Developmental Testbed Center

2019 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) Global Systems Laboratory (GSL). 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 2019 was developed based on recommendations from the DTC's Science Advisory Board (SAB), the priorities of NCEP's Environmental Modeling Center (EMC) as articulated by the EMC team leads, and priorities expressed by the DTC sponsors through their DTC Management Board (MB) members. This plan represents a collection of coordinated activities funded by a variety of sponsors. The period of performance (PoP) for these activities varies by sponsor:

- NCAR: 1 October 2018 to 30 September 2019
- NOAA: 4 May 2019 to 3 May 2020
- HFIP: 1 April 2019 to 31 March 2020
- Air Force: August 2019 to January 2020

Director's Office

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.

Project Deliverables

- Quarterly reports to EC
- Reports to sponsors

- Quarterly DTC newsletter

Sponsors: NOAA, Air Force and NCAR

Community Interactions and Outreach

Unified Forecast System (UFS) User Workshop

Motivation

As the Next Generation Global Prediction System (NGGPS) evolves to become the Unified Forecast System (UFS), it is envisioned to be a community-based, coupled Earth modeling system designed to accommodate both the research and operational communities. To support this goal, it is important to bring together a diverse group of scientists working on the various aspects of the overall modeling system (atmosphere, ocean, sea ice, data assimilation, verification, etc.) and range of applications (seasonal, global, regional, hurricane, etc.) to discuss experiences with the UFS and learn from each other, while identifying parallel efforts for collaboration and avoiding redundancies. Inviting the broader community to take part in such a gathering will open up communications regarding the state of the UFS and provide an opportunity for them to learn how they can contribute to the advancement of this community system.

Project Description

The DTC proposes to co-host the 1st UFS Users Workshop with EMC to be held in Boulder, CO likely in the early 2020 timeframe. The best timing for this event will take into consideration the various NGGPS and UFS meetings, as well as national and international conferences and workshops. Having the right people involved in the planning process goes a long way towards determining how successful and productive a workshop is. The DTC will work with our partners at EMC and relevant NOAA agencies to put together a strong organizing committee that will reflect the vision for this workshop. This committee will outline session topics for the workshop and strategize on how to attract broad community participation. Communication with the UFS Steering Committee and Strategic Implementation Plan (SIP) Working Groups will be important to ensure proper coordination among all relevant and interested parties. Inviting groups to provide instructional sessions relevant to the UFS similar to the format used for the WRF Users' Workshop will also be taken into consideration. The Common Community Physics Package (CCPP) may be an ideal candidate for such an instructional session. In addition, this workshop would provide an opportunity for SIP Working Group side meetings. The DTC will ultimately lead the preparation of the workshop agenda and chair selected sessions related to staff expertise. In addition, the DTC will provide logistical support for the workshop (hosting a website with workshop information, establishing a registration page, etc.). To attract the next-generation workforce, the DTC will sponsor travel for students to participate in the workshop. An application process will be established and advertised. Students will be selected based on criteria put together by the workshop organizing committee with an eye towards providing the broadest community exposure for the UFS. Finally, the DTC will solicit feedback from workshop participants with regards to refining plans for future workshops.

Project deliverables

- Co-host the 1st UFS User Workshop
- Feedback survey report

Sponsors: NOAA

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 $75 K from the DTC's NOAA funds to support visitor projects and submit a proposal to NSF to match this $100 K. The additional $25 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

Sponsors: NOAA, NSF

Community System Support

WRF software support

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, which supports three NOAA operational applications: the Rapid Refresh (RAP), High Resolution Rapid Refresh (HRRR), and Hurricane WRF (HWRF). The RAP and HRRR, which are developed by NOAA GSD, are based on the WRF-ARW dynamic core developed and supported by MMM. Over the years, MMM has worked closely with GSD to trouble-shoot problems that arise and test new innovations with potential to advance the forecast skill of the RAP and HRRR. The atmospheric component of HWRF employs the WRF Nonhydrostatic Mesoscale Model (NMM) dynamical core, developed by NOAA's Environmental Modeling Center, and utilizes physics packages available in the WRF repository. WRF repository support from MMM supports the continued community engagement in advancing the skill of HWRF.

Project Description

The DTC proposes to continue to provide funding to NCAR's MMM to maintain the WRF repository and ensure that robust software packages are distributed to the user community. The HWRF code is developed within a fork of the WRF and WPS repositories. In order to avoid code divergence, the DTC merges the HWRF fork and the WRF master after the HWRF operational implementation and prior to the WRF and HWRF community code releases. Regression testing of the WRF repository is performed with each new code commit proposal. The regression test suite currently includes 27 Nonhydrostatic Mesoscale Model (NMM) tests and 4 HWRF tests in addition to an extensive list of WRF-ARW 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.

In addition to supporting basic WRF repository maintenance, the DTC proposes to provide funding to MMM to collaborate with GSD on configuration testing directed at improving the skill of the HRRR. The two types of testing under consideration are: 1) additional vertical levels and their impact on the development of clouds and inversion layers and 2) a quasi-Lagrangian vertical advection scheme developed as a collaborative effort between Lou Wicker of NSSL and MMM. Increasing vertical resolution may help with cloud deficiencies that currently exist between -5 to -20 C (around 700 hPa), potentially improving winter precipitation forecasting, as well as the retention of initialized cloud layers and the resolution of vertically propagating mountain waves. Implications may also exist to inform PBL physics parameterization improvement for both cold and warm season forecasts. The new vertical advection scheme allows for a larger time step in combination with the potential for higher vertical resolution. In addition, a relaxation of the constraint on latent heating (to limit vertical motion) is also possible. Each of these two improvements could be incorporated into the HRRR for potential operational implementation.

Project deliverables

- Report on frequency of regression testing and number of issues resolved
- Report on outcome of testing new configuration(s) of WRF-ARW for HRRR

Sponsors: NOAA

Data assimilation software support and community engagement

Motivation

All current NCEP global and regional operational modeling systems use hybrid ensemble-variational (EnVar) data assimilation (DA) through the Gridpoint Statistical Interpolation (GSI) system for their deterministic forecasts. The global DA 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. The GSI/EnKF-based DA components are also used in the new FV3GFS system and will be part of the EMC forecast systems until the Joint Effort for Data Assimilaiton Integration (JEDI) system becomes mature enough to replace the GSI/EnKF. For AOP 2019, community developer support and code management for NCEP's operational GSI and EnKF systems is still essential for the research community to make direct contributions to the GSI and EnKF operational applications.

Project Description

For AOP 2019, the DTC proposes to continue to contribute to the code management for NCEP's two operational DA systems: GSI and EnKF. The DTC will maintain the code management framework through working with the joint GSI and EnKF DA Review Committee (DRC). An important component of

this framework is the unified Multiple-Platform Multiple-Case (MPMC) testing suite developed by the DTC. The DTC proposes to continue to exercise this test suite for the master repository and community developments to facilitate code development and transitions between research and operations. As a member of DRC, the DTC plays an important role in reviewing and testing proposed code changes, especially for portability and robustness of the code. The DTC also provides feedback and suggestions on code development and outreach. In addition, the DTC will continue to provide code access to community developers for various applications through the unified GSI/EnKF repository on NOAA VLab and provide assistance to community DA developers with committing their code to the repository, in particular, data assimilation researchers supported through DTC Visitor Program and developers funded by NOAA programs like HFIP and NGGPS. The DTC will also enhance the ProdGSI regression test suite by adding an EnKF case for HWRF. And finally, the DTC will continue its support for community users of the current DA system release through its current help desk capability and start to transition this support to a community forum in coordination with other DTC-supported software systems. A new release of the community GSI/EnKF system is not included in this proposal based on discussions with EMC's DA lead. Rather, the DTC is proposing, under a separate activity, to begin engaging in testing directed at helping EMC determine the readiness of JEDI components for operational implementation. Foregoing a new release means the community GSI/EnKF webpages will remain at their current status without further updating.

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

Project Deliverables

- Data assimilation community user support service

Sponsors: NOAA

Hurricane Weather Research and Forecasting (HWRF) software support and community engagement

Motivation

The state-of-the-art HWRF end-to-end system currently has over 1700 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 Hurricane Forecast Improvement Project (HFIP) and the DTC Visitor Program grants rely on a stable code repository 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. To avoid divergence of development efforts and ensure new development can be easily integrated into the centralized HWRF repository, it is imperative that developers work on the same code base that includes the latest changes included in NCEP's 2019 version of the operational HWRF model. New HFIP awards were granted during 2018, which has the potential to bring in new HWRF developers. To ensure 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 leads to more rapid transition of research developments to operations (R2O) and ultimately to improved HWRF forecasts.

Project Description

Code management

The DTC currently hosts the HWRF code repository, which is comprised of a sophisticated set of scripts plus eight components: WRF atmospheric model, WRF Preprocessing System (WPS), Gridpoint Statistical Interpolation (GSI) data assimilation system, *hwrf-utilities* (which includes several libraries and a vortex initialization package), ocean-atmosphere coupler, MPIPOM-TC ocean model, Unified Post Processor (UPP), and the GFDL Vortex Tracker. For AOP 2019, 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, ensuring that the main HWRF development and the community codes remain synchronized. HWRF is affected by repository changes for individual components. During AOP 2019, the GSI and UPP components may transition to Git in Github, rather than 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. The code check-out process will be streamlined to address these repository changes. Integrity of the HWRF repository 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 all components of the HWRF system. The code management of the HWRF system is the foundation of the HWRF user and developer support activities, and is imperative for all proposed activities described below.

Developer support

The DTC proposes to continue to facilitate the use of code management tools by 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 2019, the DTC will continue to update online instructional and training materials pertaining to topics such as the code check-out procedure and development using Git. 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. 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. 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. As specific HWRF components undergo repository transitions (e.g. potential transition of GSI and UPP to Git in Github), 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.

User support

For AOP 2019, the DTC proposes to maintain support for existing publicly released systems. The DTC will continue to staff 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 HWRF v4.0a, released in November 2018. Additionally, the stand-alone GFDL vortex tracker (v3.9a, released April 2018), will also be supported via the helpdesk. In order to gradually stand down DTC support for HWRF, work towards transitioning the user helpdesk over to a community-driven forum will be undertaken. The current user webpage will be maintained through updated FAQ, Known Issues, and posted bug fixes, as needed.

Project deliverables

Code management

- Unified HWRF scripts and code maintained with code integrity tested through regression and consistency checks, as applicable

Developer support

- Helpdesk serving HWRF developers, including DTC Visitor Program PIs
- New developments contained in repository branches ready for testing by EMC and DTC staff
- Updated training materials posted to developer webpage

User support

- Community user support help desk, with progress towards a community-driven forum

Sponsors: NOAA, HFIP

Unified Forecast System Convection-Allowing Model (UFS-CAM) software support & community engagement

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 a 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 (including regression testing protocols), community access to code and datasets, documentation, and user support.

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. 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. 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.

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. To engage the broadest aspects of the research community, such an infrastructure will also need to support two tiers of contributors: 1) developers who will need to engage directly with the code repositories and have active communication mechanisms to allow timely sharing of information across all development groups, and 2) general users conducting research with a public release of the code.

Project Description

The UFS Convective-Allowing Model (CAM) capability underwent rapid development in an effort to establish a stand-alone regional (SAR) version of the FV3 during AOP 2018. A number of operational and research partners collaborated on this quickly-changing code base to advance the system. This rapid development is expected to continue during AOP 2019, emphasizing the need for robust governance of repositories and extensive regression testing. Recent discussions among SAR-FV3 developers have signified that repositories will likely be moving to Github to allow for access to the community at large. In close collaboration with EMC, the DTC will create a Github repository for the SAR-FV3 workflow in order to facilitate community interaction and the repository structure currently in NOAA Vlab will be migrated to the new Github repository. Code management regulations regarding software development practices and how community contributions can make their way into the workflow repository will be clearly defined in a code management plan and implemented based on protocols being put together by EMC management. A code review committee will be established with representation from the DTC, EMC, GSD, and other NOAA laboratories that will meet regularly to assess potential commits to the master workflow repository. Due to the multiple facets and large scale of this system, improvements to the governance process will be made based on experience with the process throughout the year. While it is understood that each community has specific needs, it will remain a goal to avoid unnecessary divergence between the operational agencies and the research community, with the operational configuration remaining a subset of the larger community workflow repository capabilities. To facilitate this goal, development of the community workflow will continue in a branch of the SAR-FV3 workflow (fv3sar_workflow) repository, with the EMC workflow contained in the master branch of the same repository. Periodic merges will be conducted in accordance with the established code management plan between the two workflow branches. Finally, the DTC will assist community developers with the governance protocol when contributing scripts and utilities to the workflow repository.

As part of this process, it is essential to put a series of regression tests into place to ensure the scripts remain in a working state after each commit. The DTC will establish these tests for each task defined within the end-to-end workflow process during AOP 2019. Code management for software packages used by the workflow (e.g., pre-processing, model, post-processing, data assimilation, verification) is already (or will soon be) handled by external repositories for each component, with the work proposed here focusing only on the workflow repository. It will be important to remain up to date with developments as new tasks are integrated into the SAR-FV3 workflow, including data assimilation and verification tasks. The regression tests will be deployed across the supercomputing platforms readily

available to the DTC and will be made available for community users to run on additional platforms of interest.

In order to facilitate use of the SAR-FV3 among the research community, portability of the system will be necessary. Work on this front began during AOP 2018 with efforts to port the community workflow to multiple OAR supercomputers. During AOP 2019, efforts will continue with a focus on additional community accessible platforms, such as Cheyenne. Modifications will be made to allow the community workflow to run as seamlessly as possible on different supercomputers with a simple change to a user-defined machine variable.

Based on discussions taking place in the FV3-SAR coordination group meetings, the DTC anticipates an initial release of the SAR-FV3 model code (either through a tar file distribution or Github depending on the status of the latter), along with pre-processing utilities, based on a specific tag/commit from the master branch of the repository to the community at large will take place during AOP 2019. The lead institution for packaging and distributing the release is still unclear; however, the DTC will contribute as a supporting institution to this effort. As it is anticipated that the community workflow will be released with the SAR-FV3, it will be critical for the DTC to conduct pre-release testing of this capability. Regression testing established during AOP 2019 will assist with this effort. In addition, a critical component to successful deployment and community engagement with any modeling system is a well-written users' guide. During AOP 2018, the DTC compiled an initial LaTeX document describing the necessary steps to clone, build, and run the SAR-FV3 workflow from pre- to post-processing. This work will continue in AOP 2019, with an expansion of the current documentation to include additional tasks integrated into the workflow as it evolves (e.g., verification and data assimilation tasks). Through this process, both Doxygen and Sphinx will be utilized to help seamlessly transfer code comments into scientific and user guide documents as appropriate. Publication of the latest version of the users' guide will coincide with the release. A community SAR-FV3 website will also be designed by the DTC that will feature a users' forum for both developers and the general community to provide support to help others running the code.

Due to the state of rapid development on this effort, the DTC will work closely with EMC, the UFS-CAM Working Group, and other NOAA laboratories to ensure the scope of the work plan evolves in an appropriate manner that satisfies requirements for both the operational and research communities.

Project Deliverables

- SAR-FV3 workflow repository transitioned to Github
- Workflow review committee created as defined in the developed code management protocols
- Full end-to-end regression test established for the community SAR-FV3 workflow repository
- Enhanced community SAR-FV3 workflow with new tasks as development of a full system matures
- Updated documentation to support the initial release of the SAR-FV3 system to the community
- SAR-FV3 Users' Forum designed and made available to facilitate community support

Sponsors: NOAA

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), and Hurricane WRF (HWRF) applications. In addition, UPP has undergone updates to be able to process output from the new dynamical core (Finite Volume Cubed-Sphere: FV3). With the expansion to more applications spinning up, the DTC has expanded its UPP support to include both regional and global forecast applications with FV3. The UPP user base continues to expand as the capabilities grow with an increase in requests received for support among the research and operational users, especially in regards to implementing new diagnostic fields and utilizing output for both regional and global 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 UPP repository and code syncing procedures will continue to be aligned with EMC as they evolve. The community UPP distribution will continue to be supported for use with the Weather Research and Forecasting (WRF) Advanced Research WRF (WRF-ARW) modeling core. During AOP 2019 the WRF Non-hydrostatic mesoscale model (WRF-NMM), as a component of the HWRF, and the publicly released version of the FV3 modeling core will also be supported. 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 and FV3 nemsio and 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. As time allows, scripts and containers to facilitate cross-compiler testing using containers will be established to make it easy to compile/test UPP using multiple compiler types and versions. Updates to documentation (including User Guide, online tutorial, etc.) will be made available to the user community with each release; expansion to describe new capabilities, especially with regards to FV3, will be added as necessary. User support will be provided by the DTC through the email help desk while initial efforts to transition to an online forum are pursued in coordination with other software support tasks in the DTC. Updates to the existing UPP container with the new release will be packaged and made available on Github, with corresponding documentation on how to use it added to the UPP website.

Emphasis for user support 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. The DTC will also collaborate with EMC on the re-engineering of the UPP code base scheduled to get underway at EMC by Spring of 2019. Involvement in the refactoring will include engagement during the project planning phase to ensure community needs are represented, beta testing as progress is made, especially in

regards to portability, and other community-pertinent tasks mutually agreed upon by both the EMC and DTC teams.

Project Deliverables

- Code release and updated documentation
- Community support for expanding user base, including general support and developer-focused support through the help desk for facilitating R20 code development and transition
- Early phases of the UPP re-engineered capabilities tested with an emphasis on ensuring portability

Sponsors: NOAA

METplus Development, Software Support and Community Engagement

Motivation

The DTC METplus team has been collaborating with the verification teams within NOAA and the AF on adopting the verification suite METplus as part of an ongoing verification unification effort. MET and METviewer are at its core, along with a suite of python wrappers for the tools. MET is a widely used community-supported software package with over 3,700 registered users from a wide variety of universities (48%), government (27%), non-profit organizations (14%), and private companies (11%). METviewer has a batch engine and highly configurable user interface to allow model developers extensive analysis capability. METviewer is primarily used by DTC and EMC at this time, will be adopted by the AF in 2019, and is anticipated to be more broadly adopted by other community users over the next few years. A second display system, called METexpress, is being developed through an NGGPS project during FY19 and will be available for use in the DTC and EMC during AOP 2019. METexpress uses the same database and computation back-end and will eventually provide the UFS community with a pre-defined suite of plots. This work covers helpdesk support, releases with documentation, repository maintenance, tutorials and outreach.

Helpdesk: So far in AOP 2018 (through mid-December), the MET helpdesk has responded to just over 200 helpdesk tickets, which suggests it will close approximately 320-360 by the end of the AOP. This is up from 293 during AOP 2017, with 152 tickets from NOAA users and 16 from AF users. Each helpdesk ticket requires 2-10 or more email responses from DTC staff. It is anticipated that this demand will increase over the next year with an increase in METplus adoption. The number of active NOAA users has increased from tens to hundreds in recent years. 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. Aspects of METplus are now in use at EMC, NSSL, MDL, GFSL, OPC, and WPC at this time as well. The result is an increased need for METplus community support through helpdesk, documentation and tutorials. Supporting METplus to the community is necessary to meet the DTC mission of connecting the research and operational communities by using common tools.

Releases and Documentation: In AOP 2018, there have already been several releases, including for METplus (3), MET (3) and METviewer (8). This increase over previous years is due to the need for the NOAA weather enterprise (NCEP centers and NOAA laboratories) to have updates more routinely to accelerate their adoption of METplus, as dictated by the UFS SIP. The METplus team has developed a protocol to provide coordinated releases of the components. This protocol includes pre-release testing, documentation, and one on-line tutorial a year. METplus is also released with use-cases to provide examples for how to use the tools to accomplish a verification goal. A use-case constitutes the scripting and configuration file settings necessary to execute a particular type of verification. Current use-cases

include grid_to_grid, grid_to_obs, feature_relative, track_and_intensity, qpf, mode, ensemble, and examples for use in NOAA testbeds.

Development: Currently, three mechanisms are used to determine what enhancements need to be added to MET, METviewer and METplus under DTC funding:

1. Requests from the DTC partner community via met_help@ucar.edu emails and not addressed by other NCAR or GSD projects (primarily NOAA funds)
2. Requests from the research community via met_help@ucar.edu emails and identification of promising techniques through conference attendance (primarily NCAR funds)
3. Requests from DTC teams that are identified during testing and evaluation and not included in their activities

Over the past few years, the verification team has been very focused on NOAA requirements through mechanism 1, making it difficult to be directly responsive to the research community and DTC T&E needs (mechanism 2 and 3, respectively). For AOP 2019, the METplus team would like to achieve better balance between the priorities.

For AOP 2018, the AF is funding the DTC to conduct Fortify cyber-security scans of the MET and METviewer software and address the finding of these scans in preparation for the AF implementation these packages on their operational systems. Code refactoring to address these cyber-security findings is leading to more robust software packages.

The UFS momentum towards a unified suite of verification tools has caught the attention of several other organizations both nationally and internationally. For example, METplus is being considered an option for part of the unification effort within NCAR. Over this past year, ONR, UKMO and ECMWF have expressed an interest in collaborating on METplus with in-kind contributions. The Taiwan Central Weather Bureau and Australian Bureau of Meteorology have also started looking at METplus. The potential broadening of the METplus developer resources is an appealing opportunity to consider.

Repository and Scripts: During AOP 2018, the MET repository will be moved from SVN to GitHub to be consistent with the METplus scripts and METviewer repositories. As part of the nightly build cycle, MET and METviewer are also being scanned using Fortify cyber security software for the Air Force.

Community Engagement: At the request of the user community, an in-residence MET tutorial was added back into DTC's AOP in 2017 and a METplus tutorial is scheduled to be presented February 4-6, 2019 in conjunction with the WRF/MPAS Tutorial at NCAR. Additionally, presentations regarding updates to MET, and now METplus have been routinely made at appropriate conferences such as the AMS Annual Meeting.

Project Description

This proposed activity is focused on software support and development of METplus components (MET, METviewer, and Python scripts). It also focuses on the engagement of the community to expedite the transition to the unified system for DTC, NOAA, AF and the US research community.

Helpdesk: The MET helpdesk responds to approximately 7-12 emails per day, resulting in approximately 300-400 tickets closed per year. There is a need for increased funding to support the growing community while the METplus team works to streamline certain aspects of support. It is anticipated that this demand will increase over the next year with the release of METplus and METviewer on Github. Helpdesk will continue to be a high priority activity. Requests from NOAA will continue to receive prioritized responses and be addressed using NOAA funds. Help requests from AF users will be covered by AF funds.

Releases and Documentation: To respond quickly to project requirements for DTC and externally, MET will have a maximum of 2 releases per year. They will include development supported through this activity, along with other projects through sponsors such as NGGPS, OWAQ, NESDIS, NASA, and Harvey Hurricane

Supplemental. The first coordinated METplus, MET and METviewer release of the AOP will be accompanied by updated online tutorials. The cost of the release is limited to pre-release testing, finalizing documentation, and installation on NCAR and NOAA computing platforms. Bug-fix releases will be made available as necessary. New capabilities needed by partners prior to the official community release will be made available as beta releases, which will not undergo the same level of testing associated with a community release. Additionally, METplus developers would like to publish the user's guides online to make them more searchable. As in other years, the cost of releases will be split across NOAA and NCAR funds.

Development: METplus developers would like to achieve a better balance between competing priorities within DTC, including expanding support for community requirements and continuing to support DTC T&E. Development efforts that focus on NOAA requirements will be prioritized through conversations with key stakeholders such as the EMC VPPPG (verification group) Branch Chief and verification leads at the other NOAA centers and labs. It is anticipated that much of the development work will be focused on ensemble related verification across all temporal and spatial scales. Additionally, NOAA's MDL has expressed interest in having some focused support for their transition from their legacy system to MET. Development to address research community requirements will be prioritized by potential for substantive positive impacts for the entire community. Potential areas for development include improved support for WMO datasets and methods, support for additional community data formats, and development of at least one METplus use-case requested by the community. This activity would also encompass addressing community requests for shared development that could benefit DTC and the broader university research community. For example:

- ONR and FNMOC are interested in adopting METplus but would like to collaborate on data assimilation and ensemble verification.
- UKMO would like to collaborate on expanding ensemble and probability verification for both regional and global scales.

While DTC T&E activities will specifically include required METplus development, there may be unexpected needs by the DTC staff that come up through the course of the AOP. This activity will work to address them within the bounds of funding. One additional critical development task is needed for METplus before the end of 2019 calendar year. In 2020, Python v2.7 is scheduled to be deprecated. This activity will be responsible for migrating from version 2.7 to version 3.6 or 3.7 based on operational requirements.

Repository and Scripts: An AOP 2018 deliverable is to develop a community repository governance recommendation for implementation in AOP 2019. It will include support for three verification code bases (MET, METviewer, and METplus scripts). Based on our initial analysis, there will be a requirement for 1) repository maintenance, 2) introduction of an externals management capability to tie components into the METplus umbrella repository, 3) set up continuous integration testing for requests to pull community contributions into the GitHub repository, 4) systems to check to see if the contribution is accompanied by sufficient documentation, and 5) add required tests to the nightly builds. Setting up a fully-functioning automated repository management system is critical to managing growing costs and ensuring the success of the unified verification effort in which DTC is participating. Additionally, for AOP 2019, the DTC will maintain its Fortify cyber security scanning software and continue to run it on MET and METviewer during the nightly build testing. The DTC will make the scan results available to facilitate discussion on the findings during the AOP, prior to a release, and then along with the release. Finally, METexpress will be available for DTC and EMC to use during their T&E activities if they desire. This will to allow the METplus

team to gather feedback from friendly-users and complete much needed pre-release testing in preparation for a community release in subsequent AOPs.

Community Engagement: The METplus team proposes to develop a series of short videos to be posted on the DTC website to provide more visual support to users. It is anticipated watching a sub-set of the training suite would be a pre-requisite for attending a METplus tutorial in the future. The team will also give presentations at several relevant workshops or conferences.

Project Deliverables

- Helpdesk support for all METplus verification software
- 2 coordinated METplus suite releases with documentation
- METplus suite bug fixes and repository maintenance
- MET and METviewer releases pass Fortify scan
- METexpress pre-release testing
- 5-6 major METplus enhancements (approx. 1-2 per component)
- METplus Python migrated to version 3.x
- METplus umbrella repository and governance strategy implemented
- METplus suite online tutorials updated
- User's Guides ported to the web
- Suite of video tutorials hosted on DTC website
- Presentations at relevant workshops and conferences

Sponsors: NOAA, AF, NCAR

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 model innovations and development. Support of end-to-end NWP containers is an effective approach for fulfilling this mission. Through the use of container technology, complete software systems can 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. In recent years, end-to-end NWP software components [including WRF Pre-Processing System (WPS), Weather Research and Forecasting (WRF) model, Gridpoint Statistical Interpolation (GSI) data assimilation, 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. Through this complementary work, a full end-to-end NWP system was established.

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 2019, the DTC is proposing to maintain the current NWP containers as new versions are released and update the website accordingly. In addition to the code itself, these containers will include all critical test datasets. All established containers will be made publicly accessible on DockerHub. Work will be undertaken to set up automated builds for these containers on DockerHub by watching a tag or branch from the source code repository and automatically rebuilding and republishing the corresponding container. The online tutorial created to step users through building and running an end-to-end system will be preserved to provide community support to users running the DTC containers, which is essential to attracting and maintaining 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 datasets 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. The containers will be executed on a cloud computing provider platform as a proof of concept. To supplement the funds included in this proposal for cloud computing, we will also apply for Amazon Web Services (AWS) Cloud Credits. In addition, the DTC will expand the end-to-end system containers to one additional container platform (e.g., Singularity, Shifter, Charliecloud) in order to 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 100th AMS Annual Meeting. It is anticipated that with the inclusion of the Numerical Weather Prediction (NWP)/Weather and Forecasting (WAF) conference at this meeting, it will be possible to draw in a larger number of interested participants.

Project Deliverables

- All DTC containers published to DockerHub
- Containers autogenerated and republished to DockerHub with commits to the corresponding repository
- Containers exercised on a cloud computing platform
- Containers expanded to an additional platform that supports HPC execution

Sponsors: NCAR

Testing and Evaluation

Hurricane Weather Research and Forecasting (HWRF) pre-implementation testing and evaluation

Motivation

The Environmental Modeling Center (EMC) conducts testing and evaluation (T&E) of potential upgrades to the HWRF system on an annual basis. Because there are many potential candidates to consider each year that can be applied in many different combinations, EMC relies on DTC staff to assist them in performing the annual pre-implementation testing. The testing performed by DTC staff often focuses on contributions made by scientists funded through the DTC Visitor Program and the Hurricane Forecast Improvement Program (HFIP), for which the DTC provides developer support. Since DTC staff work closely with these developers to assist them in adding their contributions to the HWRF code base, they are already familiar with the innovations and are well positioned to perform the T&E.

Project Description

The DTC proposes to continue to contribute to HWRF pre-implementation testing for AOP 2019. Prior to the beginning of pre-implementation testing, DTC staff will seek guidance from EMC staff on what potential new configurations of the HWRF system should be tested. These contributions may include assimilating new observation types, other data assimilation upgrades or changes, testing new physics schemes, changes to specific parameterizations within the existing operational HWRF physics suite, or some combination of these. During this process, DTC staff will make EMC aware of any new contributions to the HWRF code base made through the DTC Visitor Program to ensure that all possible candidates are considered for testing. Two potential candidates for testing in AOP 2019 contributed through the DTC Visitor Program are the Mellor-Yamada-Nakanishi-Niino (MYNN) Planetary Boundary Layer scheme and four different possible configurations of the cloud overlap parameterization in the Rapid Radiative Transfer Model for General circulation models (RRTMG). In addition, the Grell-Freitas cumulus scheme is a potential candidate for testing.

Once the candidate HWRF configurations are selected for testing, the DTC will work with EMC to develop a timeline for conducting the tests and identify the appropriate set of model cycles to run for each configuration. DTC will create one or more T&E branches from the HWRF trunk and prepare run scripts that contain the experimental settings and model cycles to be tested for each configuration. The code branches and run scripts will be reviewed with EMC staff to ensure that the experimental configurations are accurate and consistent with other testing configurations.

Following approval of the experimental configurations, DTC will launch the experiments using cron and the Rocoto workflow management system. Progress of the experiments will be inspected regularly and any failed jobs will be troubleshooted and resubmitted. DTC staff will report on the progress of the experiments through email and/or during weekly EMC pre-implementation meetings. The number of core hours and disk space remaining for the tests will be monitored and EMC will be informed if additional resources will be required to complete the experiments. Finally, track, intensity, and wind structure statistics in Automated Tropical Cyclone Forecasting system (ATCF) format will be provided to EMC staff so that the forecast performance of each configuration can be assessed.

Project deliverables

- Code branches created and run scripts prepared to perform pre-implementation tests.
- Track, intensity, and wind structure statistics in ATCF format for each test.

Sponsors: NOAA

Quantify and evaluate the observation departure differences between JEDI-UFO and GSI-observer

Motivation

NOAA/NCEP global operational numerical weather prediction has moved to a FV3-based Global Forecast System (FV3-GFS), which is still using GSI as the data assimilation (DA) component for deterministic forecasts and the GSI observer for EnKF in its Global Data Assimilation System (GDAS). GSI conducts analysis on a Gaussian grid to provide initial conditions for FV3-GFS model forecasts. At the same time, the Joint Effort for Data Assimilation Integration (JEDI) is being actively developed under leadership from the Joint Center for Satellite Data Assimilation (JCSDA) with the end goal of JEDI, which is a next generation DA system, replacing the current GSI-based operational DA. The first step in NCEP's JEDI transition plan is to replace the GSI observer with the JEDI-Unified Forward Operator (UFO) to generate observation departures (O-F) for the EnKF in GDAS. NCEP does not expect departures generated by these two software systems to be identical. Hence, a test plan that sets forth informed expectations and investigates the reasons behind the differences will be critical to NCEP's transition plan.

Project Description

For AOP 2019, the DTC proposes to work with EMC data assimilation experts to develop a strategy for defining difference acceptance thresholds for JEDI UFO to be qualified to replace the GSI observer. The strategy will document the observation operator calculation methods used in the JEDI-UFO and GSI-observer, list the criteria for decision making, such as data selection, O-F values, observation error, quality control, and bias correction, and propose expected acceptance thresholds for those criteria.

There are a large number of observation types used in operations. The complete test of observation departure differences for all operational data types will be a multiple year task. DTC will work with EMC DA group to prioritize the data types to be tested and identify several major conventional observations to be tested during AOP 2019.

As the start of the evaluation, the DTC will set up several baseline FV3-GSI cases from the operational or retrospective FV3GFS system, and run the JEDI-UFO for FV3 with the same background and observations from the baseline FV3-GSI cases. The observation departures (O-F) obtained with the FV3-GSI observer will then be compared against the ones generated with the JEDI-UFO in each criterion defined in the plan. Those differences that don't meet acceptance threshold will be investigated to determine the source of the differences. The DTC will then extend the baseline cases for a period of time (a week to a month based on the resources) to compare the JEDI-UFO and GSI observer to generate more statistics on the differences between the two observers.

In the process of the evaluation, DTC will work with EMC and JEDI group to develop necessary tools for facilitating the acceptance tests. These tools can serve as building blocks for a future DA hierarchical test framework.

Project Deliverables

- Test plan for defining difference acceptance threshold for JEDI-UFO.
- Report on the GSI-observer and JEDI-UFO differences for several major conventional observations

Sponsors: NOAA

Evaluation of Common Community Physics Package (CCPP) physics suites across spatiotemporal scales

Motivation

In response to recommendations from the UMAC, NCEP plans to evolve towards a unified modeling suite across both spatial and temporal scales. To truly achieve this goal, the Unified Forecast System (UFS) will be working towards a single physics suite that advances forecast skill across a broad range of scales. To provide a framework for accelerating the transition of new physics innovations into operations, the DTC's Global Model Testbed (GMTB) has developed the Common Community Physics Package (CCPP), which is designed to facilitate the implementation of physics innovations in state-of-the-art atmospheric models, the use of various models to develop physics, and the use of a hierarchical physics testing framework. Four physics suites are currently available in the CCPP framework. Each suite was developed with an eye towards a particular application where these suites include both global and regional applications. Available suites include the Finite-Volume Cubed-Sphere Global Forecast System (FV3GFS)v1 (slated for operational implementation), an updated version of the operational suite that uses the scale-aware turbulent kinetic energy (TKE) eddy-diffusivity mass-flux (EDMF) planetary boundary layer (PBL) scheme, Rapid Refresh (RAP)/High Resolution Rapid Refresh (HRRR), and Climate Process Team (CPT) physics suites. Additionally, several Hazardous Weather Testbed (HWT) physics suites are under preparation and, through the Hurricane Supplemental funding, the physics suite for the operational Hurricane Weather Research and Forecasting (HWRF) system will be ported to the CCPP. *A baseline assessment of the performance of these physics suites across scales for various applications would help answer the question of how close we are to having a single physics package for all model applications.*

The proliferation of physics options within the CCPP provides a fertile opportunity for investigating a problem of particular importance to the UFS user community, namely the misrepresentation of PBL thermodynamics. For many years, forecasters have identified a lack of skill on the part of the NOAA's Global Forecast System (GFS) to accurately and routinely provide modeled profiles of PBL thermodynamic variables. Noted effects also include a strong surface warm bias under observed cold-season inversions, a low frequency bias in instability in convective environments, and other examples of warm and dry surface biases over CONUS pointing to the model configuration producing too much turbulent mixing in the boundary layer for these situations. There are many potential causes for this issue, including errors from individual physics parameterizations, their interactions within suites, and errors in data assimilation, all of which likely have a dependence on horizontal and vertical model resolution. As such, attribution of the precise mixture of causes is a problem well-suited to an investigation across scales.

Project Description

For AOP 2019, the DTC proposes to undertake testing that will provide a baseline assessment of the performance of several physics suites at different model resolutions. The testing *and evaluation* will follow the hierarchical testing framework (HTF) to gain a better understanding of the strengths, weaknesses, and general behavior (e.g. tendencies, scale-awareness) of the physics schemes. Physics suites currently available in the CCPP framework will be considered for this evaluation, with future suites (e.g., HWT, HWRF) added as they become available. Specific to the modeled PBL, the problem in the GFS has been investigated somewhat informally, where much of the evidence has been more anecdotal in nature; effort is needed to better characterize and quantify the spatiotemporal extent of the *PBL* misrepresentation prior to developing a hypothesis for a workable solution. This proposed effort spans two years, where the complexity of the tests and scope of the evaluation evolves with the

expanding capabilities of the UFS. During the first year, benchmarking tests will be conducted over the available physics suites within the CCPP for several horizontal grid resolutions, and with special focus on the representation of PBL structure in the forecast produced by the various physics suites (hereafter referred to as PBL representation). In year 2, a smaller set of physics suites will be investigated thoroughly within the HTF.

During the initial year of testing, the stand-alone regional (SAR) version of the FV3 will be configured for three horizontal grid spacings to explore the performance of the schemes at resolutions used for convection-allowing, global and seasonal scales (e.g., 3-, 13-, and 25-km). The runs will be designed as cold starts in order to isolate the behavior of the physics and take into consideration the capabilities that will be available for the SAR FV3 during the performance period. The performance of the suites at each of the aforementioned resolutions will be investigated for various weather events, including both convective and stable cases. Each physics suite will be run for each application to investigate the performance of the suite under the conditions for which it was designed as well as its performance for other applications. The systematic testing of physics schemes across multiple configurations that mimic future applications allows us to compare and contrast model performance in a controlled environment. Furthermore, the single column model (SCM) will be utilized to isolate the interactions between physics parameterizations as a tool to further investigate outcomes of the SAR FV3 model runs, with focus on PBL representation in some cases. In addition to the generated SAR FV3 runs, several datasets of opportunity will be available for further investigation. Specifically, GMTB's global advanced physics test (13-km), real-time runs performed during the HWT spring experiment (3-km) and the initial Hurricane Analysis and Forecast System (HAFS) configurations under the Hurricane Forecast Improvement Program (HFIP) real-time demonstration (13-km global with 3-km nest and 3-km domain) will be available and relevant for this study.

Similarities, and, most importantly, differences in performance for specific schemes (such as the PBL parameterization) or configurations will be identified and investigated further using a suite of traditional and process-based verification metrics. These include an energy spectrum analysis and evaluation of tendencies for all configurations. The behavior of the scale-aware schemes across scales will receive particular focus to improve our understanding of their scale-aware properties. Other process-based diagnostics and traditional verification statistics appropriate for each application (e.g., anomaly correlation, track and intensity metrics, state variables) will be examined. Additional verification capabilities, such as neighborhood methods and spatial statistics, using the Model Evaluation Tools (MET) series analysis and Method for Object-based Diagnostic Evaluation (MODE) tools will be applied. Selection of observations used in the analysis will be comprehensive. Use cases will be implemented in METplus for these applications. The spectral decomposition capability will be extended for the regional applications and brought into METplus to increase the ease of future evaluations. Finally, where analysis points to systematic biases across scales with respect to PBL thermodynamic properties, we propose to generate phenomenologically-distinct SCM cases that represent such challenges using appropriate compositing techniques. Such idealized cases can be used to stress-test physics suites and further explore interactions amongst their member schemes.

Testing in year two would be expanded to include fully-cycled data assimilation (DA) experiments, given the expectation that advanced DA capabilities will be available in the SAR FV3 at that time. If additional suites become available and are deemed of interest, additional cold start runs will be run and added to the initial benchmark runs. This phase of testing will focus on the most promising suites within the CCPP as well as the hypothesized solution to address the PBL representation problem, determined by year 1 outcomes. A narrower focus, with a concentration on a more thorough investigation of a smaller set of

suites using the HTF will be pursued. The evaluation capabilities developed and metrics used during year 1 will be leveraged during year 2.

An interesting collaborative opportunity exists with the similarly-motivated NGGPS-funded project titled "Evaluation of FV3GFS Vertical Profile and Thermodynamic Environment Infidelity" led by Clark Evans at the University of Wisconsin-Milwaukee. This project follows a similar 2-year timeline and is mainly focused on the effect of over-mixing on convective weather forecasting over the central CONUS. It will make use of the HWT spring experiment and includes collaboration with NOAA Storm Prediction Center (SPC). Our proposed activity is complementary to Dr. Evans' in that we're approaching the characterization of the lack of FV3GFS PBL thermodynamics forecast skill using different methods and with an expanded geographical and phenomenological focus. While we will not exclude the effects of the problem on deep convection over the central CONUS, we propose to place a greater emphasis on the effects of over-mixing in the CONUS cold season and maritime subsidence regions. Further, we propose that DTC staff develop a collaboration with Dr. Evans' group through the sharing of lessons learned using our different methodologies.

In addition to synergies with Dr. Evans, other ongoing efforts in the community will be leveraged to strengthen the proposed activities. DTC staff will collaborate with research scientists focused on scale-aware physics with funded projects through NGGPS and the Hurricane Supplemental. The DTC Visitor Program will also be utilized to bring in a subject matter expert to work on complementary work. Members of the NGGPS Strategic Implementation Plan (SIP) for Unified Modeling working groups on SAR/CAM, Physics, and Dynamics and Nesting provide a strong community from which to build connections. Maintaining a strong collaborative relationship with EMC throughout the process will be key to the overall success of this project.

Project deliverables (year one)

- Report on findings of the testing
- Use cases for a range of applications added to METplus
- Idealized phenomenologically-based test cases added to the SCM repository
- Results presented at relevant conferences/workshops

Sponsors: NOAA