Developmental Testbed Center Annual Operating Plan
1 April 2017 – 31 March 2018

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 2017 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.

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. A detailed breakdown of the costs of operating the DTC that are included under this activity is included below:

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 $81 K from the DTC's NOAA funds to support visitor projects and submit a proposal to NSF to match this $100 K. The additional $19 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 2017 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

DO4: Community engagement with the FV3-based next-generation prediction system

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. With the selection of GFDL's Finite Volume Cubed Sphere (FV3) as the atmospheric dynamical core for its next generation global prediction system and potential regional applications, it will be important for EMC to establish a framework that will encourage the broader NWP research community to join with the operational NWP community to make significant strides towards improving the forecast skill of the U.S. modeling suite. Aspect of this framework would include use of FV3 within the context of a multi-component modeling system (with atmospheric physics, as well as forecast models for land, ocean, sea ice, chemistry, etc.), code management practices, testing and evaluation protocols, and community access to code and datasets.

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 while collaborating in the U.S. weather prediction enterprise. An important aspect of this framework will be clearly defining the roles and responsibilities of the key partners.

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 achieve the goals of NGGPS, effective R2O is critical to facilitate the contributions of the research NWP community to support the continued development and improvement of NGGPS. To optimize the use of available resources and to maximize the return for investment, how 'community model' is defined and operates will need to be carefully scrutinized. Defining the roles and responsibility of the key partners will ensure that NGGPS can be supported effectively as a community model.

Project Description

For AOP 2017, the DTC proposes to set aside funding for the DTC to assist NWS and the NGGPS Program Office with the process of defining the 'community model' aspect of NCEP's next generation unified modeling suite. The work plan for this activity would be defined in consultation with EMC and the NGGPS Program Office. The DTC anticipates this activity would involve facilitating discussions between the key partners and representatives of the broader research community directed at assessing what current infrastructures can be used to effectively support the engagement of a broad spectrum of the community in advancing NCEP's modeling suite. Points that will need to be addressed are: 1) the needs of each key partner, 2) what is meant by community model, 3) mechanisms for engaging the broader research community, and 4) roles and responsibilities of each partner. A NGGPS Community Development Workshop is being planned for the week of 17-21 April 2017. Based on the recommendations from the workshop, DTC will work with EMC and NGGPS Program Office to develop a work plan for this task. An important topic for discussion at the workshop is a framework for

collaboration on the continued development of NGGPS, including the roles and responsibilities of each partner. We anticipate that DTC will begin the initial development of a framework to support the collaborative development of NGGPS by participating partners.

Project Deliverables

- Deliverables will be defined after a work plan is established by June 2017.

Regional Ensembles

RE1: WRF software support & community engagement

Motivation

The Weather Research and Forecasting (WRF) model is a community code with distributed development and centralized support. Though NCAR's Mesoscale and Microscale Meteorology (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, tutorials and user support) additional activities are not well funded that 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.

Project Description

The DTC works in collaboration with NCAR's MMM 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 528 ARW real-data tests, 188 ARW idealized tests, 16 WRF-Chem tests, 27 NMM tests, and 4 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 to the WRF infrastructure, updates to WPS to support the latest functionality in WRF, and packaging the code for distribution.

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 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), and Hurricane WRF (HWRF) applications. With the formation of the Global Model Test Bed (GMTB), the DTC has expanded to supporting 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, in 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 the future NGGPS 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 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 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 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 be supported for the Weather Research and Forecasting (WRF) Advanced Research WRF (WRF-ARW) modeling core, with extension to development support for additional modeling cores as time allows. 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. Updates to documentation will be made available to the user community with each release; current documentation will be expanded to provide users with enhanced detail on output field options (Users Guide and webpage). In addition, new procedural documentation will be developed to guide community users and developers in customizing and contributing to UPP; for example, information on how to add new diagnostics to the code base will be detailed to help facilitate R2O development and transitions. An online tutorial will be developed including step-by-step instructions and examples on how to run UPP. The scope of the aforementioned documentation activities will be prioritized and addressed as time permits. 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
- UPP presentation at the Basic WRF Tutorials held at NCAR
- Documentation updates and expansion (as time allows)
- Online tutorial
- Community support for expanding user base, including general and developer-focused help desk support for facilitating R20 code development and transition

RE3: Model Evaluation for Research Innovation Transition (MERIT)

Motivation

Over the last several years, the DTC established and actively maintained the Mesoscale Model Evaluation Testbed (MMET), with the primary motivation of assessing the merits of new community model physics developments that have potential to positively impact operations. A goal of MMET is to

foster an environment of active development and testing with open communication of results among the participating partners of the transition process: researchers, the DTC, and operational centers. To build upon previous experiences related to MMET, to better coordinate synergistic efforts within the DTC, and to support NOAA's goal of model unification across scales, we propose to merge MMET, which is currently focused on a regional modeling framework, with the global modeling framework established by the Global Model Test Bed (GMTB) under NGGPS funding. Since the purpose of this framework is to assess community innovations, we have named it MERIT, Model Evaluation for Research Innovation Transition.

MERIT fits well within the concept of hierarchical testing established within GMTB, which 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 to providing a framework for assessing community contributions, MERIT will be made available for NCEP's Environmental Modeling Center (EMC) to test their model developments.

As a step in the DTC's hierarchical testing, MERIT will be used to assess physical suites and parameterizations for possible inclusion in the Common Community Physics Package (CCPP). While the initial focus of MERIT will be on existing capabilities available in the global model framework, this activity is expected to include high-resolution regional and global capabilities in future years. Therefore, this activity could expand to include cases geared toward higher-resolution/convection-permitting modeling as the capabilities of the system expand. 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.

Project Description

During AOP 2017, MERIT will use and build upon capabilities established by the GMTB Physics Testbed for running the Finite-Volume Cubed-Sphere (FV3) model – the newly selected dynamic core for the Next Generation Global Prediction System (NGGPS), post-processing model output, verifying model simulations, and plotting model output using Python utilities. The focus of MERIT during the first year will be on 1-3 cases of interest to EMC's Model Evaluation Group (MEG), and/or cases that expose persistent operational biases/shortcomings. Limiting the number of cases provides the opportunity for more in-depth investigation and enhanced case-relevant diagnostics by DTC staff, which will lead to a more complete physical understanding of the strengths and weaknesses of the model performance. To facilitate benchmarking of results, operational Global Forecast System (GFS) baselines will be established and made available to the community for the chosen cases, including objective verification statistics. As part of the process, comparisons between the GFS and FV3 will be conducted and sensitivity testing using available physics options will be explored.

The initial capability of running cases through the end-to-end system will be supported on the 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 will be provided to the community with access to Theia, along with information regarding the individual case studies via a project webpage. Essential to MERIT's initial success will be securing sufficient compute resources on Theia for the DTC to establish the baselines and work with interested community users. It

should be noted that including data assimilation and/or higher-resolution global runs would come at higher computational cost, but would be beneficial to encouraging the broader use of MERIT.

To make MERIT successful from its installation, strong collaboration with the research and operational communities is essential. For the first year, it will be imperative to build connections with NGGPS PIs and encourage DTC Visitor Program proposals specifically geared toward engaging with MERIT. In addition, if model physics developers are required by code governance plans to run test cases prior to inclusion in the CCPP, MERIT will fill a key role in providing the capability to run and evaluate case studies through the end-to-end system. Another avenue that will be pursued is strengthening communication and collaboration with MEG participants. As with MMET, 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 MERIT and results from case studies at conferences as well as potentially presenting at MEG meetings throughout the year. As a "lesson learned" from MMET, continuous effort is needed to broadly advertise MERIT capabilities in order to make them effective utilities for the community.

In addition to establishing MERIT, it is important to recognize the previous efforts and successes of MMET. While MERIT will supersede MMET, the MMET cases made available by DTC to the research community via the RAMADDA data server will continue to be maintained. This effort should require minimal effort.

Project Deliverables

- Maintain current MMET cases available via RAMADDA
- Identify 1-3 cases of interest to include in MERIT
- Provide baseline model data, verification statistics, and relevant diagnostics for selected cases via Theia and project website
- Provide code, configuration files, and scripts used in the testing infrastructure

RE4: Testbed collaborations with HWT

Motivation

During NOAA Testbed experiments that occur throughout the year [e.g., Hazardous Weather Testbed (HWT), Weather Prediction Center (WPC) Hydrometeorological Testbed (HMT)], a plethora of experimental model data is produced to support the typically several weeks-long events. While this data is subjectively assessed daily during the experiments, there is often times a lack of extensive objective verification after the experiment to thoroughly investigate the contributed model configuration strengths and weaknesses. The large datasets produced during these testbed experiments provide an excellent opportunity to help identify and begin to answer the most pressing scientific questions that need to be addressed.

Project Description

During the 2016 HWT Spring Forecasting Experiment (SFE), an effort to coordinate the contributed model output from participating groups around a unified setup (e.g., WRF versions, domain size, vertical levels and spacing, etc.) was undertaken to create a super-ensemble of over 60 members called the Community Leveraged Unified Ensemble (CLUE). The careful coordination and construction of CLUE allowed for meaningful comparisons among a variety of members to be performed. With a convection-allowing ensemble planned for operational implementation in the near future, it is critical to investigate key scientific questions related to informing the best configuration strategies for producing such an ensemble based on an evidence-driven approach. While the exact configurations included as members of CLUE during the 2017 HWT SFE are still being solidified, they will include Weather Research and

Forecasting (WRF) and NOAA Earth Modeling System (NEMS) based configurations, along with a configuration of the newly selected dynamic core for the Next Generation Global Prediction System (NGGPS) –Finite-Volume Cubed-Sphere (FV3). A coordinated approach on the final selection will be employed to provide a rich dataset for further investigation.

Many questions remain regarding the best approach to constructing a convection-allowing model (CAM) ensemble system. For example, should model uncertainty be addressed through multiple dynamic cores, multiple physics parameterizations, stochastic physics, or some combination of these? CLUE will provide the datasets necessary to begin to explore this question; the methods targeted for this proposal will include examining single physics/core vs. multi-physics and/or multi-core approaches. 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. In particular, it will be important to evaluate the deterministic forecast performance of FV3 configured to run at high resolution (~3 km) given this is a new application for this dynamic core.

During AOP 2017, this extensive evaluation to investigate the probabilistic performance of ensembles constructed from select CLUE members, along with deterministic forecasts from individual members available in CLUE, 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), neighborhood methods applied to deterministic and probabilistic output (e.g., Fractions Skill Score), and a new method available in MET that helps evaluate forecast consistency measures amongst CLUE members and the resulting products. 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., updraft helicity, radar reflectivity, convective initiation indicators) will be conducted through a collaboration with NSSL researchers.

Project Deliverables

- Final report
- Presentation at a relevant workshop/conference

RE5: Addressing model uncertainty through stochastic parameter perturbations within the HRRR ensemble

Motivation

In most existing regional ensemble systems, model-related forecast uncertainty is addressed by using multi-dycore, multi-physics suites, or a combination thereof. While such multi-model ensembles have demonstrated potential, their maintenance is resource-intensive. Also, a multi-physics (and potentially multi-perturbed parameter) ensemble could fail if the members from such an ensemble do not have exchangeable error statistics, depending on how they are constructed. If member 1 always has a positive adjustment to a particular coefficient and member 2 always has a negative, this may create, over the period of forecast integration, a systematic difference. In which case, the ensemble members do not reflect situational uncertainty so much as the bias in different systems.

Recently, the National Centers for Environmental Prediction (NCEP)/Environmental Modeling Center (EMC) made a commitment to move towards a more unified and sustainable operational forecasting

system. The overarching goal of this proposed activity is to find realistic approaches to represent sources of model uncertainty in a single-dycore ensemble system. For the purpose of designing a unified storm-scale ensemble forecasting system, the utilization of a single dynamic core with a single physics suite and stochastic approaches would be beneficial. Hence, we propose to extensively test an alternative option for creating desirable spread and reliability by perturbing the members stochastically within a storm-scale ensemble. The stochastic-dynamic approach results in statistically consistent ensemble distributions. Two widely used stochastic schemes are the Stochastic-Kinetic Energy Backscatter (SKEB) and the Stochastic Perturbations of Physics Tendencies (SPPT). These methods are formulated to represent the effect of unresolved subgrid-scale variability and are added a posteriori to independently tuned models. An additional approach is the Stochastic Parameter Perturbation (SPP) scheme, which targets parameter uncertainty in the physical parameterization schemes directly.

Project Background

For AOP 2016, the DTC Regional Ensemble Task successfully built the necessary infrastructure for execution of a HRRR-based ensemble for prolonged retrospective runs. The system mimics the HRRR operational environment (continuous cycling of soil variables and an hourly pre-forecast with additional data assimilation for atmosphere). In the latest version of the HRRR code, an option for generating a field of random perturbations that can be applied to a variety of parameters in physics schemes was added. This stochastic parameter perturbation option was implemented into both the planetary boundary layer (PBL) and land-surface model (LSM) schemes (MYNN and RUC, respectively) used in the HRRR physics suite.

Preliminary tests with the HRRR-based ensemble employing stochastic approaches are being conducted using two baselines for comparison: 1) a control multi-physics HRRR ensemble that includes variations in PBL and LSM schemes and 2) the Storm Scale Ensemble of Opportunity (SSEO) obtained from the Storm Prediction Center (SPC) during the 2016 Hazardous Weather Testbed (HWT) Spring Forecasting Experiment (SFE). SSEO is a storm-scale ensemble that includes a variety of dynamic cores, physics suites, and initial conditions. To this point, the tests have included SPP of several variables within the PBL scheme (e.g. cloud fraction, roughness length, mass fluxes) and preliminary tests of the impact of stochastic perturbations on the soil-moisture field at the initial time. Preliminary results from comparisons between the stochastically-perturbed ensemble and a limited number of fields available from the SSEO indicate a storm-scale ensemble based on a *single dynamic-core and single physics suite* with *stochastic perturbations* can perform comparably to a multi-physics ensemble. Based on this preliminary investigation, HWT leads invited the DTC Regional Ensemble team to contribute a set of *initial* configurations for ten stochastically-perturbed ensemble members for inclusion within the Community Leveraged Unified Ensemble (CLUE) during HWT 2017. In order to support this effort and provide improved configurations for HWT 2018, we propose to continue and expand on the stochastic work started during AOP 2016.

Project Description

Using the infrastructure established during AOP 2016 to perform computationally complex, storm-scale ensemble simulations over the Continental United States (CONUS), the DTC Regional Ensembles team will conduct extensive testing of refined stochastic approaches for AOP 2017. We propose to test the impact of stochastic perturbations (SPP) for application to a CONUS-scale ensemble with a focus on cloud microphysics.

For this activity, the Regional Ensembles team will implement stochastic parameter physics for the Thompson cloud microphysics, which is a part of the RAP/HRRR operational physics suite, in collaboration with the developer. We will identify parameters of interest and adequate perturbation

ranges and evaluate within case studies and retrospective tests. The applied perturbations will be physically based in terms of the perturbations' magnitude and spatial and temporal de-correlation lengths, which will be ensured by working in close collaboration with the scheme developer and using information from corresponding literature. We will add this SPP capability to previously developed SPP applications to other physics (along with SPPT and SKEB) and evaluate in retrospective HRRR-based ensemble and possibly CLUE configurations. For this purpose an 8-member, HRRR-based, 3-km grid spacing ensemble will be used. The focus will be on periods characterized by active convective weather. Given a 3-km grid spacing CONUS-wide ensemble is computationally expensive (e.g. ~1 million core hours per 10-day retrospective run), the impact of a specific stochastic perturbations will be assessed through a limited number of case studies prior to performing extensive retrospective runs. The Regional Ensembles team will also consult with other stochastic physics developers (Berner, Hamill, Hacker, Bao and others) on the SPP design for storm-scale ensemble effectiveness.

For this T&E activity, the impact of SPP within each physics scheme individually and in combination will be evaluated. In these tests, the stochastic-based ensemble performance will be evaluated in terms of fields such as updraft-helicity, accumulated precipitation, and radar reflectivity. Similar to AOP 2016, the ensemble performance will also be compared to the High Resolution Ensemble Forecast v2 (current operational version of SSEO).

Project Deliverables

- Provide improved stochastic membership for CLUE
- Report on the experiment results
- Results presented at relevant conferences/workshops
- Article on outcome of testing submitted to an appropriate journal for publication

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

Motivation

With the release of the WRF v3.9 model in Spring 2017, new capabilities will be available for use by NCEP's ARW applications (e.g., RAP and HRRR). These capabilities include new physical parameterization schemes, higher-resolution static data over the continental US, more generalized input functionality for chemistry, optimized advection routines, and a new vertical coordinate. A test and evaluation capability by ARW developers will accelerate improvements to ARW applications at NCEP, including RAP/HRRR.

Project Background

During 2016, NCAR/MMM and NOAA/GSD worked closely on a few development projects. The MMM team provided a capability in the WRF Preprocessing System (WPS) to directly ingest the rotated latitude-longitude GRIB data from the high-resolution operational models, allowing the use of these models to initialize downstream WRF modeling systems (high resolution windows are now able to be initialized with the native horizontal data from RAP or HRRR). While this work was delivered in 2016, the initial request was made during 2015. The lag was due to prioritization determined largely from funding agency exigencies. During this past year, GSD tested initial versions of the soon-to-be-released hybrid vertical coordinate to determine the impact in the RAP/HRRR applications. Initial results from the single domain simulations using this new hybrid vertical coordinate are promising, while testing at GSD for the nested WRF domains has not yet been completed. A rapid response between MMM and GSD facilitated software validation and improved forecast metrics. Both the native horizontal domain enhancement to WPS for GSD and the hybrid coordinate testing at GSD would have moved ahead more quickly with a direct MMM/GSD relationship through a test and evaluation capability within MMM.

Both MMM and GSD have benefited from an on-going good working relationship. To allow GSD-specific modifications to get back into the WRF release branch, MMM staff recently worked to include the addition of the stochastic parameter perturbation capability. The results of this effort will see the inclusion of the MYNN PBL, the RUC LSM, and the GF cumulus schemes in the next WRF release without the need to modify the operational code that has enabled the stochastic capabilities. This capability toward stochastic physics will be applied toward the HRRR Ensemble in both ensemble data assimilation and improved model forecast spread and skill.

Project Description

The MMM WRF team will interact with GSD staff to develop a testing and evaluation program, mostly for numerical components of WRF, but which could include physical parameterizations at the request of GSD. Recommendations and identification of new capabilities suited for use by the RAP/HRRR will be provided as MMM developers begin running the GSD regional models in case-study mode. MMM and GSD will work together to decide what capabilities MMM will test and evaluate. 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.

Project Deliverables

- Monthly reports covering testing and evaluation
- Results presented at relevant conferences/workshops

Data Assimilation

DA1: Data assimilation system (GSI and EnKF) code management and user support

Motivation

Recent research indicates positive forecast impacts when introducing ensemble information to traditional variational data assimilation algorithms. Many operational centers have implemented such an algorithm through a hybrid ensemble-variational (EnVar) data assimilation system. The NCEP hybrid system uses two separate data assimilation systems for its Global Forecast System (GFS): the Gridpoint Statistical Interpolation (GSI) system, which updates the deterministic analyses, and the Ensemble Kalman Filter (EnKF) system, which updates the ensemble perturbations. For operational regional applications (e.g., NAMS, RAP, etc), NCEP currently uses the GFS EnKF ensembles for its hybrid system. Potential uses of regional model specific ensembles, updated through EnKF, are still under investigation. Supporting NCEP's GSI and EnKF systems to the research community provides an efficient framework for direct research transitions to these two operational systems for both global and regional applications.

Project Description

For AOP 2017, the DTC is proposing to continue providing code management for NCEP's two operational data assimilation systems: GSI and EnKF. The DTC will work with EMC to maintain and improve the code management framework through 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 chair of the DRC, the DTC hosts development meetings and implements code review procedures. The DTC also fulfills committee member duties (reviewing proposed code changes, testing proposed changes, and providing feedback and suggestions to code development). Under this activity, the DTC will maintain active communication with EMC and JCSDA to examine the state of next-generation data assimilation system development and prepare, if needed, the transition of current efforts to support the new system.

The DTC will continue to maintain the DTC community repository and provide code access to community developers for various applications (e.g. developers for HWRF). During AOP 2016, the DTC moved its repository server (discontinued IT support) to the NOAA Vlab. Use of Vlab opens the pathway to unify the EMC operational repository and the DTC community repository (mirror of the EMC repository). The DTC repository is currently necessary due to the security constraints on open access to the current EMC repository. The DTC will work with EMC to further explore NOAA Vlab functionalities and build a unified repository for both EMC and DTC. The DTC will also continue to improve the system user interface and portability. The goal of this effort is to eventually build one data assimilation repository for both the operational and research communities.

The DTC will provide one code release for GSI and EnKF for AOP 2017. The code release effort will include multiple-platform pre-release tests for both systems, documentation (e.g., user's guide, release notes), webpage support (e.g., download, on-line tutorials), and code/utility updates. Bug fixes discovered during the code release tests will be shared with all developers through the EMC operational GSI/EnKF code repository and the DTC community repository.

The DTC will provide a help desk service for the annual release code. The DTC proposes to host a joint GSI and EnKF residential tutorial at NCWCP, in collaboration with EMC and JCSDA, to provide onsite lectures and hands-on practice sessions for both internal and external users. The DTC will also provide an online tutorial that will be available to all users.

This task will be conducted as a collaborative effort between NCAR and NOAA/ESRL/GSD.

Project Deliverables

- GSI and EnKF code releases
- Joint GSI and EnKF tutorial
- Data assimilation community user support service
- Unified GSI/EnKF code repository for EMC and DTC

DA2: Testing DA advancement in observation aspects and evaluation for operational readiness

Motivation

As NCEP advances its operational data assimilation system, researchers continue to add new types of observations to the DA systems and further improve assimilation performance for existing data types. Such developments benefit from new observing systems and improved data processing, advanced DA techniques and methods (e.g., 4D vs 3D, high-frequency cycling, new bias correction), as well as forecast model improvements (e.g., better background, increased resolutions). The DTC Visitor Program provides an opportunity for researchers to work with DTC staff to contribute developmental code to the code repository for sharing with operational agencies and further testing of their new contributions through applications across multiple spatial/temporal scales. Past experience has shown that testing activities where the DTC establishes a close collaboration with a subject matter expert or developer provide the most informative outcomes. Hence, the DTC Data Assimilation team proposes to focus its AOP 2017 testing and evaluation activity on a new capability slated to be added through a DTC visitor project. Such an effort will provide an opportunity to conduct extensive testing, the results of which can be used to inform EMC's implementation process, accelerating the potential for R2O transitions.

Project Description

For AOP 2016, the DTC built a functionally similar testing environment for evaluating GSI 3D/4D EnVar capabilities for high resolution (3 km) regional applications. The DTC proposes to use this infrastructure

to test and evaluate new observational capabilities of the GSI EnVar system. The primary candidate for this T&E activity is radar data assimilation. Currently, developers at universities (e.g., University of Oklahoma) and operational developers (EMC, GSD) are advancing this capability aiming for future operational implementation. The DTC proposes to contribute to this effort by testing this research capability in the context of operational GSI configurations. The DTC proposes to test this new operator for high-impact convective systems using its high-resolution GSI EnVar framework. A testing period with convective cases will be selected and radar reflectivity/radial velocity will be assimilated in a 3-km regional domain. Experiments with and without 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 (e.g., cycling frequency), to EMC regarding this community contribution for further parallel tests at EMC. The readiness of this new capability is required to complete this proposed task. The DTC will work closely with the code developers, as well as EMC, to make research capabilities available as operational candidates and therefore maximize the potential for completing the R2O process.

Since the emphasis of this work is on testing a recent observer development, the outcome regarding the impacts of observation types and assimilation methods (including configuration tuning) will be beneficial to the operational Ensemble Kalman Filter (EnKF) data assimilation system (using GSI observation operators), as well as the next generation data assimilation system for the NCEP unified model, which is under development.

This task will be conducted as a collaborative effort between NCAR and NOAA/ESRL/GSD.

Project Deliverables

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

Hurricane

HU1: HWRF code management and user support

Motivation

The state-of-the-art HWRF end-to-end system currently has over 1300 registered users. By supporting the HWRF system to the community at large, NCEP will receive more feedback on the model's performance, which will lead to model improvements. In addition to its use by the community at large, recipients of HFIP and DTC Visitor Program grants rely on a stable code repository, the publicly released HWRF code and/or documentation to conduct their research. The HWRF system undergoes substantial annual upgrades that are making great strides towards improving its forecast skill. In order 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. Given the rapidly evolving HWRF system and complexity of the system, providing in-person tutorials is an essential mechanism for engaging the HWRF user community.

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 2017, 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 and GSI to SVN in VLAB). The DTC 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 additional component, WAVEWATCH III, was added to the 2016 operational implementation. Pending the decision to include this component in the HWRF repository, the DTC will update the code management plan accordingly and implement it for the WAVEWATCH III component. 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 2017, the DTC proposes to continue its HWRF user support activities. These activities will include an HWRF v3.9a release that will contain updates included in the 2017 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, 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, with the potential addition of the WAVEWATCH III component (pending support decision). During the 2016 operational HWRF implementation, one-way wave coupling using WAVEWATCH III was introduced. Following discussions with EMC, WAVEWATCH III was not included in the v3.8a public release. DTC will explore adding this component for the v3.9a release, which will require increased testing and further documentation.

An HWRF tutorial is proposed for College Park, MD. The tutorial will consist of lectures by EMC and DTC staff, as well as invited speakers from URI, GFDL, and HRD. Additionally, Nanjing University (NJU) has expressed interest in hosting an HWRF tutorial in Nanjing, China during the summer of 2017. DTC participation in this tutorial, in collaboration with EMC colleagues, would require travel expenses be covered by the host institution with staff time for this event supported by allocations in HU1.

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 given. Many HWRF projects continue to be funded, 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 v3.9a public release with updated documentation and HWRF Users' Page
- Community user support help desk and support for DTC visitor program PIs

- In-person HWRF tutorial

HU2: 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. 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 the inter-developer collaborations, which will lead to timelier model advancement.

Project Description

The DTC proposes to continue to facilitate the use of code management tools to HWRF developers 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 2017, 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. However, enhancements to the *multistorm* configuration will not be undertaken. 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 and serves as a platform for exchange of information. The HWRF Developers Committee meetings also ensure code commits are well communicated and follow proper code management protocols. Finally, the DTC will maintain the mailing lists used by the HWRF developers, allow developers access to code repositories, and centralize the overall communication among HWRF developers.

In order 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
- Unified HWRF scripts and code with additional developments ready for testing by EMC.
- Maintenance of *hwrf-contrib* repository

HU3: HWRF physics advancement

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 physics 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, microphysics, 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 conducted tests of HWRF using the Thompson microphysics (Thompson et al. 2008), which is a more physically realistic scheme than the one used in the operational HWRF. Past results indicated mixed forecast performance, thus further testing is necessary before operational implementation is possible. Additionally, the DTC has begun testing the Grell-Freitas (G-F) scale-aware cumulus parameterization for the HWRF system. Tests are now underway to help determine whether the G-F scheme shows improvement over the scale-aware Simplified Arakawa Schubert (SASAS) deep and shallow convection schemes currently used in the operational HWRF system. Past successful transitions to the operational HWRF have typically occurred over multi-year testing and evaluation timelines (e.g. RRTMG radiation upgrades), thus continued testing of the Thompson and G-F schemes provide the best opportunity for further improvements in the operational system. Finally, the focus on the G-F and Thompson schemes is also important because both schemes are used in the operational RAP model and are undergoing testing for NCEP's global application; therefore, this testing has potential to positively impact multiple NCEP forecast applications.

Project Description

For AOP 2017, the DTC proposes to pursue physical process diagnostics directed at improving the representation of physical processes in HWRF. The DTC proposes to work with developers of the selected physics schemes, as well as with subject area experts, to improve physical parameterizations for the next operational HWRF implementation, as well as NCEP's next-generation unified modeling system. The DTC is in a unique position to coordinate and test innovations, and to provide EMC with information and codes that can be transferred into the operational system. Additionally, two funded DTC Visitor projects will be leveraged to bolster our process diagnostic work. Dr. S. Bao (Coastal Carolina University) will evaluate the microphysics schemes in HWRF using remote sensing data, and Prof. R. Fovell (Univ. Albany) will examine the impact of PBL assumptions on HWRF forecast skill. PBL scheme diagnostics have potential to help refine shallow cumulus testing.

The DTC will run HWRF retrospective forecasts using the 2017 operational HWRF model, in order to effectively inform the 2018 HWRF pre-implementation process. Sensitivity tests will be performed to determine the impact of alternate physics for either microphysics (Thompson replacement for Ferrier-Aligo) or deep and shallow cumulus (G-F replacement for SASAS), which have been selected based on recent discussions with EMC. Final parameterization selection for testing will be established in collaboration with EMC's hurricane team based on the final 2017 operational configuration. The evaluation will consist of comparisons of Quantitative Precipitation Forecasts (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 the representation of physical processes for the candidate parameterization tested.

The DTC will facilitate the R2O transition through effective communication with EMC concerning controlled diagnostics, sensitivity experiments, and multiple storm testing of the aforementioned parameterization. Any advancement deemed viable will be made available to EMC for pre-implementation testing.

Project deliverables

- Project report on results of the sensitivity experiments.
- Assessment of improved parameterizations in the context of the operational HWRF system with new capabilities in HWRF physics made available to EMC for testing.
- Results presented at relevant conferences/workshops.

Verification

VX1: MET development and research community support

Motivation

The Model Evaluation Tools (MET) verification package 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 package or through the METViewer database and display system. MET is a community-supported software package with over 3200 users (over 300 new since last year) from a wide variety of universities (48%), government (27%), non-profit organizations (14%), and private companies (11%). Following its August 2016 release, METv5.2 has 110 new registered users and 240 downloads were requested. As well as supporting the research community, the DTC Verification team has been collaborating with the verification teams within NOAA on adopting MET and the accompanying database and display system, METViewer, to facilitate unification of verification. During the last three years, the number of active NOAA users has increased from a few to over fifty. These estimates are based on DTC's interactions with users via met_help, monthly telecons and in-person meetings. Additionally, METViewer has been installed for developmental use by EMC on the NCEP Central Operations (NCO) virtual machine compute farm and for use by GSD on the HIWPP platform. Through a close collaboration between DTC and EMC, MET and METViewer was integrated into the North American Model Rapid Refresh (NAM-RR) parallel testing workflow. This collaborative effort facilitated meaningful discussion between EMC and DTC regarding how to improve MET and METViewer for use within the operational community.

Besides helping the research community refine numerical weather prediction through objective evaluation, MET and specifically MODE (Method for Object-based Diagnostic Evaluation) are being used either operationally or to make operational decisions at NCEP's Environmental Modeling Center (EMC) and 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 directed toward assessing forecast skill and informing the model development process.

Project Description

The MET help desk responds to approximately 4-7 emails per day, resulting in approximately 250 tickets closed per year. MET releases occur 1-2 times per year and usually include 30-50 issues, including 3-5 major enhancements per year. METViewer releases usually occur monthly or bi-monthly and include 5-10 issues per release. Decisions regarding what to include in the next software release are made via requirements assessment based on input from the community and other DTC task areas and discussions with stakeholders. Priorities for the software release are recorded in our features tracking and bug-fix package (JIRA). This activity is focused on maintaining community help desk support and providing one

major and, if needed, one minor release of MET during AOP 2017. The release includes bug fixes, upgrades needed to improve performance issues and documentation. Basic METViewer enhancements and bug fixes are also supported by this activity. Areas of critical development for the next annual MET release will include:

- Enhancing MET and potentially MODE to have greater flexibility for event definition (e.g. percentile thresholding)
- Enhancing MODE tools to filter objects by latitude and longitude
- Adding methods to handle observational uncertainty in statistics computation
- Improving the METViewer user interface and functionality as specified by user base
- Enhancing Stat-Analysis to perform event equalization and compute pair-wise differences.

Training both new and returning scientists in the use of MET is a critical part of expanding the use of MET as well as keeping MET-help requests down. The MET team has witnessed an uptick in user requests for an in-house tutorial over the past year and hence propose to re-establish the MET User's Tutorial this AOP. The target would be to hold it in conjunction with the WRF Tutorial in Summer 2017. The last in-house tutorial was held in January 2015. To keep costs down, we hope to leverage training and tutorial material developed during AOP 2016. Additionally, staying in touch with the current statistical and verification approaches and maintaining the DTC's reputation as an international leader in verification is key to serving the research community. In light of this need, the proposal includes a presentation at the WRF user's workshop, a trip to an AMS conference as well as to the World Meteorological Organization (WMO) Forecast Verification Workshop in Berlin in May and the Working Group on Numerical Experimentation (WGNE) Systematic Error Workshop in Montreal in June. A publication on MET will also help with communicating the community support.

This activity will be a collaborative effort between NCAR/RAL/JNTP and NOAA/ESRL/GSD.

Project Deliverables

- MET release with 4-6 new capabilities
- 1-2 major upgrades to METViewer
- Updated MET and METViewer documentation.
- MET Tutorial held at NCAR
- Presentation at WRF User's workshop and at least one conference
- Journal manuscript on MET

VX2: NOAA-DTC verification unification

Motivation

For the past few years, the DTC Verification team has collaborated with NOAA verification teams on adopting MET and the accompanying database and display system, METViewer, to facilitate unification of verification capabilities. The number of NOAA MET users is on the increase partially as a result of MET being installed in a public location on NOAA's High Performance Computing platforms WCOSS, Theia, and Jet, removing the requirement for individuals with access to these platforms to download their own copy. Additionally, the DTC Verification team has become more closely linked with EMC model developers and has had funding to start addressing their needs. Finally, METViewer is now available for developmental use by EMC on the NCEP Central Operations (NCO) virtual machine (VM) compute farm and for use by GSD on the HIWPP platform.

A recommendation by the Next Generation Global Prediction System (NGGPS) Verification and Validation team and the UCAR Model Advisory Committee (UMAC) to unify verification capabilities led to the DTC and NGGPS team members gathering and synthesizing initial requirements for a unified

system under AOP 2016 funding. The report was completed in September 2016 and made available to the EMC director and the NGGPS Verification and Validation team. The result of these discussions was a list of 99 specific functional needs along with additional non-functional requirements. The DTC Verification team and NGGPS Verification and Validation team have been working to address these needs over the past year. The current status of the requirements list may be found on the Google Drive at: https://drive.google.com/a/noaa.gov/file/d/0BwjqxMjULl-DUWtnU0RNanBiZEU/view?usp=sharing. Ultimately, 90% of the Priority 1 and 80% of Priority 2 requirements will be completed through AOP 2016 (ending March 2017) and NGGPS Year 1 (ending June 2017) funding. That leaves 10-15% of the Priority 1 & 2, along with many priority 3 and 4 requirements to be addressed. While the verification team has made good progress over the past year toward addressing user needs, much of this progress was due to MET already having many of the needed capabilities. Addressing the remaining Priority 2-4 requirements from the diverse user base within EMC will not proceed as quickly as requirements addressed during the first year because many of these requirements are less well defined and need more work to identify use cases and accomplish development.

Many of the EMC users are housed within the Mesoscale Modeling Branch, including Ben Blake, who developed MET workflow to run consistently for evaluating the NAM-Rapid Refresh (NAM-RR). There are also a few users in the Global Climate and Weather Modeling Branch, including Tracey Dorian who uses MODE for her work with the Model Evaluation Group (MEG). The DTC and EMC have started monthly telecons to discuss questions, concerns and requests regarding MET and METViewer, which the DTC has found highly beneficial for determining priorities and addressing the immediate needs of EMC staff. When asked for feedback on MET/METViewer, the DTC received the following comments:

- ***Jacob Carley*** *– "MET and METViewer are becoming game-changing tools at EMC by providing a unified mechanism for analysis and verification of our diverse set of NWP systems. Therefore, its continued development and support are important to not only the success of MET and METViewer, but to EMC's continual progress in NWP development and messaging…"*
- ***Binbin Zhou*** *– "After several months of testing and usage of MET and METViewer at EMC, we (at lease me) think MET/METViewer is a very good unified tool and have potential expansion in use at EMC particularly during such a transition time for NGGPS here. I support this initiative…"*
- ***Ben Blake*** *– "MET and METViewer have both been very helpful to me for the projects I've been working on. I also appreciate all of the help and feedback I've gotten thus far, and the monthly telecons have been very useful. I will gladly continue to utilize MET and METViewer as verification tools."*

Along with these responses, several people provided a short list of areas the DTC should focus on for AOP 2017. These areas include: 1) improved and more extensive documentation and training; 2) additional work with EMC NCO to improve the loading and batch engine processing of plots in METViewer (including a discussion of putting the database on WCOSS and mirroring it to the VM compute farm); and 3) many enhancements to MET and METViewer to make using the tools for their research easier. One step the Verification team is taking to make setting up and running MET and METViewer easier is to follow the example set by Hurricane WRF (HWRF) and develop a system of python wrappers to help with verification workflow. The bundled system, including MET, METViewer and the python wrappers is called MET+.

Project Description

This activity is focused on unification efforts to help NOAA address the UMAC recommendations and to facilitate "evidence driven decision making" within the operational and research communities. Before NOAA and the community can address the other recommendation to "improve verification and

diagnostic methods", it must be working with the same tools. While progress has been made in this arena, the DTC has received many inquiries as to how much more time it will take for MET+ to be made available to different groups within EMC (e.g. mesoscale, oceans, sea ice, aerosols, etc…). Providing a solution 2-3 years from now will not suffice as it will allow for continued development of the multiple verification tools, leading to more work to unite the systems. Thus there is a strong need to accelerate the adoption of MET+ by addressing many of the current needs through AOP 2017 funding and complementary NGGPS Year 2 funding.

This activity will be directed toward 1) accelerated development of MET+ to reduce the time required to transition to the unified system; 2) prioritized NOAA outreach and support to Labs (ESRL, NSSL, GFDL) and Centers (EMC, WPC, SPC, NHC, AWC, etc…); and 3) meeting the immediate needs of the current and growing community of EMC users (in coordination with unification goals) along with NOAA users in other centers (WPC, SPC, NHC, AWC, RFCs) to make model development discussions with EMC more meaningful. Specific activities include completing MET+ wrappers for several different use cases and developing METViewer regression testing to promote robustness of the system. It will include enhancement of MET and METViewer components to encompass most of the mesoscale and ensemble priority 2-3 requirements along with additional requirements that are uncovered through extended tool use, refactoring the METViewer interface to allow for more individual control over METViewer and speed up loading and queries. MET+ documentation will be developed, including an online tutorial. Finally, DTC will engage NCO regarding discussions about how to prepare MET+ for operations.

This activity will be a collaborative effort between NCAR/RAL/JNTP and NOAA/ESRL/GSD.

Project Deliverables

- MET+ development to handle 4-6 priority use cases.
- METViewer regression test framework.
- MET+ documentation including an on-line tutorial.
- Improved METViewer database performance and user preferences capability.
- Prioritized MET+ support for NOAA users.
- Engage NCO regarding how to make tools more accessible on operation systems.
- 4 collaboration/training trips to EMC

VX3: Enhancing community collaborations through DTC-supported software containers

Motivation

A core mission of the DTC is to assist the research community in efficiently demonstrating the merits of new developments that could positively impact an operational configuration in the future. A key tool in demonstrating improvement is the Model Evaluation Tools (MET) developed, maintained, and supported by the DTC. MET is designed to be a highly-configurable, state-of-the-art suite of verification tools offering both traditional and spatial evaluation capability. Through the common modeling framework established by the DTC, which includes the Weather Research and Forecasting (WRF) model, the Unified Post-Processor (UPP), and MET as the verification tool, researchers have the ability to perform comparisons between multiple innovations tested by the research community and/or against the baseline operational configurations made available by the DTC.

In recent years, end-to-end testing and evaluation software components, including WRF, UPP, and MET were implemented into Docker "containers" to assist the user community in alleviating one of the biggest hurdles when running a new software system – getting it set up and compiled on the intended

computer platform. This new container technology allows for the complete software system with pre-compiled executables to be bundled and shipped to users to facilitate a reduction in spin-up time and higher efficiency in the setup process. The containers include everything that is needed to run the software component, including the operating system (tools and libraries) and code, thus, allowing the user to quickly produce output without being delayed by technical issues of compiling on their specific platform. The work conducted by DTC staff during AOP 2016 complimented Big Weather Web (http://bigweatherweb.org/), which is an NSF funded project with a goal of "making big data infrastructure affordable and adequate for university members of the Numerical Weather Prediction community by combining the application of three recent technologies: virtualization, federated smart storage, and big data management."

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. One aspect of making information on DTC activities available to the community is posting information on the DTC website; another is presenting information at relevant conferences or workshops. As highlighted by the DTC Science Advisory Board in previous years, continued effort needs to be made to more broadly advertise MET and DTC-supported test harness capabilities in order to make them effective utilities for the community-at-large.

Project Description

For AOP 2017, the DTC is proposing to build on the original containers established for UPP, MET and critical test data sets (including initialization and verification data) during AOP 2016 and then present it to the community to ignite interest in the tool. This work would include enhancements to the original containers to meet the requirements for distributing a robust software capability. In addition, it is desirable to lower the very high barrier to using synthesis tools such as METViewer for community users. The knowledge gained during the process of establishing the initial containers will be used to streamline the process of implementing similar technology for METViewer in the coming year.

To accomplish the goal of reaching and engaging with interested parties in the user community, a combined short course at the AMS Annual meeting would be prepared and offered to raise awareness about the community tools and facilities available, including the emerging set of tools in Docker containers. A general overview of topics including the unified modeling framework and verification data archive for end-to-end system testing, MET, and METViewer would be provided and specific usage examples would be highlighted during the course. The timing of the short course would be well aligned with the rebranding of the Mesoscale Model Evaluation Testbed (MMET) to better align with the hierarchical testing framework by the Global Model Test Bed (GMTB) Physics Testbed (i.e., MERIT; proposed as a separate task for AOP 2017) to energize and entice the user community to work with the DTC on common goals utilizing DTC-supported containers to the extent possible.

By utilizing this groundbreaking container technology to promote ease of use for several DTC-supported software components and offering information through a short course to advertise the capabilities, the opportunity to establish connections with future community collaborators will be greatly expanded.

Project Deliverables

- Establish METViewer Docker container
- Robust Docker containers provided to community users
- Short-course offered at AMS Annual meeting (January 2018)