DTC Annual Operating Plan 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) Global Systems Laboratory (GSL). 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. 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 activities, (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), 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, UFS R2O project, Air Force and NCAR

Community Interactions and Outreach

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 for making research innovations available for consideration 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 $100 K from the NOAA funds to support this visitor program and submit a proposal to NSF to match this $100 K.

Project Deliverables

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

Sponsors: NOAA with potential matching funds from NSF

Unified Forecast System (UFS) Users' Workshop

Motivation

As the Next Generation Global Prediction System (NGGPS) evolves to become the Unified Forecast System (UFS), it is envisioned to be a coupled Earth modeling system designed to accommodate the broader research community, including researchers, developers and users from NOAA, educational institutions, federal agencies, and the private sector. To support this goal, it is important to bring together a diverse group of scientists and researchers 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, ultimately resulting in forecast improvements. The DTC led the planning and provided logistical support for the 1st UFS Users' Workshop, which took place on July 27-29, 2020.

Project Description

The DTC proposes to help organize the 2nd UFS Users' Workshop to be held in Boulder, CO, likely in July 2021. 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 finalize the scope, formulate the agenda, outline session topics for the workshop, and strategize how to attract broad community participation. The DTC will also communicate closely with the UFS Steering Committee and Strategic Implementation Plan (SIP) Working Groups (WGs) to ensure proper coordination among all relevant and interested parties, and facilitate scheduling SIP WG side meetings, as needed. If funding for this activity continues in the next performance period, the DTC will provide logistical support for the workshop, such as hosting a website with the workshop information, establishing a registration page, and providing information related to travel/lodging, etc. To attract the next-generation workforce, the DTC proposes to sponsor travel for students and postdocs 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

- Organizing committee established for 2nd UFS Users' Workshop
- Announcement distributed for 2nd UFS Users' Workshop

Sponsors: NOAA

Unified Forecast System (UFS) Training

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 weather prediction model. In response to recommendations from the University Corporation for Atmospheric Research Community Advisory Committee for NCEP (UCACN) Model Advisory Committee (UMAC), NOAA's operational NWP system is moving towards a unified modeling suite across all spatial (regional and global) and temporal (weather, sub-seasonal and seasonal) scales. At the center of this plan is the Unified Forecast System (UFS), which uses GFDL's Finite-Volume Cubed-Sphere (FV3) as the atmospheric dynamical core. Engaging a broad sector of the NWP community in the advancement of the UFS requires a framework that includes well-defined code management practices (including regression testing protocols), open access to code and datasets, thorough documentation, and active user support. Providing training to educate and engage the user community in this complex system is also essential.

Project Description

An event providing UFS training focused on the Medium-Range Weather (MRW) application is proposed to be held in Boulder, CO to encourage the community to engage in using and developing the UFS. The training will be hosted by the DTC, along with colleagues at the Environmental Modeling Center (EMC), NOAA laboratories, and collaborating institutions (such as the National Center for Atmospheric Research). DTC staff will be responsible for initially organizing the structure of the training, including determining the content and organization of the lectures and lining up subject matter experts to present the lectures. The full MRW application will be described, including: pre-processing, the atmospheric model, connection to the Common Community Physics Package (CCPP), and post-processing. In addition, a one-day optional extension will focus on more in-depth information needed for developers to transition techniques from research to operations (R2O). Topics on the final day will include code management protocols, details on how to add variables to the output, adding a new physics suite, etc. As soon as the logistics for timing and content of the training have been determined, an announcement and associated registration page will be made available to the community. In particular, the DTC will reach out to NOAA-funded principal investigators (PIs) to ensure they are aware of this training opportunity. The DTC will contribute to the associated documentation and training materials needed to ensure the information is clear and concise. DTC staff will also build hands-on practical sessions for MRW applications to foster the learning process. All of the material prepared for the training will be made available to the community through a webpage before the event, for participant access during the event and public access after the event.

Project Deliverables

- Organize 1st UFS training and announce to the community, with emphasis on NOAA-funded PIs
- Host 1st Annual UFS training focusing on the MRW application

Sponsors: NOAA, UFS R2O Project

Community System Support

Data assimilation software support and community engagement

Motivation

All current NCEP global and regional operational modeling systems use the Gridpoint Statistical Interpolation (GSI)/ the Ensemble Kalman Filter (EnKF) data assimilation (DA) systems, where the GSI with hybrid ensemble-variational (EnVar) DA is used for their deterministic forecasts and EnKF is used for ensemble DA for both global and storm scale cycling. For the next two to three years, GSI/EnKF will be used in the operational systems, such as GFS, RAP/HRRR, RTMA, etc. The GSI/EnKF could be part of the NCEP forecast systems beyond two to three years depending on when the Joint Effort for Data Assimilation Integration (JEDI) system becomes mature enough to replace the GSI/EnKF. Hence, 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

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 that will be transitioning to GitHub 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. And finally, the DTC will continue its support for community users of the current DA system release through a community forum. The community GSI/EnKF webpages and User's Guide will remain at their current status without further updating.

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

Project Deliverables

- Data assimilation community user support service

Sponsors: NOAA

CCPP software support & community engagement

Motivation

A primary goal of the DTC is to accelerate the research-to-operations (R2O) transition of broad community innovations in physical parameterizations and suites to NOAA Unified Forecast System (UFS) operational applications in order to improve numerical guidance. This activity includes supporting the community in using the Common Community Physics Package (CCPP), which is composed of a library of physical parameterizations (CCPP-Physics) and associated infrastructure (CCPP-Framework).

The host model-physics interface is provided by the CCPP-Framework, effectively replacing classical physics drivers. It relies on metadata describing host-provided and physics-requested variables together with external files describing physics suite construction to auto-generate this software layer. Although being developed as a model-agnostic component, its initial design was focused around the finite-volume cubed sphere (FV3) dynamical core of the UFS. The focus has since widened, especially in light of the NOAA-NCAR Memorandum of Agreement, and today the CCPP-Framework is at various stages of integration with the CCPP Single Column Model (SCM), the NRL NEPTUNE model, and all NCAR flagship models. The decision to jointly develop and use the CCPP-Framework is an opportunity to leverage the improvements and additions made by NCAR and the wider research community, but is also a challenge to meet the requirements of the different organizations and models. Limitations of the current system are being addressed with a next-generation code generator (*capgen.py)*, developed primarily by the NCAR Climate and Global Dynamics Laboratory. It is important that the DTC remains part of the CCPP-Framework development effort to assist and direct the work in a way that ensures an optimal solution for the UFS. Particular concerns are runtime performance and memory consumption, but at the same time user-friendliness tailored to the needs of NOAA internal (e.g. at EMC) and external developers. The CCPP-Physics is currently undergoing rapid development and it is expected that by the end of June 2020, all physics development for the UFS will have transitioned to the CCPP. Following this development, it is critical that the DTC continues its steady management and curation of this repository, resulting in consolidation of its use at EMC and the broader UFS community.

Project Description

The DTC is proposing to continue to collaborate with EMC and physics developers to make physics available for the community to use and improve. The *ccpp-physics* and *ccpp-framework* code repositories will be maintained by DTC staff and code management and governance will facilitate community contributions. Regression tests will be conducted before contributions are accepted to maintain code integrity and platform portability. Cases of duplicate parameterizations will be addressed along with primary code developers and other distributors of CCPP-compliant atmospheric physics, such as NCAR.

At least one new community release of the CCPP will be distributed annually, with intermediate releases distributed as needed to incorporate bug fixes and/or support the needs of the various UFS applications. With each release, extensive pre-release testing will be performed. Updates to the technical and scientific documentation will be made available to the user community with each release. User support will be provided through an online forum, and DTC staff will prioritize support for projects funded by or of interest to NOAA.

The DTC will develop and implement rules for variable standard names that build upon community standards and provide developers with tools for discovery of existing variable standard names. In addition, the DTC will improve the code with further compliance to agreed-upon standards, for example, standardization of how constants are kept and propagated to all schemes. This work is synergistic with the proposed transition to the NCAR-led next-generation code generator, and is critical for continued community engagement.

The DTC is also proposing to improve the usability of the framework by ensuring consistency between the suite definition file (SDF) and the UFS namelist and by providing methods that expedite the porting of physics. One example of porting facilitation is the auto-conversion of variables, to be used when a scheme needs variables that are not available in the dycore, but that can be calculated from variables that the dycore provides (e.g., calculate temperature from potential temperature and pressure). Another example is auto-transformation of arrays, to be used when the memory layout of a scheme is different from the host model (e.g., [i,k] array indices versus [i,k,j]). The standardization of how transformations are done provides simplicity and lowers the bar for interoperability and community engagement. While such transformations are a desirable capability for research and development purposes, they are typically computationally inefficient, and their use will be appropriately communicated to developers to signal the need for optimization for runtime performance and memory usage prior to operational implementation.

Additional capabilities slated next in the order of priority that may be delivered if time allows or funding is augmented are:

- Transition of additional advancements in the CCPP-Framework developed by NCAR to the UFS.
- User-controllable suite creation with process-split or time-split physics for flexibility of the physics-dynamics interface.
- Streamlined GFS suite with fewer interstitial parameterizations.

Project Deliverables

- Support to EMC in using CCPP for research and operations in the UFS.
- Code management and governance for the *ccpp-physics* and *ccpp-framework* repositories.
- Transition of selected advancements in the CCPP-Framework developed by NCAR such as the next-generation code generator to the UFS.
- Public release with updated documentation, online tutorial, user and developer support.
- Capability to auto-convert variables and auto-transform arrays.
- Assured consistency between SDF and namelist.
- Rules for variable naming and developer tools for existing variable discovery.

Sponsors: UFS R2O project

CCPP SCM software support & community engagement

Motivation

The CCPP SCM plays two critical roles for UFS physics development and testing. First, within the physics Hierarchical Testing Framework (HTF), it serves as a simple and economical platform for understanding interaction among physics schemes within a suite. Second, for physics parameterization development within the CCPP, it serves as a simple host model for rapidly developing and testing CCPP-compliance. Given these roles, it is important that the SCM code keeps pace with changes within the CCPP-physics, CCPP-framework, and the UFS Atmosphere model component. Further, periodic public releases together with comprehensive documentation and tutorials provide a consistent link with both the research and operational communities and help to foster these communities' joint participation in UFS development and evaluation activities.

Project Description

While the IFAA (aka "hurricane supplemental") Project 1A-2-2b focuses on the development of new features, capabilities, and improving the CCPP SCM user interface, it does not provide for the support of existing capabilities, routine software updates necessary to stay up-to-date with the expanding CCPP or UFS Atmosphere. One of the primary goals of this project is to provide such updates to the authoritative GitHub repository on an as-needed basis throughout the performance period. As the CCPP SCM software has matured, it has become necessary to develop regression tests to make such software updates more robust and easier to implement; such tests will be implemented.

Support to the community will be facilitated via the use of online forums, updates to the DTC website, an online tutorial, and updates to existing documentation. Periodic public releases will continue to coincide with CCPP public releases to provide stable versions for the growing user base.

Project Deliverables

- Development of CCPP SCM regression tests to maintain integrity of repository
- CCPP SCM community repository with clear governance and leadership in the code management
- CCPP SCM user and developer support, including updates to website describing supported capabilities and online tutorial
- CCPP SCM public release
- CCPP SCM interface consistent with advances in ccpp-physics, ccpp-framework, and UFS Atmosphere

Sponsors: UFS R2O project

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, and the academic community) 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 over the last two years, with a number of operational and research partners collaborating on this quickly-evolving code base to advance the system. This accelerated development is expected to continue as a lead up to an anticipated 2023 operational implementation of the Rapid Refresh Forecast System (RRFS). To ensure success, the need for robust governance of repositories and extensive regression testing is critical. Several foundational pieces for maintaining the UFS CAM Application workflow repository will be put into place by the end of the current period of performance (PoP), including: required component repositories moved to Github, code management plan developed, and code review committee established. Due to the multiple facets and large scale of this system, improvements to the governance process will be made throughout the next PoP based on experience with the process throughout the year. In addition, communication is key, thus, regular attendance on all relevant NGGPS strategic implementation plan (SIP) working groups will continue such that the team can remain aware of relevant activities happening across the UFS enterprise.

It is also essential to regularly maintain and enhance a series of regression tests to ensure the scripts remain in a working state after each commit. While the code management for software packages used by the workflow (e.g., pre-processing, model, post-processing, data assimilation, verification) is handled by external repositories for each component, the DTC will remain responsible for ensuring regression tests for each task defined within the end-to-end UFS-CAM Application workflow are sufficient and are expanded as new capabilities are introduced, especially related to data assimilation and verification tasks. The regression tests will be maintained across the supercomputing platforms readily available to the DTC, which will also ensure portability across this subset of systems, and will be made available for community users to run on additional platforms of interest. As development of the UFS CAM Application workflow continues, consideration will be given priority to allow the community workflow to run as seamlessly as possible on different supercomputers with a simple change to a user-defined machine variable. The DTC will also assist community developers with the governance protocol when the developers would like to contribute scripts and utilities to the workflow repository.

Based on discussions taking place in the UFS-CAM Application Team (AT) coordination meetings, the DTC anticipates an initial release of the UFS-CAM Application based on a specific tag/commit from the master branch of the repository to the community at large will take place during the next PoP. The DTC will be a key contributor to this effort. As it is anticipated that the community workflow will be released with the UFS-CAM Application, it will be critical for the DTC to conduct pre-release testing of this capability. Regression testing established during the current PoP 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 the current PoP, the DTC is initiating documentation of the UFS-CAM workflow, which will be finalized and publicized with the official release of the system. User support for the workflow will be offered for both developers and the general community through the web-based UFS Users' Forum. DTC staff will contribute to answering questions within their area of expertise, while non-DTC Subject Matter Experts (SMEs) will monitor and address questions related to their specific components.

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

- Community UFS-CAM workflow repository review committee lead by DTC staff as defined in the developed code management protocols
- End-to-end regression test updated and enhanced for the community UFS-CAM workflow repository

- Community UFS-CAM workflow enhanced with new tasks as development of a full system matures
- Detailed documentation published to support releases of the UFS CAM Application to the community
- UFS Users' Forum (CAM Application portion) monitored and questions answered as needed to facilitate community support

Sponsors: NOAA

UFS Medium Range Weather App 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. Engaging a broad sector of the NWP community in the advancement of the NOAA modeling suite will require well-defined code management practices (including regression testing protocols), community access to code and datasets, documentation, and user support. For the past year, the DTC has been working closely with UFS Medium Range Weather (MRW) Application (App) developers with a focus on ensuring key elements are in place when this capability is scheduled to be released to the broader community. This work has focused on the development of a portable community-friendly atmosphere model that is also used for operations, as well as the associated documentation. On-going releases of the UFS-MRW App capability are anticipated in the coming year, so work in the next PoP will include contributing to the release preparations and maintaining a support framework.

Project Description

During the current PoP, the UFS-MRW App will be released to the broader community, at which point the DTC will begin contributing to the UFS support effort by monitoring questions posted to the UFS Users' Forum and contributing responses to those questions that fall within the DTC staff's expertise. Non-DTC Subject Matter Experts (SMEs) for each component of the UFS-MRW App are expected to provide in-depth support on their specific components. Given the plans to provide incremental releases as new capabilities reach maturity, the DTC anticipates contributing to release preparations as appropriate under the auspices of maintaining a unified system.

Incremental community releases of the UFS-MRW App will be distributed as needed to incorporate bug fixes and/or include the ongoing development of the UFS-MRW Application. With each release, DTC will be a key contributor to the pre-release testing. Updates to the technical and scientific documentation will be led by DTC, with contributions from non-DTC SMEs, and made available to the user community. User support will be provided through an online forum, and DTC staff will prioritize support for projects funded by or of interest to NOAA. As the complexity of the UFS-MRW App increases with new capabilities, such as coupling with the ocean, sea ice, and waves, as well as data assimilation, additional resources will be needed to provide a consistent level of support. Additional resources would also be required to extend the current proposal to encompass support for developers to add new capabilities to the app, as the current scope is limited to supporting users in exercising existing capabilities.

Project Deliverables

- Support the community in using the UFS Medium-Range Weather Application releases

- Support EMC in the preparation of incremental releases of the UFS Medium-Range Weather Application

Sponsors: UFS R2O Project

Hurricane system software support and community engagement

Motivation

The state-of-the-art HWRF end-to-end system has been supported by the DTC for nearly ten years. 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 2020 version of the operational HWRF model. As NCEP progresses towards the implementation of the hurricane application of the Unified Forecast System (UFS), development efforts for the HWRF system are expected to slow. Increased and distributed development activity is anticipated for the UFS hurricane application, called the Hurricane Analysis and Forecast System (HAFS). In order to ensure distributed development for HAFS sees the same successes as the HWRF system, a code management and support structure that fits within the parameters of the entire UFS effort must be established and disseminated to HAFS developers. Providing strong governance and support will lead to more rapid transition of research developments to operations (R2O) and ultimately to improved HAFS forecasts.

Project Description

HWRF

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-Ensemble Kalman Filter (GSI-EnKF) 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. The DTC proposes to continue to maintain the HWRF code repository and coordinate the links to all external source code components. 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. Given the shifting focus from HWRF to HAFS, the DTC is proposing a lower level of overall effort for the HWRF system.

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 assistance and repository access for 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 by addressing in-depth questions from developers that are posted to the HWRF Users' Forum to support cutting-edge research and provide an opportunity for developers to respond to peers. Online instructional and training materials pertaining to topics such as the code check-out procedure and development using Git will be updated 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. 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. 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

The DTC proposes to maintain basic support for existing publicly-released systems. The DTC will continue to support users in troubleshooting compilation and run-time issues using an online forum. This 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 UFS Users' Forum.

HAFS

Code management

The DTC will take the first steps towards standing up a code management and governance structure for the UFS hurricane application, HAFS. Effort will largely be focused on reviewing requirements and needs from the community and ensuring the HAFS effort is properly coordinated with the larger UFS effort. Given the nature of the code management of all the earth system components (source code and authoritative repository) within the UFS and the expertise on each component residing at various institutions, the DTC proposes to focus code management efforts for the HAFS system, at least initially, on the scripts and workflow. This effort will include leveraging the use of GitHub issue tracking for workflow requirements. As requirements from the developer community are determined, effort to address workflow requirements for HAFS will be identified. A funded hurricane supplemental project (PI: E. Kalina) complements this work because it is currently collecting requirements to develop a community-friendly HAFS workflow, but does not have the resources to address all of the various requirements. As development branches are created and merged into the master repository, code integrity of the HAFS scripts will be maintained via regression testing.

Project deliverables

HWRF

- Unified HWRF scripts and code maintained with code integrity tested through regression and consistency checks, as applicable
- New developments contained in HWRF repository branches ready for testing by EMC and DTC staff
- HWRF community user and developer support provided via a community-driven forum

HAFS

- Preliminary governance strategy for the HAFS repository posted to the UFS Github wiki
- HAFS scripts and workflow maintained with code integrity tested through regression and consistency checks, as applicable

Sponsors: NOAA, UFS R2O project

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 supports to the community to facilitate operations to research (O2R) and research to operations (R2O) transitions. The UPP provides the capability to take raw model output and compute a variety of diagnostic fields and interpolate to pressure levels or other vertical coordinates. Output from the UPP is in National Weather Service (NWS) and World Meteorological Organization (WMO) GRIB2 format and can be used directly by visualization, plotting, or verification (e.g. Model Evaluation Tools (MET)) packages, or further downstream post-processing (e.g. statistical post-processing techniques). Currently, the UPP is used in operations with the Global Forecast System (GFS), Global 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, the UPP is being implemented as the post-processing component for Unified Forecasting System (UFS) applications, including the Medium Range Weather and Convection Allowing Model applications. Given the UPP will be an important component of the public releases for these applications, it is essential that support for the UPP to the community continues.

Project Description

The DTC proposes to continue to collaborate with EMC to make the UPP tool available to the research community. The UPP repository will be maintained by NCAR and GSL staff in coordination with EMC staff in a manner such that updates and enhancements may be contributed by, and shared between, both the operational and research communities. The code management plan will be updated in coordination with EMC to reflect the recent migration to GitHub and related changes to code development and contribution procedures. The DTC will continue to be a critical contributor to preparations for the UPP component of the community UFS public release as well as providing user support and facilitating post-processing and diagnostic investigations and advancements through O2R and R2O efforts. Community release(s) of UPP will be distributed in coordination with UFS application releases, with bug fix release(s) as needed. With each release, extensive testing of UFS-Atmosphere nemsio and NetCDF output will be performed and the full suite of tests will be run on computing platforms available to the DTC using a variety of compilers. The DTC will work with EMC to establish a set of shared tests that can be used to test portability to community environments, as well as bit-for-bit regression testing on operational systems, and will also work with non-EMC contributors to add new tests to include new capabilities as needed. Updates to documentation (including User Guide, online tutorial, wiki, etc.) will be made available to the user community with each release or as needed. Considerable effort will be made to align documentation with UFS applications and public releases. The existing UPP container will be updated with the new release and made available on Github, with corresponding documentation on how to use it added to the UPP website. The community UPP distributions provided by the DTC will no longer formally support Weather Research and Forecasting (WRF) Advanced Research WRF (ARW) applications. User support for WRF applications will be gradually phased out to ensure the community has support during this transition. This phase-out will include migrating helpdesk content to a community forum for crowd-sourced user support with increasingly reduced effort from the DTC staff. The email help desk will be retired. User support for UFS applications will be provided by the DTC through an online forum with an initial effort to populate the forum with useful information in support of the user community. 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, as well as for UFS applications. DTC staff will continue training on UFS applications as they come online in an effort to provide support for those applications. The DTC will also collaborate with EMC on the re-engineering of the UPP code base with DTC's involvement focusing on beta testing as progress is made, especially in regards to portability, ensuring community needs are represented and taking on other community-pertinent tasks mutually agreed upon by both the EMC and DTC teams.

Project Deliverables

- Code release(s) aligned with UFS community application release(s); including updated corresponding documentation
- Community user support including general support through online forum in coordination with UFS, developer-focused on as-needed basis
- Sub-section for UPP on WRF's forum to migrate WRF-related support
- Assistance with EMC's UPP re-engineering effort with emphasis on testing to ensure portability
- Revised code management plan that reflects new repository and contribution procedures
- Collection of use cases for regression testing
- Updated Docker container

Sponsors: NOAA

DTC METplus Air Force Community Support

Motivation

The Model Evaluation Tools (MET) has been developed and supported to the community via the Developmental Testbed Center (DTC) for a decade now. METviewer is the associated database and display system designed for in-depth analysis of MET output and routine plotting. The Air Force 557th Weather Wing would like to use it for their operational verification package. To facilitate this, they have a requirement these two packages routinely pass cyber-security scans using the HP Fortify software package. Fortify software eliminates software security risk by ensuring that all business software is trustworthy and in compliance with internal and external security mandates. Additionally, during AOP 2018, MET helpdesk fielded 4-20 emails per month (on new or open issues) from 557th Weather Wing staff. With the adoption of MET and METviewer in operations, it is expected these interactions will continue at the same or higher level.

Project Description

For a performance period of July 2019 – June 2020, the DTC is proposing to maintain its subscription for the Fortify cyber security scanning software and run it on MET and METviewer prior to all releases. The DTC will make the scan results available to the Air Force for review and will address any concerns from the Air Force as they arise. With remaining funds, DTC will provide prioritized help-desk support to verification staff from the 557th Weather Wing. If funds are expended prior to the end of the PoP, Air Force requests will be addressed in a timely manner via standard helpdesk procedures. The project will also host an in-person tutorial at the 557th Weather Wing.

Project Deliverables

- Maintain Fortify license
- MET and METviewer releases pass Fortify scan
- Prioritized helpdesk support
- 2-3 day in-person tutorial at 557th Weather Wing

Sponsors: Air Force

DTC NCAR Base METplus Community Support and Development

Motivation

The Model Evaluation Tools (MET) were developed by DTC over a decade ago to provide a state-of-the-science verification tools to the atmospheric science community. The goal was to develop a framework that included both traditional statistics and burgeoning approaches while also making it platform independent and extensible. The initial funding for MET came from the Air Force, with NCAR and NOAA supporting the development a year or two later. MET is comprised of a series of tools designed to help users with pre-processing, data inspection, and calculation of both traditional and spatial statistics. Aggregation of those statistics and attributes can be performed using the MET analysis packages or through the accompanying METviewer database and display system. In addition to supporting the research community, the Developmental Testbed Center (DTC) METplus team has been collaborating with other verification and diagnostics teams on developing the unified verification framework called METplus, with MET and METviewer at its core. Work with NOAA provides the foundation for a unified verification capability for the Unified Forecast System (UFS). Similarly, work has begun to determine how METplus fits into NCAR's System for Integrated Modeling of the Atmosphere (SIMA). Both of these efforts feed directly into the NCAR-NOAA Memorandum of Agreement (MOA). Finally, the Naval Research Laboratory (NRL) is working on adopting METplus and will be contributing to its development during FY2020. This fiscal year, there will be 1-2 coordinated major releases of METplus. Requests from the community for support have increased substantially over the past year, with a tripling of requests in calendar year 2019 (through September). DTC's interactions with users is generally via met_help, monthly telecons and in-person meetings. The DTC has also received many requests for an in-person tutorial to be re-established and given at NCAR. Finally, while the research community can now contribute directly to METplus via open GitHub repositories, there are still significant needs within the community for the METplus team to assist in the enhancement and integration of new capabilities to benefit the broader research community.

Project Description

This aspect of DTC funding will be focused on serving the needs of NCAR and the broader research community. The MET helpdesk has expanded to support users of METplus wrappers, MET, METviewer, and the containerized versions of these tools. The METplus team is expected to respond to approximately 300-400 tickets this fiscal year. Figure 1 depicts the upward trend in helpdesk requests and indicates the community requests are the fastest growing fraction at this time. It is anticipated that this demand will increase over the next year with growing interest in METplus as a likely a core part of SIMA as well as the UFS verification capability. METplus will likely be the last DTC package to move away from helpdesk to forums due to the active nature of the user community via helpdesk. For this reason, significant resources will have to be used for this activity this year.

Another activity of this project will be to provide public releases of METplus to the community. Much of the work associated with preparing for releases has been absorbed by METplus projects. If an enhancement is added by a project external to the DTC, the unit-test and documentation for that feature or use-case is added as part of that project. However, there still needs to be one place to bundle up the code, do the cross-platform testing, make sure all aspects of the release are documented, and physically make the tag and release available on Github. DTC will fill that role. The METplus team will maintain the release schedule of two per year for this fiscal year to allow the community to have expeditious access to new verification and diagnostic methods during the rapidly evolving unification activities both at NCAR and NOAA. All releases will include pre-release testing, final packaging of documentation (both downloadable and on-line) and the online tutorial.

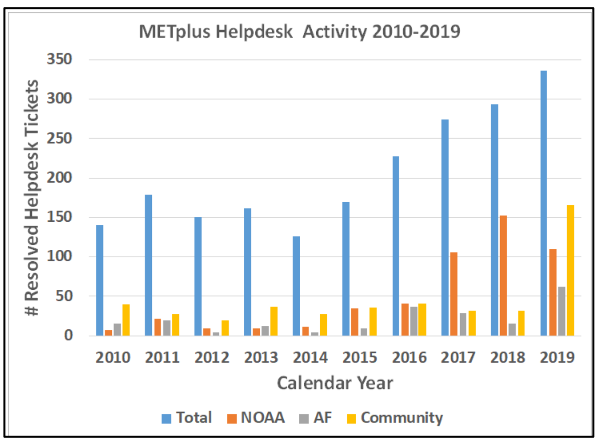

Figure 1. METplus Helpdesk Activity during calendar years 2010 through 2019. Total number of resolved tickets is in blue, with the requestors portioned out as NOAA (dark orange), Air Force (gray), and Community (light orange).

The transition to community development requires a shift in activities to continue to shore up the METplus infrastructure. Initial progress on this task has been made but additional activities are necessary to solidify the framework, including: 1) repository maintenance; 2) supporting collaborators in the addition of the manage externals cap to their contributed packages; 3) maintenance of continuous integration testing for pull requests to the GitHub repositories; 4) maintenance and expansion of systems to check to see if the contribution is accompanied by sufficient documentation; and 5) augmentation of required tests to the nightly builds.

While the METplus team is actively working with a wide cross-section of the research community, including academia, private industry, and government centers and labs, currently there is no mechanism other than through DTC to add enhancements that are requested by the community not actively collaborating on a project with the METplus team. For this reason, it is expected that this task will continue to address the requests for enhanced capability coming from the greater community, including aspects of NCAR projects that do not fit under current METplus projects. A roadmap for unifying the verification and diagnostic capability for SIMA is being developed through a seperate NCAR

Reinvestment project focused on developing the SIMA infrastructure. This project will provide 1-2 enhancements to METplus based on the requirements gathered by the roadmap.

The proposal includes presentations at relevant NCAR-related conferences or workshops (i.e. WRF/MPAS Workshop) to ensure the community is aware of all that METplus has to offer. This activity would also provide an in-residence METplus tutorial held at NCAR before the end of FY20.

Project Deliverables

- METplus helpdesk for the community not supported by NOAA, AF, and other community contributor funding
- METplus releases, bug fixes, documentation and on-line tutorials
- Implementation of necessary components for METplus community repository governance
- Development of at least 1-2 capabilities based on requirements gathered during NCAR Reinvestment Project on SIMA
- In-person tutorial held at NCAR

Sponsors: NCAR

DTC METplus NOAA Community Support and Development

Motivation

The Model Evaluation Tools (MET) was developed by DTC over a decade ago to provide state-of-the-science verification tools to the atmospheric science community. The goal was to develop a framework that included both traditional statistics and burgeoning approaches while also making it platform independent and extensible. The initial funding for MET came from the Air Force with NCAR and NOAA supporting the development a year or two later. MET developers used the NOAA Environmental Modeling Center (EMC) mesoscale Verification Statistics Database (VSDB) as a starting point to develop a platform independent and extensible state-of-the-science community verification package. MET is comprised of a series of tools designed to help users with pre-processing, data inspection, and calculation of both traditional and spatial statistics. Aggregation of those statistics and attributes can be performed using the MET analysis packages or through the accompanying METviewer and METexpress database and display systems. It should be noted that externally funded refactoring of the METviewer computation and plotting software layer allows for increased library sharing between METviewer and METexpress interfaces.

The Developmental Testbed Center (DTC) METplus team has been collaborating with other verification and diagnostics teams on developing the unified verification framework called METplus, with MET and METviewer at its core. METplus projects with NOAA provide the foundation of a unified verification capability for the Unified Forecast System (UFS). In previous years, this work was performed through DTC projects as well as Next Generation Global Prediction System (NGGPS) projects directly contracted with the two core nodes of the DTC, namely NCAR/RAL and NOAA/Global Systems Laboratory (GSL). It has been requested that the independent NGGPS projects be brought under the DTC umbrella. This proposal includes work performed through the DTC's core NOAA/OAR and NGGPS funding. Work has begun to determine how METplus fits into NCAR's System for Integrated Modeling of the Atmosphere (SIMA). Both the UFS and SIMA efforts feed directly into the NCAR-NOAA Memorandum of Agreement (MOA).

During 2019, the METplus development community expanded beyond NCAR, GSL and EMC. The Air Force has adopted aspects of METplus for its operational use and the Naval Research Laboratory (NRL) is working on adopting METplus with a goal of contributing to its development during FY2020. Finally, the Met Office and Unified Model partners, such as the Australian Bureau of Meteorology and South African

Weather Service, have opened discussions on how they might use and contribute to METplus. With this expansion of the development community, the necessity of a well-supported infrastructure and governance to ensure code viability and integrity will become paramount. Community contributions to METplus outside the DTC Charter members will be provided through explicit funding and in-kind contribution from those organizations.

Project Description

Overall, the METplus community software support and development will be focused on serving the needs of NOAA, NCAR, and the USAF users, along with the broader research community. This proposal includes the work to further align METplus with the UFS infrastructure and making it more accessible to the entire UFS community. To do this, the DTC needs to provide support to users and contributors, governance for inclusion of methods under the METplus framework, development of additional capability to support the ensuing fully-coupled UFS, and the maintenance and packaging of the METplus code for coordinated releases.

Support: During recent years, the MET helpdesk has expanded to support users of METplus wrappers and use-cases, MET, METviewer, and the containerized versions of these tools. The METplus team plans to continue current supported components and start supporting METexpress more extensively. During 2019, met-help addressed nearly 350 tickets and it is expected requests for help will increase. While METplus will likely be the last DTC package to move completely away from helpdesk to forums due to the rapidly expanding capability and active nature of the user community via helpdesk, a METplus forum will be developed during 2020 with an expectation of full transition to the forum the following year. Help-desk/forum support for NOAA users, as well as Office of Science and Technology Integration (OSTI) and Weather Program Office (WPO) contributor support will be provided by this project.

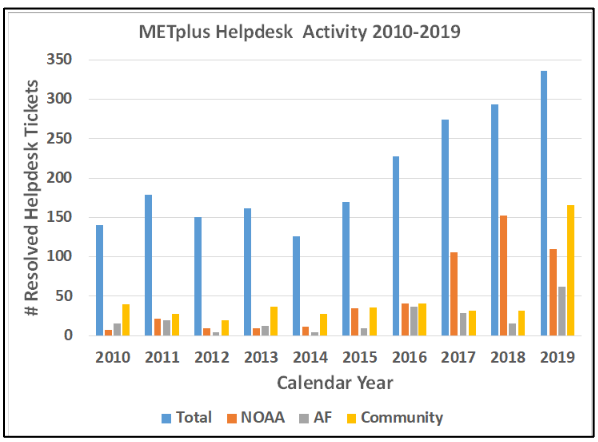

Figure 1. METplus Helpdesk Activity during calendar years 2010 through 2019. Total number of resolved tickets is in blue, with the requestors portioned out as NOAA (dark orange), Air Force (gray), and Community (light orange).

Governance, Code Maintenance, and Releases: Another activity of this project will be to provide public releases of METplus to the community. Over the past two years, much of the work associated with preparing for releases has been absorbed by individual METplus projects. If an enhancement is added by a project external to the DTC, the unit-test and documentation for that feature (or use-case) is added as part of that project. However, there still needs to be a cohesive activity to bundle up the code, do the integration and cross-platform testing, ensure consistency across tools and wrappers, develop and test installation procedures, make sure all aspects of the release are documented, and physically tag and release the code on GitHub. DTC will fill that role. The METplus team will maintain the release schedule of one to two major releases per year to allow the community to have expeditious access to new verification and diagnostic methods during the rapidly evolving unification activities both at NCAR and NOAA. All releases will include pre-release testing, final packaging of documentation (both downloadable and on-line) and the online tutorials.

The transition to community development requires a shift in activities to continue to open up the METplus infrastructure to contributions from external partners. Initial progress on this task has been made but additional activities are necessary to solidify the framework, including: 1) repository maintenance; 2) supporting collaborators in the addition of the manage externals cap to their contributed packages; 3) maintenance of continuous integration testing for pull requests to the GitHub repositories; 4) maintenance and expansion of systems to check to see if the contribution is accompanied by sufficient documentation; and 5) augmentation of required tests used in the nightly builds.

Development: The METplus framework has been broken into several components to allow for the most flexible application of the tools and interoperability with other applications. There are now seven repositories, including the METplus umbrella repository with wrappers and use-cases, MET (core statistical tools), METviewer (deep-dive data analysis), METexpress (pre-defined plots), METdbload (database tools), METcalcpy (calculations necessary for analysis), and METplotpy (plotting routines). The repositories are drawn together as the METplus evaluation framework using manage_externals, developed by the Community Earth System Modeling (CESM) project. The DTC will be responsible for the development of the core METplus tools, as needed, based on the priorities set forth by NOAA collaborators. Development will be optimized through coordination with other core contributors (e.g. NCAR, AF, NRL and Met Office). Examples of development include 1) enhancing MET to provide integrated capability for computing statistics and diagnostics that require use of the MET libraries and configuration options, 2) enhancing the user interfaces of METviewer and METexpress to improve usability and add functionality; 3) continued enhancements to loading features of METdbload and exploration of a federated database of distributed METdb instances for use by the user interfaces; 4) expansion of the METcalcpy computation layer and METplotpy plotting layer for use by the user interfaces as well as on the command-line; 5) expansion of plotting functionality to incorporate visualization options driven by community contributions and user needs; 6) a concerted effort to fully leverage the soon-to-be developed interfaces between METplus and the Unified Post-Processor (UPP) and Joint Effort for Data assimilation Integration (JEDI).

The development listed above is intended to continue to advance METplus for use in the evaluation of the coupled UFS while serving the needs of the individual UFS application teams, such as the Convection Allowing Models (CAM), Medium and Extended Range (MER), and others. Jason Levit, the Verification, Post-Processing, and Product Generation Branch Chief at EMC has prioritized marine; aerosols and air quality; and CAM ensemble verification for the coming year.

Outreach: The proposal includes presentations at two relevant conferences per year and collaboration and training trips to College Park, MD. It also includes a Metrics workshop to complete the work started during the 2018 DTC UFS Community Test Plan and Metrics Workshop. The workshop will take place in College Park and will include participant support costs to support travel for 3-4 subject matter experts to present at the workshop.

Project Deliverables

- METplus helpdesk for the NOAA community
- Priority contributor support of 3-6 OSTI and WPO funded projects targeted for METplus integration
- METplus releases, bug fixes, documentation, and on-line tutorials
- Fully functional METplus community repository governance
- Two to four (2-4) new features per year in each core component (MET, METviewer, METexpress, METplotpy and METcalcpy, METdbload)
- Two to four (2-4) METplus use-cases per year for EMC priority applications

- Plan for accessing federated database systems

Sponsors: NOAA, UFS R2O project

Enhancing community collaborations through containerization of NWP system components and cloud compute platforms

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. Over the past several 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 WRF-based end-to-end NWP system was established.

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 and computing resources can be overwhelming, especially on local work stations. One way to address these increasing data storage and compute power requirements is through cloud computing, which allows for the ability to store large data sets in concert with virtual computing resources that are available to and accessible by the community. With the increasing size of data volumes, it is less feasible to move the data around to different machines and platforms; 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.

At the same time, we do not want to overlook the opportunity containers and cloud computing provide in terms of fostering an interest and excitement in NWP while educating the next-generation workforce. With worldwide access to large compute resources and containerized components that decrease the burden of the initial startup process, these tools promote an innovative teaching tool to integrate NWP directly into a course curriculum using hands-on learning.

Project Description

A single column model (SCM) can be a valuable tool for diagnosing the performance of a physics suite, from validating that schemes have been integrated into a suite correctly to deep dives into how physical processes are being represented by the approximating code. The SCM associated with the Common Community Physics Package has the advantage of working with a library of physical parameterizations for atmospheric numerical models and the associated framework for connecting potentially any atmospheric model to physics suites constructed from its member parameterizations. In fact, this SCM serves as perhaps the simplest example for using the CCPP and its framework in an atmospheric model. The SCM is also in important piece of the DTC's hierarchical physics testing framework. Given this, during FY2020 the CCPP SCM will be targeted for containerization by the DTC. In addition, the DTC is proposing to maintain the current WRF-based NWP containers as new versions of the components are released and update the website accordingly. As applications are run over larger domains and/or finer resolution, multi-node computation becomes increasing important. Work towards expanding the current container capabilities to address this need using tools such as Docker Swarm or Singularity will be explored. Along with the code itself, these containers will include all critical test datasets. All newly established containers will be made publicly accessible on DockerHub. As new containers are established, 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 a WRF-based end-to-end system will be preserved and enhanced to include information related to running the SCM. Community support for specific questions regarding containers or cloud computing aspects of the system will be provided to users running the DTC containers, which is essential to attracting and maintaining an active user community. General questions related to running the components themselves will be referred to the component's support forum for assistance.

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 and containers offer an excellent opportunity to provide a sandbox for the community to share output and datasets, allowing for more cross-community interactions, while avoiding platform portability issues that may arise. The containers will be executed on a cloud computing provider platform [e.g., Amazon Web Services (AWS)]. To supplement the funds included in this proposal for cloud computing, we will also apply for AWS Cloud Credits.

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. To fulfill this need, a full-day short course titled "Integrating NWP system components using container technology and cloud services" will be offered at the 100th AMS Annual Meeting in Boston, MA. 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. This work will also be leveraged to run the CCPP SCM on AWS as part of another short course at the 100th AMS Annual Meeting entitled "Experimentation and Development of Physical Parameterizations for Numerical Weather Prediction Using a Single-Column Model and the Common Community Physics Package (CCPP)" through the DTC's funding from NGGPS.

Project Deliverables

- Multi-node computation investigated
- Docker container created for CCPP SCM
- All DTC containers published and maintained on DockerHub
- Containers supported on a cloud computing platform
- Short Course at AMS Annual meeting in January 2020

Sponsors: NCAR

Testing and Evaluation

Evaluation of Unified Forecast System (UFS) physics suites using the CCPP single column model and stand-alone regional configuration of the UFS-Atmosphere

Motivation

The Medium-Range Weather (MRW) and Convection-Allowing Model (CAM) applications of the Unified Forecast System (UFS) must produce timely and accurate forecasts for a variety of weather phenomena, including heavy rainfall, severe weather outbreaks, hurricanes, snowstorms, dense fog, and various other hazardous and non-hazardous weather events. To achieve this goal, each UFS application must utilize a physics suite that advances forecast skill across a broad range of spatial and temporal scales. To provide a framework for accelerating the transition of new physics innovations into operations, the DTC 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 (HTF). Currently, four physics suites are available in the CCPP framework, with two suites available in the UFS CAM community workflow. Each suite was developed for a particular set of global and/or regional applications. Available CCPP-compliant suites within the UFS CAM community workflow include the Global Forecast System (GFS) v15 and the physics suite developed by the Global Systems Laboratory (GSL) for the Rapid Refresh (RAP)/ High-Resolution RAP (HRRR) systems. Additional suites available within the CCPP include 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 and the Climate Process Team (CPT) physics suite. Furthermore, several Hazardous Weather Testbed (HWT) physics suites are under preparation, and the physics suite from the operational Hurricane Weather Research and Forecast (HWRF) system is being added to the CCPP as part of a Hurricane Supplemental project. The DTC is currently involved in many related efforts, including the UFS CAM community workflow development (OAR funded), enhancements to drive the CCPP Single Column Model (SCM) with UFS Atmosphere input/output, the creation of an integrated Hierarchical Testing Framework, and CCPP code updates to output physics tendencies (HSUP funded). These development and support activities are strengthened by exercising the code for specific testing and evaluation activities to provide feedback to physics developers and to allow staff to gain expertise on the supported code bases. Furthermore, two DTC testing and evaluation activities are included within the NGGPS-funded UFS R2O project that would provide synergistic physics evaluation opportunities. The first (1.6 UFS-R2O MER/S2S Sub-Project Atmospheric Physics) involves an assessment of GFSv16 physics for medium-range and coupled subseasonal applications. The second (2.2 UFS-R2O CAM Sub-Project: RRFS and Retirement of Legacy Models) focuses on the evaluation of the selected physics suite for the Rapid Refresh Forecast System (RRFS). While each project has different motivations and testing elements, common threads between the activities can be leveraged to support a unified physics testing environment.

The proliferation of physics options within the CCPP provides a valuable opportunity to investigate important forecast challenges and the sensitivity of the forecast skill to model physics suite and horizontal grid spacing. Specifically, there is a particular need to provide skillful quantitative precipitation forecasts (QPFs) for flooding rainfall events, including those from landfalling tropical cyclones. Inland flooding is the second-leading weather-related cause of death in the United States over the past 30 years (NOAA 2018), and more than half of fatalities from tropical cyclones are caused by inland flooding (NOAA 2005). The relationship between the accuracy of the UFS QPF and the microphysical structure of clouds and precipitation has yet to be explored and quantified. Secondly, forecaster feedback has indicated that NOAA's GFS lacks routine skill in producing accurate model profiles of PBL thermodynamic variables. Symptoms of the problem 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 that suggest the GFS produces too much turbulent mixing in the boundary layer in 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

During the second year of this project, the DTC proposes to continue testing that will document the performance of multiple physics suites at different model resolutions. The testing and evaluation will apply portions of the HTF to gain a better understanding of the strengths, weaknesses, and general behavior (e.g. tendencies, scale-awareness) of the physics schemes. During the first year, the DTC was funded to begin exploring the scalability of the CCPP-available physics suites within the stand-alone regional configuration of the UFS-Atmosphere (referred to hereafter as SAR UFS-Atmosphere), with an emphasis on known PBL deficiencies, to start addressing the question: *how close are we to having a single physics package for all model applications*? The SAR UFS-Atmosphere was 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) for GFS and GSL physics suites using the CCPP. Cold start runs were performed for three different events: June 2019 severe weather event with both locally and synoptically driven areas of convection, Hurricane Barry (2019), and the July 2019 heat wave across the central CONUS. Verification and diagnostic capabilities were developed to interrogate these cases, which will be included in a METplus use case by the conclusion of the first year. Timely feedback and debugging of the community workflow were provided to the UFS CAM team, which resolved multiple sources of model crashes and led to a more flexible, robust workflow. Communication with several community collaborators and subject matter experts has been established, with one DTC Visitor Program proposal awarded.

For year 2, the DTC proposes to continue this effort with a stronger emphasis on community interactions and the HTF. Now that the team has experience running the system and has an evaluation workflow in place, increased participation from developers and external collaborators will be more fruitful and an environment for an iterative development/evaluation process will be fully exercised. The team will implement regular discussion groups where developers, subject matter experts, and teams working on complementary physics evaluations will be convened in an informal setting to allow for regular two-way discussions regarding UFS physics deficiencies and improvements. The evaluation will continue to focus on the aforementioned cases, with additional runs and/or physics suites evaluated as deemed appropriate. The team will strive to add pre-existing suite definition files (SDF) to the community workflow for CCPP-compliant physics suites of interest for testing. 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. 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. Therefore, effort will continue to better characterize and quantify the spatiotemporal extent of the PBL misrepresentation prior to developing a hypothesis for a workable solution.

An additional focus in Year 2 is to examine the accuracy of UFS QPFs and their relationship to the modeled microphysical structure of convective weather. To assess the skill in predicting heavy precipitation, QPFs for the Hurricane Barry and severe weather cases will be compared to estimates of precipitation amounts from NWS dual-polarization radars. Cross sections of reflectivity, hydrometeor type, and ice and liquid water content/path inferred from the radar measurements also will be compared to representative cross sections from the model forecasts to assess the model depiction of the microphysics. The analysis will focus on quantifying the differences between the QPFs and microphysical structure in the 13-km runs and the 3-km runs. The goals are 1) to determine the added benefit of forecasting microphysical characteristics and heavy rainfall at the convection-allowing scale relative to the scales of the current global forecast models and 2) to quantify the QPF skill of several of the physics suites in the CCPP, particularly the GFS, GSL, and HWRF suites.

Anticipated developments to extend the capabilities of the CCPP SCM and output physics tendencies from the CCPP will be utilized to isolate the interactions between physics parameterizations and diagnose the causes of forecast failures, with a focus on the PBL representation in the heat wave case and on the heavy rainfall forecasts in the tropical cyclone and severe weather cases. Similarities, and, most importantly, differences in performance across specific types of schemes (such as the PBL and microphysics parameterizations) will be identified and investigated further using a suite of traditional and process-based verification metrics. The behavior of the scale-aware schemes across scales will receive particular attention to improve our understanding of their performance from convective to seasonal scales. The capability to output the physics tendencies, which will be implemented by May 2020 by the CCPP team, will be crucial to analyzing this behavior and iterating with developers to improve the performance of their physics schemes. Process-based diagnostics, and traditional and non-traditional verification statistics appropriate for each application that were developed during the initial year of the project will be leveraged and built upon. These tools include vertical profiles of temperature, moisture, and winds output directly from the native FV3 model grid, analysis of the cloud fields, visualization of the microphysical and boundary layer structure in Hurricane Barry in storm-relative coordinates, and the hurricane track error diagnostic from Galarneau and Davis (MWR, 2019). Observational corollaries from radiosondes, ground-level radiation measurement stations, dual-polarization radars, and dropsondes will continue to be refined for comparison to the model results and shared with physics developers. Finally, where analysis points to systematic biases across scales with respect to PBL thermodynamic properties, the DTC proposes to drive the CCPP SCM with dynamics tendencies from the UFS-Atmosphere (capability available next year from the CCPP SCM team) to investigate the interactions between the physics schemes and deduce the source of the biases.

Opportunities for collaboration exist 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 the NOAA Storm Prediction Center (SPC). Our proposed activity is complementary to the project awarded to Dr. Evans because we are approaching the PBL problem with a different phenomenological focus (heat wave versus convection initiation). During year 1, DTC staff discussed collaboration opportunities with Dr. Evans to be pursued during year 2. In addition to synergies with Dr. Evans, other ongoing efforts in the community will be leveraged to strengthen the proposed activities. William Gallus (Iowa State University) was recently awarded a DTC Visitor Project titled "Evaluating CCPP Physics Across Scales for Severe Convective Events," to work with the DTC on a project complementary to this effort. Dr. Gallus plans to investigate the predictability of convective systems, convective morphology, and cold pool characteristics across scales and physics suites using the SAR UFS-Atmosphere. Coordination and open dialog between all DTC physics testing and evaluation activities will support the overarching goals of unified physics and improved forecast skill. The DTC has also developed relationships with physics developers and subject matter experts who will be utilized for iterative discussions of deficiencies and solutions for testing. Maintaining a strong collaborative relationship with EMC throughout the process will be key to the overall success of this project. The DTC is hosting the 1st annual UFS workshop in July 2020 in Boulder, CO. The team will be active participants in this workshop with several anticipated presentations and will provide a key entry point for community participants to develop collaboration opportunities with the DTC.

Project deliverables

- Report on findings of the testing
- Results presented in briefings given to physics developers and subject-matter experts
- Results presented at relevant conferences/workshops

Sponsors: NOAA

Rapid Refresh Forecast System (RRFS) Development and Retirement of Regional Mesoscale Modeling Systems

Motivation

Within the NOAA model unification effort, a key area of interest is the evolution of the North American Mesoscale (NAM), Rapid Refresh (RAP), High-Resolution Rapid Refresh (HRRR), and High-Resolution Ensemble Forecast (HREF) systems to a new, unified FV3-based deterministic and ensemble storm-scale system, to be known as the Rapid Refresh Forecast System (RRFS). This ongoing unification effort to move from the existing NOAA prediction systems to the UFS is a major multi-year undertaking with the new RRFS system targeted for initial operational implementation in late 2023.

The most overarching benefit to the U.S. weather enterprise is focusing human resources and expertise from across the meteorological community on a single, shared system and avoidance of duplicative efforts. The evolution toward this developmental paradigm reflects a broad consensus that only with such a shared system, and an associated shared collective expertise, can NOAA maximize forecast skill across the many model applications. In addition, simplification of the operational NCEP suite of models will allow for optimization of existing and future high-performance computer resources and a reduction in overhead of software maintenance related to resources spent on maintaining multiple dynamic cores.

A successful transition to the Rapid Refresh Forecast System (RRFS) will involve the phased retirement of several regional prediction systems currently in operation at NCEP. This is in part because the RRFS will subsume the roles of several of the regional systems and the continued advancement of the Global Ensemble Forecast System (GEFS) will complement this process. Regional systems planned for retirement include the Short-Range Ensemble Forecast (SREF) System, the NAM model and its associated nests, the HREF, RAP, and HRRR. A significant challenge in reaching a unified endpoint is the retirement of the SREF system, which is currently comprised of ARW and NMMB members, a mix of physics parameterization schemes, and features diversity in sources of initial conditions.

Project Description

The progression toward the eventual implementation of the RRFS requires coordinated development across several, interconnected areas spanning the dynamic core, data assimilation, and chosen physics suite. Integral throughout this process is careful objective and subjective diagnostic analysis of forecast output in the form of case studies and metrics. During the course of this project, DTC staff will engage specifically through testing and evaluation of physics suite options.

The CAM Application Team recently came to a consensus regarding a physics baseline that focuses on the following schemes: Thompson microphysics, MYNN turbulence and surface layer, Noah-MP land surface scheme, and RRTMG for longwave and shortwave radiation. This decision was based on years of experience in operational NWP as well as over a decade of physics-based experiments at CAM scales in NOAA testbeds, especially through the Community Leveraged Unified Ensemble (CLUE). Using this physics suite baseline, the DTC will create benchmark forecast performance results to facilitate configuration comparisons in the future as optimization and improvement to the physics suite progresses. This testing will leverage the UFS Convection-Allowing Model (CAM) Application workflow and expand the components to efficiently conduct verification through the use of the Model Evaluation Tools (MET). As configurations are compared, a CAM scorecard created using METviewer will be used to identify weaknesses and strengths of each configuration.

To begin the retirement of frozen pieces of the production suite, it is imperative to proceed in an order that does not interrupt upstream/downstream dependencies. For example, the SREF system depends upon both the NAM and RAP systems as a source for initial conditions. Therefore, the NAM and the RAP cannot be retired prior to the SREF. Given this dependency, it is proposed to start the retirement process with the SREF.

Ideally the SREF will be subsumed by the GEFS as it continues to approach and exceed the resolution of the SREF (16 km). However, at present, there are significant outstanding issues that preclude taking this step with the current (v11) and next iteration (v12, scheduled for FY20) of the GEFS because they are not likely to address the outstanding issues sufficiently enough to facilitate retirement of the SREF. The SREF remains the preferred ensemble system for day-2 and day-3 forecasts, most notably for convective and aviation weather. Feedback provided generally indicates that 1) the GEFS does not accurately portray boundary layer thermodynamic structure (inherited from the GFS) and 2) is often under-dispersive in the day-1 to day-3 time range. These two outstanding issues are known, scientific impediments in retiring the SREF and replacing it with the GEFS.

The earliest possible time at which the GEFS could address the issues to allow for the retirement of the SREF would be with an FY22 upgrade, moratorium notwithstanding. Therefore, work is needed to investigate potential ways in which NOAA can accelerate the retirement of the SREF while still meeting stakeholder needs. The DTC will engage in this process by conducting comparisons of the legacy ensemble systems (SREF and HREF) to the GEFS through the use of MET and scorecards. Operational output will be obtained and an extensive evaluation will follow.

Project Deliverables

- Forecast performance benchmark of the RRFS baseline physics suite created with MET
- Performance of the RRFS baseline physics suite monitored through testing and evaluation as optimization/improvement continue
- Legacy operational ensemble systems (SREF and HREF) compared to GEFS using MET and scorecards

Sponsors: UFS R2O Project

Testing and Evaluation of UFS Physics for Coupled Medium-range Weather and Subseasonal Forecasting

Motivation

Forecast uncertainties are the consequence of imperfect model initialization, dynamics, and physics. Among these factors, advancing physical parameterizations is essential to continuously improve the representation of physical processes and the overall predictive skill in the weather-to-seasonal forecasts. To ensure that the improvements of model physics will be properly implemented in the Unified Forecast System (UFS) and to encourage developers to actively engage in the developmental process, it is necessary to adopt a testing and evaluation (T&E) procedure that is agile (frequent, fast, automated), in-depth, neutral, collaborative, and operation-relevant but not operation-prescriptive. The Developmental Testbed Center (DTC), an established NOAA testbed with long-term track record of testing innovations for the National Centers for Environmental Prediction (NCEP), is well-positioned to conduct this T&E activity.

The objective of this proposal is therefore to provide objective evaluation and actionable suggestions to thoroughly inform decisions on the physics development of the UFS, and to ensure that the evaluation methods adopted can be usable for the broader community after completion of the project. The effort is expected to explicitly and continuously advance the model physics with the ultimate goal to improve the overall capability of the UFS.

Project Description

Unlike conventional and routinely adopted T&E of forecasting systems, the proposed work will provide information that can support and influence the developmental process of the model physics. The work will have the following foci:

1) The T&E seeks to primarily explain the systematic biases in the operational GFSv16 physics suite. In addition to the critical issues listed in the *UFS Development Goals and Priorities* [such as Planetary Boundary Layer (PBL) biases, 2-m temperature and precipitation biases over the CONUS, and tropical cyclone track errors beyond day 5], other biases particularly related to stratocumulus and shallow and deep convection will be identified using benchmark datasets including reliable observations and reanalysis.

2) The root causes and error contributions from physical parameterizations will be diagnosed by applying the “UFS Column Replay Capability”[1] and “Process Isolation Capability”[2] of the Single-Column Models (SCMs) in the Hierarchical Developmental System (HDS) and analyzing the physical tendencies.

3) Given that ocean conditions and sea ice are major sources of subseasonal predictability, the role of a coupled atmosphere-ocean-ice forecast system in generating the extended-range forecasts and subseasonal prediction will be investigated by comparing atmosphere-only and coupled configurations (with MOM6 ocean model and CICE5 sea ice model). As the coupled configurations become available,

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[1] *Code capability to force a SCM with saved dynamical tendencies and initial condition from a previous run of regional or global model.*

[2] *Code capability to use an arbitrary subset of active physical parameterizations of a physics suite (regardless of the forcing or initial conditions) and to allow the omitted physics to be substituted with a data component. The data component is obtained from a previous run of the SCM.*

capabilities offered through the Common Infrastructure for Modeling the Earth (CIME) will be adopted to plug-and-play different component models and control component feedbacks.

4) Physics innovations (such as the development of “an advanced moist physics suite”) that are relatively mature and involve close research-and-operational collaborations will be examined to funnel efforts from the research community to the operational physics (including GFS v17/GEFS v13 and beyond).

5) All the evaluation metrics adopted are expected to be “evidence-based and process-oriented” and consistent with the spirit of DTC’s contribution to the selection of an advanced physics suite for GFS v16. For example, the metrics for evaluating the PBL structure and evolution may include the vertical profiles of dynamic and thermodynamic fields, spatial and temporal variations of PBL height, the PBL-related cloud and precipitation development, and estimated inversion strength (EIS) or lower-troposphere stability (LTS). In addition to the in-house diagnostic metrics, the unified metrics emerging from METplus and the V&V WG for timescales from synoptic to seasonal will be considered.

Project deliverables

- Test plan for assessment of GFS v16 retrospective runs conducted by EMC
- Report on the evaluation of GFS v16 retrospective runs and the investigation of using HDS to offer insight into GFS v17/GEFS v13
- Assessment of physics innovations developed by the community, including the UFS Project #30 to develop an advanced moist physics suite

Sponsors: UFS R2O Project

Informing the Air Force Implementation Process through Verification and Validation Activities

Evaluate Latest Land Information System (LIS) Upgrades on Global Air-Land Weather Exploitation Model (GALWEM) Performance

Motivation

The AF requires skillful numerical guidance for a broad spectrum of weather and forecasting applications. A critical component of NWP systems is the Land Information System (LIS), which produces land surface states and fluxes that are used downstream in the forecast model. Under FY17 funding, the DTC is conducting an evaluation of LIS 7.2’s impact on the overall system. The AF is currently exploring upgrades to LIS 7.2, which will not only affect land surface-specific fields but can also affect overall model performance. To assist the AF with making evidenced-based decisions and to help inform decisions regarding future operational implementation, the DTC will assess the impact of an upgraded LIS by completing a comprehensive evaluation effort.

Project Description

Using existing benchmark data sets, the DTC will conduct an objective evaluation of the latest LIS release where 7.2 is the baseline. Evaluation data will include a winter and summer season and make use of the same methodology, metrics, and parameters developed for the prior LIS 7.2 evaluation. The DTC will work closely with the AF to further define any necessary aspects of the test plan. This test plan will be delivered to the AF along with a teleconference briefing of the evaluation results and a final written report summarizing the results. In addition, communication as needed with the AF, including teleconferences and in-person visits, will aid in the forward progression of the tasking. The DTC will rely on the AF for providing the data sets necessary for the evaluation, and cost estimates are based on the assumption the DTC will be working with model data in GRIB2 format.

Support for 557 Weather Wing Model Upgrades and Implementation

Motivation

The AF's NWP modeling suite is continually evolving as technical and scientific upgrades are made to its operational Global Air-Land Weather Exploitation Model (GALWEM) forecasting system, which is based on the UK Met Office's (UKMO) Unified Model (UM). A key component of the upgrade cycle is robust testing and evaluation to ensure the new implementation is performing the same or better than the current operational capability. The AF has requested DTC assistance with developing a test plan to evaluate new implementations, particularly GALWEM-based regional ensembles at ~4 km resolution Outside the Continental United States (OCONUS).

Project Description

The DTC will work with relevant stakeholders to develop a test plan for evaluating the implementation of GALWEM-based regional ensembles at ~4 km resolution OCONUS. The DTC will work closely with the AF to define detailed aspects of the test plan, including what system component(s) will be evaluated, what key questions will be addressed in the test, what variables and metrics will be targeted, and identifying necessary data sets and time periods to include in the test. This test plan will be delivered to the AF. The DTC will also be responsible for setting up and sharing the necessary MET configuration files to be used in the full evaluation, which will be executed by the AF. In addition, communication as needed with the AF, including teleconferences and in-person visits, will aid in the forward progression of the tasking.

The DTC will only require a small amount of sample model data, in GRIB2 format, and some observation data, if not readily available, from the AF to assist with establishing a test plan and setting up the necessary MET configuration files.

Develop Capabilities for Facets Critical to AF Operations

Motivation

The AF supports a vast profile of operational forecasting needs, including atmospheric phenomena that are difficult to evaluate (e.g., clouds, dust, and visibility). Traditionally, state variables, such as temperature and moisture, have more established verification methodologies and are more easily observed, both spatially and temporally. Non-state variables, however, often provide a more complex evaluation challenge, as verification methodologies are less mature (or non-existent) and observing platforms are more difficult to identify. In addition, the AF forecasts globally, including data sparse regions, which can make verification a challenge. To assist the AF with assessing and developing capability for these challenging and mission-critical forecasting and verification areas, the DTC will explore and demonstrate methods, data sets, and/or software focused on properties most important to AF operations.

Due to the nature of the variables being addressed, a significant amount of resources will be dedicated to exploring available "truth" data sets, which may include satellite platforms (geostationary and polar orbiting), gridded analyses (global and regional), station or point-based data sets (global and regional), and radar networks. The exploration of these different data sets will consider the resolution of the model data being verified to ensure comparisons are as meaningful as possible.

In addition, new and/or cutting-edge verification tools and methods will be researched. While more traditional methodologies will be considered, more advanced methods such as spatial verification will be heavily explored. Due to the fields being explored, the use of cross-sections to investigate the three-dimensional nature of the fields may be of use. The DTC's Model Evaluation Tools (MET) Method for Object-based Diagnostic Evaluation (MODE) tool provides an excellent opportunity to identify objects in the forecast and observed fields based on user-defined parameters to then compare attributes, such as object area, centroid, intensity, and axis angle. In addition, the MODE-Time Domain (MODE-TD) tool applies a time dimension to MODE, allowing for feature tracking through time. For new methods or tools that are developed, the DTC will make available prototype versions of the capabilities and identify possible pathways and resource estimates for inclusion in MET.

1. Evaluation of Clouds

Project Description

The DTC will explore and demonstrate, based on information gathered from the 557th Weather

Wing and benchmarking initiatives undertaken by Systems Engineering, Management and Sustainment (SEMS), advanced cloud-centric evaluation metrics that can be used to inform decisions regarding the implementation of cloud forecasting systems as part of the AF operational guidance. These metrics will focus on the cloud properties that are most critical to AF operations, within the limitations of what observations are available for conducting an evaluation. The metrics will continue and expand the limited capabilities identified under FY15 and FY16 funding.

To assist the AF with the evaluation of cloud properties, particularly the variables of cloud base and top heights and 2-D cloud mask, the DTC will consider cutting-edge verification methods and observing platforms, such as Atmospheric Radiation Measurement (ARM) sites and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), which target these critical variables. ARM and CALIPSO data are free and publicly available; the DTC will be responsible for obtaining these data. If the AF has specific data sets that need to be explored for this work that are not publicly available, the AF will be responsible for providing the DTC with the necessary data. Past cloud verification findings and feedback will be summarized. Distance metrics, such as Baddeley's delta, will be implemented in MET through a separately funded DTC visitor's project. The DTC will demonstrate these distance metrics and provide meaningful application information. In addition, the DTC will consider ensemble aspects and geometric indices.

2. Evaluation of Dust

Project Description

The DTC will assist the AF with the evaluation of dust properties, with particular focus on visibility at the surface and aloft, if possible. A survey will be conducted of available data sets, such as from the Earth-observing satellites Terra and Aqua. The DTC will make an informed exploration of new techniques and assist the AF with their application. The MET MODE and distance metrics will be useful tools for evaluation of dust.

3. Rollup Software Tools for Different Models or Configurations

Project Description

The DTC will work closely with the AF to develop rollup tools to use for different models or model configurations. These may include scorecard approaches or composite scoring. The tools will be tuned to AF specific mission-critical parameters. The DTC will work with the AF to configure an informative scorecard, (e.g. include all components of the GO index). The GO index will be loaded into METviewer and then plotted. The DTC will also explore the flexibility of NWP indices. A data mining approach to optimizing the NWP index using model data or a set of case studies where the outcome is known will be explored. Also, the correlation among the different index components will be examined.

4. Evaluation of Convective-Scale Models with Different Resolutions

Project Description

The DTC will work closely with the AF to appropriately assess the value of convective scale domains against coarser global domains in order to inform the decision-making process when spending resources to run them operationally. Under FY18 funding, the DTC helped develop approaches for assessing the value of high-resolution guidance for testing more specific OCONUS domains. While the scope of this tasking is an extension of the former work, the focus is now more on exploring how to assess the value of high-resolution convection-allowing models generically, particularly where observational radar data are non-existent. One fruitful area to explore is the implementation of equivalence testing into MET as a useful tool to perform on models with different resolutions based on sampling.

5. New Data Sets to Aid Model Verification Efforts

Project Description

The DTC will explore and demonstrate available but currently not used "truth" data sets, which may include satellite platforms, gridded analyses, station or point-based data sets, and radar networks. The exploration of these different data sets will consider the resolution of the model data being verified to ensure comparisons are as meaningful as possible. The DTC will assess the strengths and weaknesses of gridded products compared to hard truth in order to make sure those datasets are fittingly applied. One useful area to explore is the nuance of handling quality control flags within these data sets and investigate pathways for ingesting into MET, potentially using Python embedding.

6. Efficacy Comparison Tools for Ensembles and Deterministic Models

Project Description

The DTC will work to assist the AF with the evaluating the efficacy of an ensemble of models compared to deterministic models where the ensemble configurations are run at coarser resolution than the deterministic configurations. There are multiple areas for exploration. The DTC will explore refinements to High Resolution Assessment (HiRA) verification. The DTC will explore different ways to compute statistics based on where observations fall within climatological distributions. In addition, confidence intervals for the Brier skill score will be considered.

7. Veracity Testing of the Global Synthetic Weather Radar Product

Project Description

The AF is interested in the DTC evaluating the Global Synthetic Weather Radar (GSWR) product, which was created to address gaps in traditional radar coverage and produces several radar-based outputs, including composite reflectivity, vertically integrated liquid (VIL), and echo tops. It is produced with machine learning techniques using forecast model output from GALWEM and observation data from satellites and weather radars. In order to verify the product has been constructed appropriately, the DTC will compare the GSWR output against appropriate observation and analyses platforms. The DTC has extensive expertise in CONUS-based observation networks [e.g., Multi-Radar Multi-Sensor (MRMS) outputs], but will need to explore additional global datasets, which may include reaching out to subject matter experts at NCAR. The test plan will be delivered to the AF along with a briefing of the veracity testing results as well as a written final report summarizing the results.

Sponsors: Air Force