, potentially causing spurious small-scale circulations. A hybrid vertical coordinate in the ARW model would improve the accuracy of the model numerics over mountainous terrain (e.g. Klemp 2011, MWR). This type of enhancement could be directly incorporated into the operational RAP and HRRR models to improve their forecast accuracy.

Project Description

MM2a: The DTC works in collaboration with NCAR's Mesoscale and Microscale Meteorology (MMM) division to maintain the WRF repository and make certain that robust software packages are distributed to the user community. As part of this process, regression testing of the WRF repository is performed on a weekly basis. The regression test suite currently includes 274 ARW real-data tests, 150 ARW idealized tests, 19 WRF-Chem tests, 42 NMM tests, and 2 HWRF tests. The regressions tests are run using three compilers on NCAR's supercomputer, Yellowstone: PGI, Intel, and GNU. Any issues that arise during the regression testing are resolved in a timely manner. Ongoing maintenance and enhancement of the regression test script to exercise new options and capabilities available in the latest code is conducted, as necessary, throughout the year.

A major WRF release is typically distributed to the user community on an annual basis, occurring in April. A minor bug-fix release often follows in July or August. In the three months leading up to the major release and one month leading up to the minor release, various tasks are conducted to ensure the quality of the released code, including maintenance of the WRF infrastructure, updates to WPS to support the latest functionality in WRF, and packaging the code for distribution.

MM2b: GSD's Environmental Modeling Branch (EMB) expressed interested in implementing a hybrid vertical coordinate in ARW to provide the opportunity to assess the impact in the RAP and HRRR systems that are developed at GSD and run operationally at NCEP. During AOP 2015, the vertical coordinate in ARW would be generalized to allow the influences of terrain on the coordinate surfaces to be removed more rapidly with increasing height and improve the accuracy of the pressure-gradient forcing term, as well as transport and dissipation terms. The project will involve recoding and/or modifying the ARW dynamical solver routines, code for generating initial and boundary conditions, and code for interfacing with physics. The new ARW dynamic solver will support both the original and hybrid terrain following coordinates and work with both ideal and real-data applications.

Project Deliverables

- MM2a: One major and one minor WRF code release
- MM2b: Generalized vertical coordinate in ARW

UPP software support and community engagement

Motivation

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 scientific techniques into operational weather forecasting. This framework is based on software systems that are a shared resource with distributed development. The current operational systems are 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 Unified Post Processor (UPP) is one such system the DTC proposes to continue to support to the community in order to facilitate operations to research (O2R) and research to operations (R2O) transitions. Currently, UPP is used in operations with the Global Forecast System (GFS), the North American Mesoscale (NAM) model, the Weather Research and Forecasting (WRF) Rapid Refresh model, and the Hurricane Weather Research and Forecasting (HWRF) model.

Project Description

The DTC is proposing to continue to collaborate with EMC to make the Unified Post Processor (UPP) tool available to the user community. UPP provides the capability to compute a variety of diagnostic fields, interpolate to pressure levels, de-stagger grids and interpolate to specified grids. These grid manipulations produce GRIB output files that can be used directly by a number of plotting packages and MET. The community UPP repository will be maintained in a manner such that updates and enhancements may be contributed by, and shared between, both the operational and research communities. A new community release of UPP will be distributed annually. Associated with each release, extensive testing will be performed. Both NetCDF and binary WRF output file formats will be tested in serial and parallel (using mpi) environments to ensure that a broad range of model output formats are compatible with the UPP software. The full suite of tests will be run on all of the computing platforms available to the DTC using a variety of compilers. Documentation updates will be made available to the user community with each release and user support will be provided by the DTC through help desk email support and presentations during the Basic WRF Tutorials. Because UPP is compatible with both WRF and NEMS, during AOP 2015, a stand-alone email help desk (upphelp) and webpage, with associated documentation, will be established and linked to the model components, as appropriate. Developer information for researchers interested in contributing to the Community UPP repository will also be compiled and made available on the UPP webpage.

Project Deliverables

- UPP code release and updated documentation
- Presentation at the Basic WRF Tutorials held at NCAR
- Stand-alone UPP webpage and email help desk established

Mesoscale Model Evaluation Testbed (MMET)

Motivation

To assist the research community with conducting detailed case study testing of newly developed techniques, the DTC established and is maintaining the Mesoscale Model Evaluation Testbed (MMET). The motivation for MMET is to assist the research community in efficiently demonstrating the merits of new developments that could positively impact an operational configuration in the future. Through the common framework provided by MMET, researchers have the ability to perform direct comparisons between multiple innovations tested by the research community and/or against the operational baselines established by the DTC. It is believed that with better coordination among the NWP community as a whole, major benefits towards improving model physics can be realized, resulting in more accurate and reliable operational NWP forecasts.

Project Description

As new versions of the WRF and NEMS code are released, the MMET cases must be rerun to provide current, relevant baseline results for the user community. Cases deemed irrelevant or too distant in the past will be eliminated from future version updates; however, previous versions will remain available through the data server. Several expansions/enhancements to MMET are proposed for AOP 2015 based on recommendations from the DTC SAB during the fall 2014 meeting. At this time, all MMET cases are cold-start forecasts with no data assimilation component. During AOP 2015, the DTC will implement the Gridpoint Statistical Interpolation (GSI) data assimilation system into the end-to-end workflow for both WRF and NEMS for the mesoscale cases. In addition, ARW baselines will be established for all cases using the operational RAP physics suite. In order to promote expanded interest among the research community, HRRR initial conditions (that include the digital filter initialization influence) and lateral boundary conditions will be made available for the MMET cases. Baseline results for each case will be run over a 15-km CONUS domain with a 5-km nest over the area of highest interest for select cases. In conjunction with adding a finer resolution nest option, inclusion of these HRRR datasets will allow the research community to closely emulate the HRRR system and conduct further research at convective-allowing scales.

The tropical cyclone (TC) community is placing increased emphasis on observational-based evaluation and diagnostics of TC numerical forecasts for the purpose of improving NWP models. This emphasis is reflected in the recommendations from the Workshop on the Strategic Use of Observations to Reduce Model Physics Uncertainty held in Boulder, CO in August 2014, and in subsequent work comparing dense Hurricane Edouard observations with model forecasts. For AOP 2015, the DTC is proposing to add a few TC cases to MMET to support and enhance the ability of scientists to conduct diagnostics and model improvements for TC NWP models, including HWRF. The DTC Hurricane Task will supply the TC runs and observations to be disseminated through MMET.

Through enhanced collaborations with community users, improvements to operational physics suites may be realized in a more efficient manner. One way to accomplish this is through the DTC Visitor Program. The research community will be encouraged to interact with the DTC on MMET cases through a variety of forums.

Project Deliverables

- Code base/configurations updated for select cases to use the latest versions of WRF and NMMB
- TC cases added
- Data assimilation component and nesting capability added
- Baseline results expanded to include NAM, RAP/HRRR, and HWRF physics suites

Test of Expanded HRRR-ARW Domain

Motivation

The High-Resolution Rapid Refresh (HRRR) model represents a major step forward in the operational prediction of severe thunderstorms and mesoscale convective systems as well as other year-round mesoscale phenomena. It became operational at NCEP on 30 September 2014, after extensive real-time evaluation by forecasters at NCEP's Aviation Weather, Storm Prediction and Weather Prediction Centers (AWC, SPC and WPC), as well as by the Federal Aviation Administration. In addition to the original purpose to improve prediction of warm–season convection and its impact on the National Aerospace System, the HRRR has found wide acceptance by forecasters in and out of the National Weather Service as guidance for a variety of weather phenomena in all seasons, including East Coast winter storms, winter precipitation type, timing and intensity of heavy non-convective and convective precipitation, land-falling tropical cyclones, and hub-height wind trends for the renewable-energy industry.

The HRRR uses the ARW dynamical core and a physics package (under continued active development) that has proved effective in capitalizing on the cloud-permitting resolution of the model. The Earth Modeling Branch of ESRL-GSD has developed unique initialization procedures using radar and satellite as well as conventional in-situ observations together with a 1-h Rapid Refresh (RAP) forecast. These are continually being improved to achieve much better forecast accuracy at very short lead times of 1-3 h. The HRRR currently uses lateral boundary conditions provided by the previous hour's RAP forecast.

As computing resources at NCEP continue to increase in coming years, we foresee that the current regional models, the NAM and RAP, will be replaced (within 5-7 years, perhaps sooner) by regional cloud-resolving configurations of similar domain size to that of the current NAM and RAP. These will be nested within the then operational global model.

Looking toward that day, and in view of the importance of accurate short-term forecasts for vulnerable coastal areas, particularly along the Gulf and Atlantic coasts, we propose to investigate the value of an initial expansion of the HRRR domain in all directions, but mainly toward the east and south. Coastal storms (aka Nor'easters) that impact the heavily populated east coast with high winds, heavy precipitation, and often a very disruptive "wintry mix" of precipitation are often close enough to the current lateral boundaries of the HRRR, particularly during their formation and deepening stages in the

Gulf of Mexico and in the southwest North Atlantic between the southeast US and Bermuda, and as they pass seaward of New England as they track north or northeastward, that the circulation is not well described within the model domain itself. The lateral boundaries of the HRRR domain are often within the storm circulation, leading to flow distortions. Such an expanded domain would also allow for improved prediction of tropical systems that are within, say, 48-h striking distance of the US mainland. Although the present HRRR forecasts only extend to 15h, there is considerable interest on the part of forecasters within and outside of the NWS to see an extension of the HRRR to 36-48h at least four times per day. The possibility of this lead-time extension further motivates an expansion of the HRRR domain.

Project Description

1. Decide on domain … adequate to satisfy concerns with present HRRR domain stated in the Motivation section, but still small enough to be practical for NCEP operations within next 2-3 years.

2. Refine existing initialization procedures in use in RAP and HRRR or under development (satellite-based cloud top cooling, other cloud analysis developments, enhanced cloud-to-cloud lightning) for convection and mesoscale convective systems using lightning and satellite.

3. Collaborate with HWRF developers, GSI developers and others on options for TC initialization as appropriate.

4. Assess model physics for ARW for larger domain applications including winter storms and tropical cyclones. Assess HRRR physics suite (Thompson aerosol-aware, MYNN PBL, RUC LSM, RRTMG, etc., all under continuing development.) Also, collaborate with HWRF on possible testing of some HWRF physics options as alternatives for improved TC forecasting.

5. Produce retrospective and real-time (to the extent computing resources permit) forecasts, and evaluate utility and forecast accuracy (relative to operational or GSD developmental RAP and HRRR). This would include evaluation of the adequacy of the existing HRRR physics suite for this application with a larger overwater portion of the domain.

Project Deliverables

- Upgraded procedures for initialization of convection-permitting models over ocean areas prone to deep convection, mesoscale convective systems and tropical cyclones.
- Recommendation for domain configuration and physics suite for expanded HRRR using ARW.

HWRF User Support

Motivation

The primary goal for this activity is to provide and support the state-of-the-art HWRF end-to-end system to the research community. With more scientists using HWRF, we can expect NCEP will receive more feedback on the model's performance, which will lead to numerical forecast improvements. In addition to its use by the community at large, several recipients of the HFIP grants are relying on the public release HWRF code and/or documentation to conduct their research.

The planned HWRF v3.7a release will contain the all updates included in the 2015 operational HWRF, plus additional research capabilities. Given the substantial HWRF advancements since the 2014 public release and tutorials, such as the multi-storm (*basinscale*) capability and the object-oriented Python running scripts, an in-person tutorial is planned for AOP 2015.

An additional software release for the stand-alone GFDL Vortex Tracker is planned. This tool can be used as a postprocessing step for any Tropical Cyclone (TC) numerical model, and as such the DTC public release is a step toward standardization of practices and codes used in the TC community.

Project Description

DTC will test the new HWRF capabilities (e.g. higher horizontal resolution, use of T1534 GFS, ocean initializations, enhanced idealized capabilities, *basinscale* configuration, alternate physics, etc.) on multiple platforms so users around the world can benefit from a range of scientific options valuable for TC research and forecasting. Revised support documents will be prepared to accompany the public release: HWRF scientific documentation, HWRF Users' Guide, datasets and an online tutorial. The HWRF FAQ, and Known Issues webpages will be updated. Bug fixes will be posted as they become available. The HWRF release and support will include a set of running scripts and eight updated components: WRF atmospheric model, WPS atmospheric preprocessor, GSI data assimilation, *hwrf-utilities* (which includes a vortex relocation package), atmosphere-ocean coupler, MPIPOM-TC ocean model, UPP postprocessor, and GFDL Vortex Tracker.

An HWRF tutorial is planned for College Park, MD, in the fall of 2015. Preliminary discussions with EMC indicate November might be a suitable time frame. The tutorial will consist of lectures by EMC and DTC staff, as well as invited speakers from URI, GFDL, and HRD.

A subset of the HWRF package, composed of libraries and the GFDL Vortex Tracker, will be tested and documented for stand-alone use with a generic NWP TC model.

The DTC will maintain a helpdesk to support users in troubleshooting compilation and running issues. A ticketing system will be implemented to keep track of the help requests.

Project deliverables

- HWRF v3.7a public release with updated documentation and HWRF Users' Page
- GFDL Vortex tracker v3.7a public release with updated Users' Guide
- User support helpdesk with ticketing system
- In-person HWRF tutorial in College Park, MD

HWRF Developer Support

Motivation

The primary goal for this activity is to facilitate HWRF development, leading to enhanced capabilities available to EMC for potential operational implementation. Through this work, we seek to maintain all HWRF developers working on the same code base, therefore avoiding divergence of efforts and creation of code that cannot be easily integrated in the centralized repository. The DTC hosts the HWRF code repository, which is composed of a sophisticated set of scripts plus eight source code components: WRF atmospheric model, WPS atmospheric preprocessor, GSI data assimilation, *hwrf-utilities* (which includes several libraries and a vortex initialization package), ocean-atmosphere coupler, MPIPOM-TC ocean model, UPP postprocessor, and vortex tracker. In addition to enhancing inter-developer collaborations, the DTC hosts non-operational aspects of HWRF, such as a repository for HYCOM and a repository (*hwrf-contrib*) that can be used by community members to share tools they develop but that are not supported or maintained by the DTC. In AOP 2015, the DTC will start the process of transitioning WAVEWATCH III as one of the HWRF components, as it is expected to become operational in the near future. An important aspect of this work is coordination and training for HWRF developers.

Project Description

The DTC will continue to maintain the HWRF code repository and coordinate the links to all external source code components. The DTC will update the main HWRF development branches with all developments in the trunk of the community source code repositories, assuring that the main HWRF development and the community codes remain synchronized. The HWRF repository integrity will be regularly checked through Consistency Checks, which are tests to ascertain that code changes not intended to alter the answer of the operational HWRF configuration indeed do not do so.

The DTC will facilitate the use of code management tools to HWRF developers external to EMC. This facilitation will be done through training and SVN assistance to developers, as well as through conducting regression tests and consistency checks on the developments, as applicable. In addition, the DTC will enhance computational platform interoperability by working with developers to make sure their code is portable and usable by the broader community. Particular emphasis will be given to supporting the HFIP principal investigators in accomplishing the development funded by their grants.

We will continue to maintain and enhance *hwrf-contrib*, anticipating having new contributions to this repository by the end of the AOP 2015. Note that DTC will maintain the *hwrf-contrib* code repository and support access to it, but maintenance, documentation and support of the codes in *hwrf-contrib* will be done by the contributors, at their discretion. In another aspect of model infrastructure, DTC will continue to enhance the HWRF build system, a set of tools designed to efficiently compile and install the HWRF source code. Finally, we will continue to host the HWRF Developers Committee meetings, maintain the mailing lists used by the HWRF developers, and centralize the overall communication among HWRF developers.

Project deliverables

- Unified HWRF code with additional developments ready for testing by EMC.
- Code integrity tested through regression and consistency checks, as applicable.
- Development of a code management and plan for inclusion of WAVEWATCH III as a supported HWRF component.
- Code repository *hwrf-contrib* maintained and protocols for contributing code well documented.

HWRF Physics Advancement

Motivation

The HFIP community has invested a substantial amount of effort over the last few years to investigate and improve the representation of physical processes in HWRF. The PBL parameterization in HWRF has been improved (by AOML/HRD) with the addition of the *alpha* parameter and with the dependency on the critical Richardson number (by EMC). These two innovations lead to forecasts that are now more consistent with observations but further refinements are being made. Through Prof. R. Fovell's (UCLA) participation in the DTC Visitor Program, additional changes to the PBL height specification have been made and are currently being tested by EMC.

The effects of the PBL parameterization on the forecast fields cannot be easily separated from those of cloud-radiative forcing (CRF). Work by Bu et al. (2014) and R. Fovell (HFIP Telecon presentation 24 Sep 2014) has shown that both the PBL scheme and cloud radiative feedback (CRF) impact storm size, which in turn influences storm motion through the beta effect. Several efforts have been taking place to improve CRF in HWRF. Those efforts include diagnostics of deficiencies in the GFDL radiation scheme used in the operational HWRF, and the push to implement a more sophisticated radiation scheme (the RRTMG parameterization). However, tests of HWRF with the RRTMG radiation parameterization conducted by EMC (with Ferrier microphysics) and by DTC (with Thompson microphysics) showed mixed results, and EMC was not able to implement the RRTMG scheme in the 2014 operational HWRF.

Additional work in this area in 2014 involved the incorporation of a scale-aware partial cloudiness scheme in RRTMG by Greg Thompson of DTC, which compensated for the lack of representation of stratus clouds in the HWRF parent domain. This innovation has been tested by DTC and transitioned to EMC for consideration for operational HWRF implementation. The DTC has performed additional diagnostics and showed that the RRTMG radiation parameterization does not create any CRF related to clouds activated by the SAS convective parameterization used in the operational HWRF. The SAS-RRTMG connection and the fine tuning of parameters in the partial cloudiness scheme are prime areas for continued work in HWRF physics improvements.

The collaborations listed above among DTC, EMC, HRD, and UCLA are augmented by additional work in physics diagnostics and development currently being conducted by DTC Visitors (Shaowu Bao of SCCU and Tom Galarneau of NCAR) and recipients of HFIP grants. The DTC has also started a collaboration with John Knaff and Kate Musgrave of CIRA on the use of satellite observations to verify HWRF cloud forecasts.

In summary, there are several ongoing efforts to improve HWRF physics by community Subject Area Experts (SAEs), and the DTC is in a unique position to coordinate and test innovations, and to provide EMC with information and codes that can be used for improving the operational HWRF.

Project Description

This project has two aspects: physically-based diagnostics and improvement in the representation of physical processes. The DTC proposes to run HWRF retrospective forecasts and compare the results of near-surface winds, QPF, clouds, and radiation against observations of the same variables or available proxies, including satellite images. These diagnostics will complement the usual track and intensity verification to provide input on HWRF's representation of physical processes.

Based on the results obtained from this diagnostic work, the DTC will work toward improvements in the HWRF physics. The DTC will conduct a sensitivity study of the cloud/radiation fields to parameters used in the partial cloudiness scheme (e.g., the dependency of the relative humidity threshold on grid spacing, and the algorithm for determining the liquid- and ice-water content of the partial clouds). The need for establishing a connection between the SAS convective clouds and the RRTMG radiation will be investigated and addressed if needed. Following controlled diagnostics, sensitivity experiments, and multi-storm testing, the DTC will make available improvements to the HWRF physics. In each activity, DTC will seek connections with community Subject Area Experts to leverage ongoing activities funded by DTC, HFIP, NGGPS, and others.

Project deliverables

- Large-scale physics diagnostic tools that can be applied to multiple HWRF T&E experiments
- Report on results of sensitivity experiments to various aspects of HWRF moist physics, including the parameters used in the partial cloudiness scheme
- New capabilities in HWRF physics made available to EMC for testing

NARRE repository maintenance and Rocoto end-to-end workflow

Motivation

The North American Rapid Refresh Ensemble (NARRE) is a complex system currently consisting of seven software components including data assimilation (GSI), two pre-processing systems (NPS and WPS), two different dynamic cores (NEMS-NMMB and WRF-ARW) and a post-processing system (UPP). In order to ensure coordinated research, development, and transition of new or enhanced techniques to operations for the various system components, it is critical to establish and maintain a NARRE repository for use among various centers, including EMC, ESRL/GSD, and NCAR.

Workflow management systems make executing large testing and evaluation activities more efficient through managing complex interdependencies and requirements. NARRE is one such complex system that requires workflow management to effectively execute the large number of tasks. When factoring in the pre-processing, including data assimilation, running the model itself, post-processing, calculating verification scores, and visualizing the results, one "run" of the ensemble modeling system can entail hundreds of individual calls to different software system components and scripts. The complexity of the system makes the process of running NARRE onerous for an operational center and nearly impossible for the research community to emulate on their own.

Project Description

During AOP 2015, the DTC is proposing to establish a well-maintained NARRE repository for use among EMC, ESRL/GSD and NCAR. The NARRE repository will be composed of links to existing repositories of the current components (GSI, NPS, WPS, NEMS, WRF, and UPP) in order to remain in sync and eliminate redundancy in repository maintenance. Making the repository available to a wider community will be a part of the AOP 2016 activities.

During AOP 2014, a Rocoto-based workflow to run the NAMRR system was ported to Yellowstone, one of the available platforms for DTC experiments, by NCAR staff. GSD staff also have access to the RAP system workflow in Rocoto. These two systems are, at the present time, expected to be the two main components of the NARRE. Using the two workflows already established, a unified workflow using Rocoto, will be established for NARRE, which will include NAMRR and RAP, the Short Range Ensemble Forecast (SREF) post-processing package, options for various initial condition perturbations (e.g. breeding used in SREF), MET for verification, and visualization scripts. For this initial year, the workflow will be designed to run on Zeus (NOAA) and Yellowstone (NCAR) supercomputers, providing the DTC with a functionally similar operational environment for future NARRE testing and evaluation.

Project Deliverables

- NARRE repository established and maintained for use by EMC, ESRL/GSD and NCAR.
- NARRE Rocoto-based workflow established on Zeus and Yellowstone supercomputers.

Testing of stochastic physics for use in NARRE

Motivation

Current plans for NARRE address model-related uncertainty by using a combination of multi-dycore (ARW and NMMB) and multi-physics, where the physics suites are those used in current operational systems (RAP and NAM) and variations of these well-tested suites. An ensemble system based on multiple physics suites comes at the price of needing to maintain multiple physics packages. To minimize ensemble system maintenance, the ultimate goal is to move towards representing model uncertainty through a stochastic physics approach. Before moving forward with such a transition, the value added by applying a stochastic physics approach must be demonstrated.

Project Description

For AOP 2015, the DTC proposes to perform an evaluation of how the performance of a multi-physics NARRE configuration compares to the performance when the model uncertainty is addressed by applying a stochastic physics approach. This work will build on the AOP 2014 pre-NARRE activity in which preliminary testing of the impact that changes in physical parameterizations have on the ensemble performance was evaluated. For the pre-NARRE testing, variations in physics were limited to the ARW members, with perturbed initial and lateral boundary conditions applied to both ARW and NMMB members (see Table 1). For AOP 2015, the DTC will use this multi-physics design as a baseline for evaluating the value added by applying a stochastic physics approach. The latest version of the ARW core includes an option for the generation of a random perturbation field that can be used for parameters in physics parameterizations (stochastically perturbed parameterization scheme SPPT, Buizza et al. 1999, Palmer et al. 2009, Berner et al. 2014). This option was implemented in ARW by Judith Berner of NCAR. The stochastic pattern is centered on zero and has a user-prescribed standard deviation. With this option, the user can specify random perturbation length-scale, temporal de-correlation of the randomly perturbed field and vertical structure of the random perturbations. One example of random patterns spatial distribution is illustrated in Figure 1. These patterns can be used to perturb either lower boundary conditions or parameters.

Table 1. Pre-NARRE configuration tested over a limited period of time during AOP 2014

	MP	Sfclay	Sfcphy	PBL	CU	IC/LBs
rap	Thompson	MYNN	RUC	MYNN	GF	GFS
rap1	Thompson	MO-MYJ	RUC	MYJ	BMJ	GEP01
rap2	Ferrier	MO-MYJ	RUC	MYJ	BMJ	GEP02
rap3	Ferrier	MYNN	RUC	MYNN	GF	GEP03
nmb	Ferrier	MYJ	NOAH	MYJ	BMJ	GFS
nmb1	Ferrier	MYJ	NOAH	MYJ	BMJ	GEP01
nmb2	Ferrier	MYJ	NOAH	MYJ	BMJ	GEP02
nmb3	Ferrier	MYJ	NOAH	MYJ	BMJ	GEP03

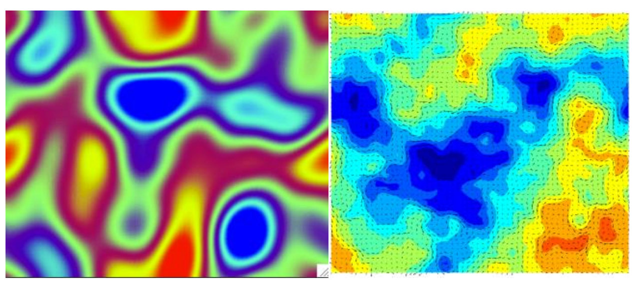

Figure 1. An illustration of random patterns that could be used to perturb either lower boundary conditions or parameters (courtesy of Judith Berner).

Close collaboration with the developers of the physical parameterizations (e.g. Thompson microphysics, MYNN PBL and RUC LSM) and of the perturbation scheme will facilitate the process of identifying parameters of interest and the range of their perturbations. The choice of what physics parameterization is stochastically perturbed will determine the design of the mixed-physics ensemble used as a baseline. For example, if the microphysics scheme is stochastically perturbed, the mixed-physics ensemble will include variations in microphysics schemes. Results obtained using Thompson microphysics would be applicable to NMMB dynamic core.

The NARRE output over an extended period of time will be evaluated on how the multi-physics vs. stochastic approach affects the ensemble performance in terms of bias, skill, accuracy, reliability and sharpness. The ensemble verification system developed by EMC will be utilized.

Project Deliverables

- Report on experiment results

Verification Outreach and Community Support of the MET system

Motivation

The Model Evaluation Tools (MET) verification package is comprised a series of tools designed to help users with pre-processing, data inspection, and calculation of both traditional and spatial statistics. Aggregation of those statistics and attributes can be performed using the MET analysis package or through the METViewer database and display system. MET is a community-supported software package with over 2550 users. Following its September 2014 release, 50 new users registered and 125 downloads were requested. MET and specifically MODE (Method for Object-based Diagnostic Evaluation) is being used either operationally or to make operational decisions at NCEP's Weather Prediction Center (WPC), the UK Met Office, and the South African Weather Bureau. Supporting MET and METViewer to the community is necessary to meet the DTC mission of connecting the research and operational communities by using common tools with repeatable results.

Project Description

User requests for expanded MET capability are logged in a JIRA ticketing package, including capabilities identified during visits to NOAA and NCEP this past year. Analysis of these requests have identified several good candidates for continued MET development, including: expanded computation of scores using climatologies and reference models, percentile thresholding for categorical statistics; conditional verification of continuous fields; and support for additional observation types. Additions to MET capabilities will require an extension to METViewer capability as well (e.g. aggregation of conditional verification of continuous fields). Hence METViewer development and optimization is also included in this task. Additionally, scoping for AOP 2016 of METViewer scalability to large datasets (i.e. global data and operational dataset for multitudes of models) will be performed.

Prior to the next MET release in the summer of 2015, several activities will need to be completed including pre-release testing and the addition of regression tests for the new MET and METViewer capabilities. Additionally, the verification team would like to substantially improve documentation for MET and add more use-case based documentation for METViewer. The goal is to move toward a system of "document once and publish in many formats" (i.e. Users Guide, website, online tutorial, usage examples, etc.). This approach will help all end-users and decrease our future costs of maintaining documentation. User support and community outreach will be achieved through maintenance of the MET website, continuing to address MET help questions in a timely manner, attending the WRF User's Workshop and offering a mini-tutorial at the WRF Users Workshop, if the opportunity arises. One person will also attend the AMS Weather Analysis and Forecasting/Numerical Weather Prediction conference.

Project Deliverables

- Addition of at least five new MET/METViewer capabilities useful for R2O, many of which are applicable to NCEP needs.
- MET release in early summer
- Improved documentation including potential time and cost savings for future years
- MET help and community outreach throughout year

NOAA/NCEP Community Support and Outreach

Motivation

The MET and METViewer systems were originally developed to provide the functionality of the NCEP verification system to the community while being platform independent and expandable. Over the past few years, the two systems have diverged to some extent. During a visit to NCEP in November 2014, NCEP's Mesoscale Modeling Branch (MMB), Global Branch, including the ensembles groups in both branches, expressed interest in many of the MET capabilities. For example, the NEMS Global Aerosol Component (NGAC) is now using MET Point-Stat to evaluate their aerosol forecasts and intends to start using Method for Object Based Diagnostic Evaluation (MODE) in the near future. The Global Forecast System (GFS) group is building a precipitation evaluation system around MODE. Furthermore, the MMB has asked NCEP Central Operations (NCO) to find a place to install METViewer for use by their staff. Outside of EMC, the Weather Prediction Center has expressed interest in expanding their use of MET and discussions with the Meteorological Development Laboratory, the Warn-On-Forecast group, and the National Severe Storms Laboratory have resulted in proposal writing and exploration of how to collaborate. Given this expressed interest in using common tools and unification of systems, it is imperative for MET to include all the critical elements of the verification systems being used at NCEP. While the DTC's current activities are focused on regional NWP applications, it seems prudent to consider not only the needs of the MMB but also those of the Global Branch to facilitate the development of a unified verification tool to reduce costs and eventually to verify the Next Generation Global Prediction System.

Project Description

During the Verification task visit to NCEP in November 2014, a few critical elements of the NCEP system were identified as missing from the MET system. Additionally, there were several areas of enhancement beyond the NCEP system that were identified as potential candidates for inclusion in MET. This proposed activity is intended to maintain the relationship with NOAA and specifically NCEP EMC. Due to the limitations of funding, the MET team has removed much of the originally proposed capability and has selected a few capabilities to be fully supported by VX1. The overall goals of this work are to take a few steps toward re-aligning the MET/METViewer system with those used at NCEP and to provide an avenue for communication between the groups for future planning.

Work has already been started to support NCEP in installing METViewer within the NCO compute farm at NCEP. This technology will ultimately allow files in both VSDB and MET formats to be available in METViewer by all NCEP users. Having METViewer capability at NCEP will allow NCEP groups to explore the utility of METViewer, as well as be available for system intercomparisons in the future. Through this proposed activity, the DTC will work with EMC staff to bring the installation process to conclusion. The verification team will also be available to support new and current NCEP and NOAA users to maximize MET's current capability. Minor enhancements to MET will be made if time and funds are available. Finally, it is clear that communication between NOAA and the DTC needs to be maintained. Hence two trips to NCEP are included in this activity, as well as staff hours to stay connected with the NOAA staff.

Project Deliverables

- Continued support of METViewer installation at NOAA/EMC
- MET support to NCEP end-users