Developmental Testbed Center

2018 Annual Operating Plan

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 2018 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. The nominal performance period for AOP 2018 is 1 April 2018 to 31 March 2018, but due to variations in the performance period of the funding mechanisms for the two nodes, some of the work described in this plan goes through early May 2019.

DO1: 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), NCAR's Mesoscale and Microscale Meteorology (MMM) Laboratory, and the Air Force] 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.

The budget for this activity includes support for the DTC Director and Assistant Director, as well as allocations for staff providing support for DTC events and the newsletter. The budget for the NCAR node also includes the cost of staff computers and expenses related to hosting the annual DTC Science Advisory Board and Management Board meeting. In addition, the budget includes a small reserve (NCAR - $25 K / GSD - $5 K).

Project Deliverables

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

DO2: 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 Air Force) 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 are 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 are 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. The proposal is to allocate $80 K from the DTC's NOAA funds to support visitor projects and submit a proposal to NSF to match this $100 K. The additional $20 K in the budget for this activity covers computing support costs for the visitors.

Project Deliverables

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

DO3: 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 2018 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 model physics, data assimilation, ensembles systems and verification techniques.

Project Deliverables

- Co-host WRF Users Workshop

DO4: Unified Forecast System user support

Motivation

Through the National Weather Service (NWS) Research to Operations (R2O) initiative, NWS is looking to engage a wide sector of the numerical weather prediction (NWP) community with the goal of making significant strides towards improving the forecast skill of its global weather prediction model. In response to recommendations from the UCACN Model Advisory Committee (UMAC), NCEP's Environmental Modeling Center (EMC) also plans to move towards a unified modeling suite across both spatial (regional and global) and temporal (weather, sub-seasonal and seasonal) scales. Unifying its modeling suite around GFDL's Finite Volume Cubed Sphere (FV3) as the atmospheric dynamical core is at the center of this plan. Engaging of broad sector of the NWP community in the advancement of the NOAA modeling suite will require a framework that includes well-defined code management practices, documentation, community access to code and datasets, user support, and testing and evaluation protocols.

Given the cultural differences between the research and operational communities, defining a framework that meets the needs of both groups is not necessarily straightforward. The research community needs flexible and simple tools that support basic research and allow graduate students to quickly engage and pursue research projects using a stable system. In contrast, EMC requires software infrastructures that minimize performance impacts and failures. As the NWS looks to its key national partners (i.e., NOAA research laboratories, NCAR, Navy, NASA) to join in an effort towards a unified modeling system, it will be important to clearly define a framework that meets the needs of all these groups.

Based on past experience, the DTC is well aware that building on existing infrastructures and engaging existing community elements can be much more cost effective then trying to establish an infrastructure and community from scratch. Due to its distributed nature, DTC staff are well connected with on-going efforts at NCAR and ESRL directed at unifying modeling efforts and engaging the research community. DTC staff also have well-established relationships with EMC staff and are aware of the needs of the operational community. Through its past and current activities, DTC staff have established good working relationships and connections with other key partners. To optimize the use of available resources and to maximize the return for investment over the long term, it will be important to carefully assess the best approaches for setting up and effectively supporting a community modeling infrastructure that meets the needs of the research and operational communities. Such an infrastructure will also need to support two tiers of community contributors: 1) core developers who will need to engage directly with the code repositories and have active communication mechanisms to allow timely sharing of information across all core development groups, and 2) general users conducting research with a public release of the code.

Project Description

For AOP 2018, the DTC proposes a two-pronged approach to standing up a user support framework for the Unified Forecast System (UFS). The first aspect of this work is geared towards meeting NOAA's immediate need to provide user support for the UFS Convective Allowing Model (CAM) capability. The DTC will stand up an initial user support framework for the UFS-CAM based the protocols used for the GSI/EnKF data assimilation system and HWRF. This framework will include a code management plan that addresses how community contributions can make their way into the code repository and testing protocols, code release procedures (including the need to address code portability), a UFS-CAM Users'

Guide, scientific documentation and helpdesk support. The DTC will work closely with the UFS-CAM developers to prepare an initial UFS-CAM Users' Guide and work with the developers to assure the scientific documentation is ready for distribution with the initial release. The UFS-CAM Users' Guide will be an evolving document that where the initial version will consist of basic instructions for setting up and running the UFS-CAM and then gradually be expanded over time as capabilities are added and the DTC staff better understand how to setup and run the system. The DTC will also establish an email helpdesk system with a ticketing capability. An initial release of the UFS-CAM capability is anticipated in the fall of 2018. A kick-off meeting is under discussion to correspond with the timing of this initial release. The DTC will work with EMC to prepare materials for this meeting, which will presumably include information on how the community can obtain the UFS-CAM code and support for running this system. The second aspect of this work will be geared towards developing a longer term vision for how to most effectively address user support for all applications of the UFS. This longer term vision will be based on an investigation of user support frameworks for existing community models that looks at the resource requirements and effectiveness of each approach.

Project Deliverables

- UFS-CAM Users' Guide
- Helpdesk support for UFS-CAM
- Proposal for longer-term UFS user support framework

DO5: Enhancing community collaborations through DTC-supported software containers

Motivation

A major hurdle for running new software systems is often compiling the necessary code on a particular computer platform. In recent years, the concept of using "containers" has been gaining momentum in the numerical weather prediction (NWP) community. This new container technology allows for the complete software system to be bundled (operating system, libraries, code, etc.) and shipped to users in order to reduce spin-up time, leading to a more efficient setup process. A core mission of the DTC is to assist the research community in efficiently demonstrating the merits of model innovations and development. Support of end-to-end NWP containers is an effective approach for fulfilling this mission.

In recent years, end-to-end NWP software components [WRF Pre-Processing System (WPS), Weather Research and Forecasting (WRF) model, Unified Post-Processor (UPP), NCAR Command Language (NCL), Model Evaluation Tools (MET), and METViewer] were implemented into Docker containers to better assist the user community. The work conducted by DTC staff leveraged and complemented previous efforts of the National Science Foundation sponsored Big Weather Web (http://bigweatherweb.org/) project that initially established NWP software containers for the WPS, WRF and NCL components. For AOP 2017, DTC staff expanded these capabilities to include UPP, MET, and METViewer in containers. Through this complementary work, a full end-to-end NWP system was established, allowing for verification of model output and visualization of statistical output. To continue to build on these efforts, a natural path forward is to explore developing additional capabilities such as the inclusion of a data assimilation capability in a container.

In addition, with the establishment of NWP end-to-end testing in software containers, focus should now be placed on increasing the functionality and usability of the containers. As models are run at higher resolution and the use of ensembles becomes more prevalent, the amount of necessary data can be overwhelming, especially on local work stations. One way to address this storage issue is through cloud computing, which will allow for the ability to store large data sets that can be accessed by the

community. With the increasing size of data volumes, it is less feasible to move the data around; rather, the need to use cloud computing in conjunction with High Performance Computing (HPC) is becoming increasingly imperative in order to bring the science to the data.

Project Description

For AOP 2018, the DTC is proposing to maintain the current NWP containers, as well as establish a new container for data assimilation. In addition to the code itself, these containers will include all critical test data sets. The knowledge gained during previous years will be leveraged to streamline the process of implementing similar technology for the DTC-supported GSI three dimensional variational data assimilation (3DVar) software system in the coming year. In addition, work during the next period of performance would include enhancements to the original containers to meet the requirements for distributing a robust software capability, including relevant bug fixes and/or version updates. All established containers would be made publicly accessible on Docker Hub. For AOP 2017, an online NWP tutorial was created to step users through building and running an end-to-end system; it is proposed to enhance this tutorial as new tools become available and provide community support to users running the DTC containers, which is essential in helping attract and maintain an active user community.

To further develop DTC NWP containers, the DTC proposes to broaden their knowledge and expertise in cloud computing and using HPC in conjunction with containers. With the expanding data sets and the increase in computational demands of higher resolution modeling, having the ability to run an end-to-end system "in the cloud" will be appealing to both students and the research community. Ultimately, cloud computing offers an excellent opportunity to provide a sandbox for the community to share output and datasets, allowing for more cross-community interactions. This work will leverage and build upon the requirements information gathered during AOP 2017 under DO4. The DTC will also explore additional container platforms beyond Docker (e.g., Singularity) that may support execution on high performance computing systems.

Communication is a key mechanism to serving as a bridge between research and operations and informing the community about this container-based platform is critical to its success as a community tool. For AOP 2017, a full-day short course titled Simplifying End-to-end Numerical Modeling using Software Containers was given at the 98th AMS Annual Meeting. This course was successful in reaching and engaging interested parties in the user community and highly rated by participants. Thus, it is proposed to offer a similar short course at the 99th AMS Annual Meeting. In addition, an abbreviated instructional session would be offered at the WRF Workshop to raise awareness about and highlight the tools available to the community-at-large.

Project Deliverables

- Support robust Docker containers provided to community users
- Establish GSI 3DVar in a Docker container
- Instructional session offered at the WRF Workshop (June 2018)
- Short-course offered at the AMS Annual meeting (January 2019)

RE1: WRF software support & community engagement

Motivation

The WRF model is a community code with distributed development and centralized support. Although NCAR's MMM Laboratory already contributes to the WRF modeling system for the community in many areas (including dynamics and physics development, WRF framework development, model system testing,

adapting user contributions to the model repository, tutorials and user support), additional activities are critical to the overall success of the WRF package and offer great benefits to WRF users around the world.

Project Description

The DTC works in collaboration with NCAR's MMM to maintain the WRF repository and ensure 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 514 Advanced Research WRF (ARW) real-data tests, 180 ARW idealized tests, 14 WRF-Chem tests, 8 WRF-ARW Data Assimilation tests, 27 Nonhydrostatic Mesoscale Model (NMM) tests, and 4 HWRF tests. The regressions tests are run using three compilers on NCAR's supercomputer, Cheyenne: PGI, Intel, and GNU. Any issues that arise during the regression testing are resolved promptly. 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, WRF Version 4.0, is planned to be distributed to the user community in June 2018. A minor bug-fix release will follow in the early fall. 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 to the WRF infrastructure, updates to WRF Preprocessing System (WPS) to support the latest functionality in WRF, and packaging the code for distribution. Because of the Version 4.0 release, there will be more rigorous testing of all modeling system components in this cycle.

Project Deliverables

- (1) Major and (1) Minor WRF code release

RE2: UPP 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 Unified Post Processor (UPP) is one such system the DTC proposes to continue to support to the community to facilitate operations to research (O2R) and research to operations (R2O) transitions. Currently, UPP is used in operations with the Global Forecast System (GFS), GFS Ensemble Forecast System (GEFS), North American Mesoscale (NAM), Rapid Refresh (RAP), High Resolution Rapid Refresh (HRRR), Short Range Ensemble Forecast (SREF), Hurricane WRF (HWRF) applications, and soon the new dynamical core (Finite Volume Cubed-Sphere: FV3) currently in transition for global applications. With the formation of the Global Model Test Bed (GMTB), the DTC has expanded its UPP use to include both regional and global forecast applications. This, in part, has led to an expanding UPP user base with an increase in requests for support among the research and operational users, especially in regards to implementing new diagnostic fields and utilizing output, for both regional and global downstream applications. As such, it is imperative that the DTC be prepared with procedures and infrastructure to support projects in conjunction with NCEP's future unified model for post-processing and diagnostic investigations through O2R and R2O efforts.

Project Description

The DTC is proposing to continue to collaborate with EMC to make the UPP tool available to the research 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 GRIB1 and GRIB2 output files that can be used directly by a number of plotting packages and the Model Evaluation Tools (MET) verification package. The community UPP repository will be maintained by NCAR and GSD staff in a manner such that updates and enhancements may be contributed by, and shared between, both the operational and research communities. The community UPP distribution will continue to be supported for the Weather Research and Forecasting (WRF) Advanced Research WRF (WRF-ARW) modeling core, and will also be extended to support the FV3 modeling core, in line with operational implementation plans at EMC. A new community release of UPP will be distributed annually, with bug fix release(s) as needed. With each release, extensive testing of WRF-ARW NetCDF model output in serial and parallel (using mpi) environments will be performed and the full suite of tests will be run on computing platforms available to the DTC using a variety of compilers. Testing of FV3 nemsio model output will be performed to ensure community user compatibility during this performance period. Updates to documentation will be made available to the user community with each release (Users Guide and webpage). The UPP repository and code syncing procedures with EMC will be transitioned to GIT-based systems as a result of the recent transition to GIT at EMC. These changes will also require an update to the UPP code management plan. Currently there is a dependency on WRF for building the UPP code; this will be removed during AOP 2018 to better align with expanded modeling core capabilities. This enhancement will also enable a more seamless implementation of the UPP Docker container to aid new users in building and using the software and improve the UPP component of the end-to-end NWP container supported by another activity. User support will be provided by the DTC through help desk email support and presentations during the Basic WRF Tutorials. Emphasis will be placed on supporting principal investigators focused on diagnostic or process-oriented evaluations to ensure R2O developments within the post-processing software are contributed back to the community, and, ultimately, the operational code base.

Project Deliverables

- Code release and documentation updates and expansion – including FV3 capability
- Repository Transition from SVN to Git
- UPP presentation at the Basic WRF Tutorials held at NCAR
- Community support for expanding user base, including general WRF support and developer-focused FV3 support through the help desk for facilitating R20 code development and transition
- Update UPP Docker Container with removal of WRF build dependency
- Update code management plan

RE3: Model Evaluation for Research Innovation Transition (MERIT)

Motivation

With a focus on a framework that allows community innovations to be readily tested, MERIT, or the Model Evaluation for Research Innovation Transition, fits well within the concept of hierarchical testing established within GMTB for testing of the Finite-Volume Cubed-Sphere (FV3) system. This hierarchy denotes that a variety of tests, of varying complexity, are needed to assess physics innovations. The focus of MERIT is a testing framework for selected meteorological cases, which will be studied in depth to help expose shortcomings/deficiencies in operational models. The findings can then be used by members of the research community to show whether their innovations, run using the same framework, address those shortcomings, with the ultimate goal of helping improve operational NWP. In addition, MERIT will be available for NCEP's Environmental Modeling Center (EMC) to test their model developments. While the initial focus of MERIT continues to be on existing capabilities available in the global model framework, this activity is expected to include high-resolution/convection-permitting

modeling for regional/global capabilities in future years as the capabilities of the FV3-based system expands. Providing the research and operational communities with an end-to-end framework will streamline the testing process to accelerate more effective and efficient physics development, encourage community engagement, and provide an infrastructure that supports R2O and O2R.

During AOP 2017, MERIT built upon capabilities established by the GMTB Physics Testbed for running the FV3 model, post-processing model output, verifying model simulations, and plotting model output using Python utilities. The focus of MERIT during the first year was on 3 cases of interest that were part of the initial FV3 public release [29 September 2016 (Hurricane Matthew), 18 January 2016 (East Coast Blizzard), and 12 August 2016 (Louisiana flooding)]. Limiting the number of cases provides the opportunity for more in-depth investigation and enhanced case-relevant diagnostics to be conducted by DTC staff, which leads to a more complete physical understanding of the strengths and weaknesses of the model performance. The initial capability of running cases through the end-to-end system is now supported on NOAA's research and development supercomputer, Theia, the platform where the GMTB has established their global model workflow. The code, configuration files, and scripts used in the testing infrastructure are provided to the community with access to Theia, along with information regarding the individual case studies via a project webpage.

Project Description

For AOP 2018, the DTC proposes to extend the AOP 2017 MERIT work. The infrastructure will be kept in sync with EMC's, through updates to the code and scripts needed to run FV3, and augmented to include updated verification and diagnostic packages. Current MERIT cases will be rerun with the new code and differences in performance will be assessed. New cases will be added with selection based on specific forecast challenges identified by the community. Hypotheses for the forecast shortcomings will be constructed and put forth to the community, enabling community members to contribute innovations that improve the prediction.

Essential to MERIT's success is securing sufficient compute resources on Theia for the DTC to establish the baselines as well as work with interested community users to support their testing of cases within MERIT using the DTC workflow infrastructure. Acquiring access to Theia will be the responsibility of the user. It should be noted that including higher-resolution global runs would come at higher computational cost, but would be beneficial to encouraging the broader use of MERIT.

In order for MERIT to result in advancing innovations to a higher readiness level (RL) in the transition process of research to NOAA operations, strong collaboration among the research and operational communities is essential. It is imperative for the team to continue building connections with Next Generation Global Prediction System (NGGPS) Principle Investigators (PIs) and encourage DTC Visitor Program proposals specifically geared toward engaging with MERIT. In addition, MERIT will fill a key role in providing the capability to run and evaluate case studies through the end-to-end system in order for researchers to demonstrate the merit of their physics innovations prior to inclusion in the Common Community Physics Package (CCPP). Another avenue that will be pursued is strengthening communication and collaboration with participants of the NCEP Model Evaluation Group (MEG). A key component of ensuring engagement and success is reaching out and broadcasting the activity to the research and operational communities; avenues for reaching out include presenting the MERIT concept and results from case studies at conferences, as well as presenting at MEG meetings throughout the year.

Project Deliverables

- Update MERIT infrastructure (keep FV3 code and scripts in sync with EMC)
- Add new case studies

- Provide baseline FV3 model data, verification statistics, and relevant diagnostics for selected cases via Theia and project website

RE4: Testbed Collaborations with HWT

Motivation

For the last several years, the Hazardous Weather Testbed (HWT) Spring Forecasting Experiment (SFE) has strived to coordinate the contributed model output from participating groups around a unified setup (e.g., WRF versions, domain size, vertical levels and spacing, etc.) to create a super-ensemble of over 60 members called the Community Leveraged Unified Ensemble (CLUE). The careful coordination and construction of CLUE allows for meaningful comparisons among a variety of members to be performed. It also provides an excellent opportunity to help identify and begin to answer the most pressing scientific questions that need to be addressed, including should model uncertainty be addressed through multiple dynamic cores, multiple physics parameterizations, stochastic physics, or some combination of these? Finally, while this data is subjectively assessed daily during the experiments, extensive objective verification after the experiment allows for thorough investigation of the contributed model configuration or ensemble construction strengths and weaknesses.

Project Description

While the exact configurations included as members of CLUE during the 2018 HWT SFE are still being solidified, they will include WRF-based configurations, along with several configurations of the Finite-Volume Cubed-Sphere (FV3) model. Prior to the beginning of HWT-SFE 2018, DTC staff will participate in planning meetings with HWT SFE leads to gain a full understanding of what model configurations will be available and collaborate on model setup and evaluation approaches. Given the future unified forecast system will be based on the FV3 dycore, the main ensemble subsets targeted for evaluation in this proposal will likely include examining a single core (FV3 only) ensemble with initial condition perturbations for a single physics suite compared to a multi-physics (also within FV3) approach. Ultimately, the probabilistic forecast performance of each targeted ensemble subset will be examined. Individual deterministic forecasts from select members will also be assessed to understand their contribution to the overall ensemble spread. It is of particular importance to evaluate the deterministic forecast performance of FV3 configured to run at high resolution (~3 km) given this is still a new application for this dynamic core.

The extensive evaluations will be conducted using the Model Evaluation Tools (MET) software system. The metrics used for probabilistic and deterministic evaluation will range from traditional metrics widely used in the community (spread, skill, error, reliability, etc.) to newer methods that provide additional diagnostic information, especially at higher resolution. These approaches will include the Method for Object-based Diagnostic Evaluation (MODE) and neighborhood methods applied to deterministic and probabilistic output (e.g., Fractions Skill Score). Along with standard meteorological fields to highlight overall model performance, an evaluation of severe weather storm-attribute fields readily available in model output or analysis fields (e.g., radar reflectivity, echo top) will be conducted through a collaboration with National Severe Storms Laboratory (NSSL) researchers.

Project Deliverables

- Article on outcome of evaluation submitted to an appropriate journal for publication
- Results presented at relevant workshops/conferences

RE6: Testing and evaluation of new ARW development for use in RAP/HRRR

Motivation

The Rapid Refresh (RAP) and High Resolution Rapid Refresh (HRRR) are both applications of the WRF-ARW that are run operationally at NCEP, providing high-impact products especially for short-range weather forecasting year-round. The NCAR/MMM and NOAA/GSD groups have a keen interest in providing the best model for operational use. Recent enhancements in the model, such as the hybrid vertical coordinate (funded by DTC) and stochastic forcing within physics schemes, have delivered improvements to the performance of the RAP and HRRR applications. These examples of a coordinated effort demonstrate that a close collaboration between the two groups is beneficial to the RAP/HRRR applications.

Project Description

During the past few years, NCAR/MMM and NOAA/GSD have worked closely on projects directly related to model development. The MMM team responded quickly to a model abort problem stemming from the newly added hybrid vertical-coordinate capability, with the GSD team agreeing to use the pre-released code for testing purposes. Both groups continued to monitor the performance of the new vertical coordinate in the upgraded versions of RAP and HRRR. In the weeks leading up to the total solar eclipse in August 2017, the MMM team provided user-contributed radiation code that considers the impact of the eclipse on the surface temperature upon request from GSD. This facilitated GSD to provide an experimental forecast product that included the (surprisingly large) eclipse effect. Both groups have started to work on incorporating better input fields to use for orographic forcing in the model. In general, each cited collaboration has proven to be beneficial for the continued improvement of RAP/HRRR verification metrics.

In 2017, the GSD group contributed their RAP/HRRR physics enhancements in Mellor-Yamada-Nakanishi-Niino (MYNN) Planetary Boundary Layer (MYNN PBL), RUC Land Surface Model (LSM), and Grell-Freitas (GF) schemes, as well as stochastic physics, back to the WRF repository code. The MMM team worked with GSD to make these improvements and new capabilities available to the larger WRF community. The stochastic physics capability is being tested in the HRRR ensemble. Both the GSD and the MMM groups have worked to incorporate new input projections for the WRF Pre-processing System (WPS). The GSD group provided invaluable testing to verify that a correct solution was reached. HRRR initialization may now by-pass an unnecessary extra horizontal interpolation.

The MMM WRF team will interact with and respond to requests by GSD regarding model issues encountered in the operational applications. The two teams will finish up improvement to orographic forcing, via modifications to both WPS and the WRF model. Recommendations and identification of new capabilities suited for use by the RAP/HRRR will be provided as they become available to the WRF community code. Upon request, this work will also include support to help identify the root causes and scientifically sound fixes for persistent errors or failures in RAP/HRRR forecasts.

This funding request covers the MMM WRF team participation in this collaboration. GSD's participation is not covered by DTC funding.

Project Deliverables

- Report describing what enhancements and trouble-shooting were provided by the MMM team and their impact on model performance

DA1: Data assimilation system code management and user support

Motivation

All current NCEP global and regional operational modeling systems use hybrid ensemble-variational (EnVar) data assimilation through the Gridpoint Statistical Interpolation (GSI) system for their deterministic forecasts. The global data assimilation system (GDAS) also includes the Ensemble Kalman Filter (EnKF) system to provide initial fields for the 80-member ensemble forecast. For operational regional/storm-scale applications (e.g., NAM, RAP/HRRR, etc), the GDAS EnKF 80-member ensemble is used for their ensemble background error covariance. Potential uses of regional/convection-scale ensembles for NAM/RAP/HRRR are still under investigation. Community support and code management for NCEP's operational GSI and EnKF systems is essential for the research community to make direct contributions to the GSI and EnKF development and advancement.

Project Description

For AOP 2018, the DTC is proposing to continue providing code management for NCEP's two operational data assimilation systems: GSI and EnKF. The DTC will maintain and improve the code management framework through working with the joint GSI and EnKF Data Assimilation Review Committee (DRC). This code management framework facilitates close collaboration among active system developers (e.g., NOAA, NASA, NCAR, etc.) and avoids code divergence among operational agencies and the research community. As a member of the DRC, the DTC will review and test proposed code changes, and provide feedback and suggestions on code development. In addition, the DTC will assist community developers with committing their code to the repository.

During AOP 2017, the DTC DA team completed the transition from the previous SVN community repository to a new Git/Gerrit unified repository for both operations and community users, facilitated by NOAA VLab. The DTC will continue to provide code access to community developers for various applications. The DTC will also continue its efforts on the unified multi-platform build system and to improve the system user interface and portability. In addition, the DTC will work to build a unified regression test suite under the new cmake system to facilitate the code development and transitions between the research and operations.

The DTC will provide one code release for GSI and EnKF for AOP 2018. The code release effort will include multiple-platform pre-release tests for both systems, updated documentation (e.g., user's guide, release notes), webpage support (e.g., download, on-line tutorials), and utility updates. Bug fixes discovered during the code release tests will be committed to the unified GSI/EnKF repository.

The DTC will continue its help desk service for the released code. The DTC will also provide an online tutorial that will be available to all users.

This work will be conducted as a collaborative effort between NCAR and GSD.

Project Deliverables

- GSI and EnKF code releases
- Data assimilation community user support service

DA3: Build operational storm-scale data assimilation testing system and test DA advancement for convection forecast

Motivation

The high-resolution rapid refresh (HRRR) is a key component of the NCEP operational modeling suite to provide high-resolution storm-scale model forecast. The HRRR system is not only used as the backbone

of accurate short-range and severe weather, aviation, and energy forecasting, its model physics and data assimilation configurations will also be used as reference to build the next generation FV3-based operational storm-scale modeling system. A functionally similar operational HRRR testing system that is available for the use by the research community is a critical link to encouraging the broader storm-scale modeling community to make their research available to operations. The DTC is building and maintaining such an operational HRRR system on NCAR's supercomputer and will make this system available to the research community in the future. The DTC DA team will also act as the first user of this system by conducting a series of operational-needs-based experiments to ensure the functionally similar operational environment for testing HRRR system is robust. These exercises with the HRRR system will help the DTC DA team build critical expertise in storm-scale data assimilation to provide high quality support to the community users of the HRRR testing system. The current T&E focus of DTC DA team is exercising new DA techniques for radar data assimilation as there are many active research community developments in this area.

Project Description

For AOP 2017, a series of experiments were conducted to test the impact of assimilating radar radial velocity on HRRR forecast. The DTC proposes to use this infrastructure to extend the T&E of new radar data assimilation capabilities in the GSI EnVar system. The primary candidate for this T&E activity is the upgraded dual-polarized radar data, which is expected to have enhanced capability to detect different phases of precipitation and to differentiate meteorology and non-meteorology echoes. These new data should lead to better storm detection and forecast with proper data assimilation techniques.

The DTC proposes to test this new observational capability for high-impact convective systems using its high-resolution GSI EnVar framework. A testing period with convective cases will be selected and dual-pol radar will be assimilated in a 3-km regional domain. Experiments with and without dual-pol radar data assimilation will be performed and compared. The DTC will examine the data impacts and provide feedback, along with recommendations for an optimal configuration, to operations.

The outcome regarding the impacts of observation types and assimilation methods will be beneficial to the FV3-based high resolution data assimilation system because it will use GSI and share most of the data and code with current HRRR system.

This work will be conducted as a collaborative effort between NCAR and GSD.

Project Deliverables

- Project reports
- Conference presentations to share outcome of tests with community

HU1: Hurricane Weather Research and Forecasting (HWRF) code management and user support

Motivation

The state-of-the-art HWRF end-to-end system currently has over 1500 registered users. By supporting the HWRF system to the community at large, NCEP receives more feedback on the model's performance, which leads to model improvements. In addition to its use by the community at large, recipients of HFIP and the DTC Visitor Program grants rely on a stable code repository, the publicly released HWRF code, and documentation to conduct their research. The HWRF system undergoes substantial annual upgrades that are making great strides towards improving its forecast skill. To ensure a stable code base, strong code management protocols and frequent code integrity tests are critical. For the community to provide useful feedback on the strengths and weaknesses of this system, it is

important for them to have timely access to the current capabilities, which requires an annual code release and updates to the accompanying documentation and training materials.

Project Description

The DTC currently hosts the HWRF code repository, which is composed of a sophisticated set of scripts plus eight components: WRF atmospheric model, WRF Preprocessing System (WPS), 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. For AOP 2018, the DTC proposes to continue to maintain the HWRF code repository and coordinate the links to all external source code components. This work will include updating the main HWRF development branches with all developments in the trunk of the community repositories, assuring that the main HWRF development and the community codes remain synchronized. To avoid divergence of the WRF component, the DTC works in collaboration with NCAR's Mesoscale and Microscale Meteorology (MMM) Laboratory to maintain the WRF repository. HWRF is affected by repository changes for individual components (e.g. WRF and WPS transition to Git in Github, GSI to Git in VLAB, and UPP to Git in VLAB). The DTC Hurricane team will continue to communicate with the associated teams, assess impacts to HWRF developers, and apply the most appropriate repository structure for all HWRF components. An assessment of whether the full HWRF repository should transition from SVN to Git will be undertaken during the upcoming AOP. An additional component, WAVEWATCH III, was added for one-way wave coupling during the 2016 operational implementation. Furthermore, the Hybrid Coordinate Ocean Model (HYCOM) was employed in the Western Pacific basin and North Indian Ocean during 2017. Pending the decision to include these components in the HWRF repository, the DTC will update the code management plan and implement the new component(s) accordingly. The HWRF repository integrity will be regularly tested 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. In addition, DTC will continue to maintain the HWRF build system, a set of tools designed to efficiently compile and install the HWRF source code.

For AOP 2018, the DTC proposes to continue its HWRF user support activities. These activities will include an HWRF v4.0a release that will contain updates included in the 2018 operational HWRF, plus additional research capabilities (such as the idealized modeling capabilities and alternate physics options). Prior to this public release, the DTC will test the new HWRF capabilities (e.g. GFS upgrades, upgraded data assimilation and ocean coupling capabilities, alternate physics, updated GFDL Vortex Tracker, etc.) on multiple platforms, enabling users around the world to benefit from a range of scientific options valuable for tropical cyclone research and forecasting. Updated support documents will be prepared to accompany the public release: HWRF scientific documentation, HWRF Users' Guide, NMM Users' Guide, datasets and an online tutorial. The HWRF FAQ and Known Issues webpage 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. Following discussions with EMC, WAVEWATCH III and HYCOM were not included in the prior public releases. DTC will once again explore the feasibility of adding the WAVEWATCHIII and HYCOM components for the v4.0a release, which would require increased testing and further documentation.

As part of its HWRF user support activities, the DTC will also continue to maintain a help desk to support users in troubleshooting compilation and run-time issues using a ticketing system to track requests. This help desk support includes all components of the full end-to-end HWRF system for the advertised capabilities of the annual release. Additionally, support for HWRF developers funded by the DTC Visitor Program will be provided. Many HWRF projects continue to be funded through the DTC Visitor Program, typically requiring training and assistance by the DTC to ensure a successful project.

Project deliverables

- Unified HWRF scripts and code maintained with code integrity tested through regression and consistency checks, as applicable
- HWRF v4.0a public release with updated documentation and HWRF Users' Page
- Community user support help desk and support for DTC Visitor Program PIs

HU2: Hurricane Weather Research and Forecasting (HWRF) developer support

Motivation

Distributed HWRF development is being facilitated through funding provided by the Hurricane Forecast Improvement Project (HFIP). To avoid divergence of these development efforts and assure new development can be easily integrated into the centralized HWRF repository, it is imperative that these developers work on the same code base that includes the latest changes included in NCEP's 2018 version of the operational HWRF model. To assure these developers work within the repository framework, it is important to provide training on the HWRF code management tools and provide assistance using these tools when necessary. Providing access to non-operational aspects of HWRF, such as candidate new components, and a mechanism for developers to share tools also enhances inter-developer collaborations, which will lead to more rapid transition of research developments to operations (R2O) and ultimately to improved HWRF forecasts.

Project Description

The DTC proposes to continue to facilitate the use of code management tools to HWRF developers who are external to EMC. This facilitation will be done through training and repository assistance to developers, as well as through conducting regression tests and consistency checks on the developments, as applicable. In addition to code management support for HWRF developers, the DTC will provide developer support through a specialized help desk. The help desk addresses in-depth questions from developers covering the full end-to-end HWRF system to support cutting-edge research. During AOP 2018, the DTC will continue to update online instructional and training materials, adding content as needed. In addition, the DTC will ensure 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. Development deemed high priority by EMC for inclusion in the operational HWRF (particularly involving scripting developments) will be addressed on a per-request basis, within the scope of the resources allocated to this activity. The DTC will continue to host the HWRF Developers Committee meetings, which is an important mechanism to ensure HWRF developers are aware of important code updates, serves as a platform for information exchange, and ensures that development in the research community is undertaken in a way that is compatible with the operational HWRF model. The HWRF Developers Committee meetings also ensure code commits are well communicated and follow proper code management protocols. Recently, the Weather Research and Forecasting (WRF) model, the WRF Preprocessing System (WPS), and the Gridpoint Statistical Interpolation (GSI) components underwent substantial repository transitions from SVN to Git, with a similar transition of the Unified Post Processor (UPP) expected to occur this year. There is also the potential for a major HWRF repository overhaul in the coming year to convert the remaining SVN repositories to Git to streamline the code checkout and development process for HWRF developers. The DTC will continue to advocate for and work with developers to gain access to the necessary repositories and to ensure seamless transitions. Finally, the DTC will maintain the mailing lists used by the HWRF developers and centralize the overall communication among HWRF developers.

To facilitate inter-developer interaction and exchange of tools and codes, the DTC will continue to maintain the *hwrf-contrib* repository. Note that DTC will maintain *hwrf-contrib* and support access to it, but maintenance, documentation and support of the codes in *hwrf-contrib* is the responsibility of the contributors.

Project deliverables

- Helpdesk serving HWRF developers
- New developments contained in repository branches ready for testing by EMC and DTC staff
- Maintenance of *hwrf-contrib* repository

HU3: Hurricane Weather Research and Forecasting (HWRF) physics advancement and diagnostic tool development for hurricanes

Motivation

The Hurricane Weather Research and Forecasting (HWRF) model has improved in recent years due to extensive upgrades of the modeling system, in part due to the substantial effort by the HFIP community to investigate and improve the representation of physical processes in HWRF. During the HWRF pre-implementation process, tests are performed with alternate configurations to evaluate which advances provide improved tropical cyclone (TC) prediction. The DTC has been involved in the testing and evaluation of physical parameterizations for HWRF, with a primary focus on radiation, moist physics, and cloud-radiative feedbacks, which are critical for the accurate representation of both large-scale and vortex-scale mass and wind fields.

In particular, the DTC has tested the Grell-Freitas (G-F) scale-aware cumulus parameterization for the HWRF system over the past two implementation periods. A retrospective test of 16 storms is now underway to help determine whether the G-F scheme shows improvement over the scale-aware Simplified Arakawa Schubert (SASAS) convection scheme currently used in the operational HWRF system. Additionally, the DTC has been engaging with DTC Visitor Program PIs M. Iacono and J. Henderson (AER) to test an alternate cloud overlap methodology within the RRTMG radiation parameterization. Past successful transitions of physics innovations to the operational HWRF have typically occurred over multi-year testing and evaluation timelines (e.g. RRTMG radiation upgrades), thus continued testing of the G-F scheme and enhancements to the RRTMG scheme provide the best opportunity for further improvements in the operational system. Regardless of whether these innovations are implemented into the 2018 operational HWRF, ongoing scheme development provides opportunities for future advancements. Finally, the focus on the G-F scheme is also important because this scheme is used in the operational RAP model and is undergoing testing for NCEP's global application; therefore, this testing has the potential to positively impact multiple NCEP forecasting applications.

Project Description

For AOP 2018, the DTC will identify developments within the research community that have the potential to improve the operational HWRF system and will work with the developers and subject area experts of the selected physics schemes to test and provide feedback on strengths and weaknesses of these parameterizations that would lead to improvements for the next operational HWRF implementation. By selecting physics advancements that have the potential to impact multiple forecast applications, the improvements also have the ability to translate to NCEP's unified forecast system (UFS). The DTC is in a unique position to coordinate and test innovations, and to provide EMC with information and codes from the research community that can be transferred into the operational system. In addition to interactions established through specialized developer support, funded DTC

visitor projects will be leveraged to bolster this activity. R. Fovell (Univ. Albany) is currently examining the impact of PBL assumptions on HWRF forecast skill, S. Bao (Coastal Carolina U.) is evaluating the performance of the advected Ferrier-Aligo microphysics scheme, J. Zhang (U. Miami and AOML/HRD) has a funded project to develop diagnostic tools to study the impact of model physics on rapid intensification, and M. Iacono and J. Henderson continue to provide enhancements to the cloud overlap methodology for RRTMG.

The DTC will run HWRF retrospective forecasts using the 2018 operational HWRF model and the innovations described above and other promising new developments from the research community to effectively inform the 2019 HWRF pre-implementation process. Involvement in the pre-implementation process is an important role for the DTC. During this period, the DTC showcases promising new innovations within the research community and has the opportunity to contribute to the operational implementation, promoting transition of research to operations (R2O). The physics innovations to be tested will be decided based on the 2018 operational configuration, an assessment of available scheme advancements, and discussions with EMC. Ideally, continuity will be maintained and scheme enhancements rather than replacement will be the focus.

Following the pre-implementation period, additional sensitivity studies of select cases will be performed to determine the impact of alternate/enhanced physics for the selected schemes. During AOP 2018, the DTC proposes to pursue development of process-level diagnostics directed at improving the representation of physical processes in HWRF. The evaluation will consist of comparisons of heating tendency profiles, boundary layer temperature and humidity profiles, Quantitative Precipitation Forecasts (QPF), clouds, and radiation. Where appropriate, observations of the same variables or available proxies from satellite, buoy, radar, and/or aircraft will be used to assess whether the experimental or current operational configuration of HWRF produces more physically consistent fields. A focus on running these diagnostic tools in storm-centric coordinates will be undertaken, in collaboration with the DTC Verification task, which has already developed a preliminary framework for storm-centered evaluation within the Model Evaluation Tools (MET) suite. Together, the aforementioned diagnostics will complement the usual track and intensity verification to provide input on the representation of physical processes for the candidate parameterization(s). To prepare for hurricane evaluation within NCEP's Unified Forecast System (UFS), the DTC Hurricane team proposes to also begin to apply the model diagnostic and verification tools to FV3 output to ensure the advanced diagnostic tools developed through this proposed work will remain relevant beyond the life of the HWRF system.

The DTC will facilitate the R2O transition through participation in the pre-implementation process and effective communication with EMC concerning controlled diagnostics, sensitivity experiments, and multiple storm testing of the aforementioned parameterization(s).

Project deliverables

- Project report on results of experiments and in-depth investigation of physical processes.
- Presentation(s) on assessment of improved parameterizations in the context of the operational HWRF system with new capabilities in HWRF physics made available to EMC for testing, accomplished through involvement in HWRF pre-implementation testing.
- New model-agnostic diagnostic tools, demonstrated through application to HWRF and FV3 output.
- Results presented at relevant conferences/workshops.

VX1: MET+ Community Support

Motivation

The Model Evaluation Tools (MET) was developed over a decade ago to replicate the National Oceanic and Atmospheric Administration (NOAA) Environmental Modeling Center (EMC) mesoscale verification capability and make it platform independent and extensible. MET is comprised of 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 packages or through the accompanying METViewer database and display system. MET is a community-supported software package with over 3500 users (over 300 new since last year) from a wide variety of universities (48%), government (27%), non-profit organizations (14%), and private companies (11%). In addition to supporting the research community, the Developmental Testbed Center (DTC) Verification team has been collaborating with the verification teams within NOAA on adopting MET and METViewer to facilitate unification of verification. During AOP 2017, and under multiple lines of funding, a suite of python wrappers was developed to instantiate a beta release of the unified verification package, MET+. There have been two MET releases, four METViewer releases, and two un-numbered MET+ releases during AOP 2017 with an additional MET and METViewer release planned for late February. The increase in releases is due to the need for EMC to have updates quickly as they adopt MET+. During the last three years, the number of active NOAA users has increased from a few to over one hundred and fifty. These estimates are based on registered users as well as DTC's interactions with users via met_help, monthly telecons and in-person meetings. Additionally, METViewer continues to be used by many EMC staff and was recently made available to the research community through containers. The result is an increased need for MET+ community support through help-desk, documentation and tutorials. 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 directed toward assessing forecast skill and informing the model development process.

Project Description

Over the past few years, the Verification Task activities have been divided between MET development and user support, and NOAA verification unification, where releases were included under the development and user support activity. The MET+ team has found it difficult to report progress in a meaningful way. Therefore, the AOP 2018 proposal is structured a little differently. This activity (VX1) is geared only toward user support, documentation, and the development and testing needed to ensure releases are successful. VX2 is focused on major development of MET+ and its components.

The MET help desk responds to approximately 5-10 emails per day, resulting in approximately 300 tickets closed per year. It is anticipated that this demand will increase over the next year with the release of MET+ and METViewer on Github. EMC requires a release version to be used in their operational workflows. To respond quickly to their requirements, MET will have 3 releases per year including development supported through proposed AOP 2018 VX2, Next Generation Global Prediction System (NGGPS) and United States Weather Research Program (USWRP) funding. The releases will include a smaller number of enhancements when compared to recent MET releases. METViewer releases will occur 5-6 times per year. Three (3) of these releases will be to support new statistics added to MET. The additional ones will be to address user needs and bug fixes in a timely manner. The first numbered release of MET+ will also occur at the beginning of AOP 2018. All releases will include regression tests, pre-release testing, documentation (both downloadable and on-line) and an online tutorial. This activity will also focus on expanding the community help desk support for MET to include community support for MET+ and the other MET+ component METViewer. . The proposal includes a presentation at the WRF Users' Workshop and a trip to an AMS conference to ensure the community is aware of what MET+ has to offer.

The first 3 deliverables represents level funding for community support ($221K). Prior to 2015, the DTC held a MET Tutorial 1-2x per year. The tutorial tradition was re-instated for AOP 2017 but a tutorial does not fit within a level budget for AOP 2018. If additional funds are available, this activity would also provide an in-residence MET+ tutorial held at NCAR.

Project Deliverables

- MET moved to GitHub and MET issue tracking to outside the NCAR firewall
- MET+, MET, and METViewer helpdesk
- MET+, MET, and METViewer , releases, bug fixes, repository maintenance documentation and on-line tutorials
- Presentations at WRF Users' Workshop and at least one conference
- MET+ Tutorial held at NCAR

VX2: MET+ Development

Motivation

Model Evaluation Tools (MET) development started over a decade ago in response to a recommendation that DTC replicate the National Oceanic and Atmospheric Administration (NOAA) Environmental Modeling Center (EMC) mesoscale verification capability and support the package to the community in a platform-independent and extensible format. MET v1.0 was released in January 2008. In 2009, the development of METViewer, a database and display system to summarize and aggregate MET output, began. Over the following years, the MET development team continued to develop MET and METViewer while EMC (and other NOAA centers and labs) continued to develop their own packages. In 2015, there was a recommendation from the Next Generation Global Prediction System (NGGPS) Verification and Validation team and the University Corporation for Atmospheric Research (UCAR) Model Advisory Committee (UMAC) to unify verification capabilities. For the past few years, the Developmental Testbed Center (DTC) Verification team has collaborated with the NOAA verification teams on adopting MET and METViewer to facilitate unification of verification capabilities. The bundled system, including MET, METViewer, and the python wrappers is called MET+.

MET+ use-cases constitute the scripting and configuration file settings necessary to execute a particular type of verification. For example, the Quantitative Precipitation Forecast (QPF) use-case has MET configuration files with settings for the C++ software and MET+ configuration files with settings for the Python software. For the QPF use-case, no development of MET capabilities was required but rather development of python scripting to call MET tools to accumulate precipitation into the same interval for both forecast and observation and pass these fields into the appropriate MET tool. In another example, the Feature Relative use-case has different MET and MET+ configuration files and required both MET C++ development and MET+ python development prior to its release. Each use-case essentially represents an example of how to use MET+ to accomplish the verification task. The use-cases (examples) will be made available to the community via VX1.

Currently, there are four mechanisms used to determine what enhancements need to be added to MET, METViewer and MET+:

1. Requests from the research community via met_help@ucar.edu emails and identification of promising techniques through conference attendance
2. Requests from the NOAA user community via met_help@ucar.edu emails
3. Requests from DTC teams that are identified during testing and evaluation and not already included in team activities
4. Unified Verification Roadmap (described below)

For AOP 2016, DTC and NGGPS team members gathered and synthesized initial requirements for a unified system. The result of these discussions was a list of 99 specific functional needs along with additional non-functional requirements. The current status of the requirements list may be found at: https://drive.google.com/a/noaa.gov/file/d/0BwjqxMjULl-DUWtnU0RNanBiZEU/view?usp=sharing.

The DTC Verification team has to date provided the following during AOP 2017: 11 major enhancements to MET, 8 major enhancements to METViewer, and provided MET+ python development to support the 4 use-cases currently in the MET+ beta release available on GitHub.

Project Description

Over the past few years, the Verification Task activities have been divided between MET development and user support, and NOAA verification unification, where releases were included under the development and user support activity. The MET+ plus team has found it difficult to report progress in a meaningful way. Therefore, the AOP 2018 proposal is structured a little differently. VX1 is geared toward user support, documentation, and the development and testing needed to ensure releases are successful. This activity (VX2) is focused on major development of MET+ and its components for request mechanisms 1-3. It is anticipated that funding for Mechanism 4 will be primarily provided through NGGPS.

This proposed activity is focused on development of MET+ (e.g. C++ for MET, Java, MySQL and R for METViewer, and Python for MET+) to reduce the time required for both NOAA and the community to transition to the unified system. The Verification team has found that even though the Unification Roadmap is extensive, it does not define all requirements for unification with MET+. The team has also seen that user's needs and priorities can change quickly and defining use-cases a year ahead of time can result in the development team seeming unresponsive to a community it is trying to unify. For this reason, the Verification team proposes to use this activity to continue to move MET+ toward the unified community verification system by addressing priority development needs not identified in the Unified Verification Roadmap. Development to address research community requirements will be funded via NCAR funding and prioritized by potential for substantive positive impacts for the entire community. Requirements of the current and growing community of NOAA users will be addressed by NOAA funding and prioritized through conversations with key stakeholders such as the EMC Branch Chief of the Verification, Post-Processing, and Product Generation Branch and verification leads at the other NOAA centers and labs. Development associated with DTC team needs will be addressed based on how the needs align with funding sources and priorities. As stated previously, development associated with priorities called out in the Unified Verification Roadmap will primarily be addressed via NGGPS projects unless a request is made to increase the priority. A mechanism for defining priorities will need to be identified during this AOP.

A few examples of projects that could fit within this activity include but are not limited to:

- Enhancing MET to have greater flexibility for event definition, refactoring code to run more efficiently and be more consistent across tools, and enhancing the analysis tools
- Enhancing METViewer to support new statistics computed by MET and new plot templates (e.g. scatter plots, quantile-quantile plots, etc…)
- Development of MET, METViewer and MET+ Python elements to establish priority MET+ use-cases (examples) that are not addressed through current and pending external funding.

Project Deliverables

- Development of 3-5 major MET enhancements
- Development of 2-4 major METViewer enhancements
- Development or enhancement of 2-4 MET+ use-cases

- Recommendation on MET+ development oversight for future years
- Presentation at AMS WAF/NWP conference in Denver, CO

VX3: Workshop on Test Plans and Metrics for Assessing Model Improvements

Motivation

A core mission of the DTC is to demonstrate the merits of new research and developments that could positively impact future operational configurations of a NWP system. NOAA values open, transparent, and evidence-driven transitions from research to operations (R2O), which require an agreed upon test plan using standard, accepted metrics. During recent Next Generation Global Prediction System (NGGPS) and Environmental Modeling Center (EMC) Strategic Implementation Plan (SIP) meetings (April and August 2017), the need for the definition of a standard suite of metrics to be included in NGGPS test plans was brought up on numerous occasions. This need is reflected in the EMC SIP version 4 document Project 1.2 (global model working group); 5.2 (physics working group), 7.2 (convection allowing model working group), 9.5 (land surface model and hydrology working group), and 13.3 (verification working group).

Given the tight timelines for upcoming implementations of the FV3-based NWP systems, it is important for NOAA to firm up procedures for the test plans and metrics for deciding on which innovations will be accepted into the next-generation operational systems. Test plans can include origin of all source codes, model resolution, model configuration (regional or global, coupled or uncoupled), initialization method (cold start or cycled), retrospective forecast period, forecast length, what metrics will be used, roles and responsibilities of test participants, deliverables, timelines, risks and mitigations, and references. In addition, test plans can include process-oriented assessments to provide feedback to model developers regarding the strengths and weaknesses of the model configuration.

Discussions at the UCAR Community Advisory Committee for NCEP (UCACN) Model Advisory Committee (UMAC) Update Meeting for NCEP Stakeholders at the 2018 AMS Annual Meeting emphasized this need. In response to the UMAC feedback, the NGGPS Program Office and EMC management have emphasized the urgency of this workshop, as well as the need for it to pertain to a scales ranging from global to convective-allowing.

Since the DTC has extensive experience testing Numerical Weather Predication innovations, it is well situated to facilitate this discussion by hosting a workshop focused on test plans and metrics for assessing promising innovations for transition to operations.

Project Description

For AOP 2018, the DTC is proposing to work with EMC and the research community to coordinate a workshop in College Park, MD 1) identify key elements of test plans for identifying model improvements that are ready for transition to operations in the FV3-based Unified Forecast System; 2) identify key metrics to include in the test plan; and 3) stratify the metrics based on applicability to different spatial and temporal scales, useful for global and Convection-Allowing Model (CAM) applications. Organization and report for this workshop will be led by the Verification team but will involve an internal collaboration across the DTC task areas, as well as EMC and relevant stakeholders in the community. Additionally, it will leverage findings from the Earth System Prediction Capability (ESPC) “Metrics and Post-Processing for Sub-seasonal to Seasonal Prediction” (S2S) workshop to be held in late February 2018. The outcome of this workshop will inform testing procedures at EMC, DTC, and GMTB, development of the Model Evaluation Tools (MET) software, and the governance system for the Common Community Physics Package.

To facilitate a well-thought-out workshop followed by a useful report, a reasonable portion of this budget is reserved for salary to plan and promote the meeting, synthesize the outcomes and write up the results. Additionally, the travel budget includes support for four to five DTC staff to attend the meeting if in College Park, and for four to five key contributors to attend the workshop.

Project Deliverables

- Workshop focused on developing test plans and key metrics to identify model improvements ready for R2O.
- Workshop report.