Developmental Testbed Center | DTC

Transitions

NWP FROM RESEARCH TO OPERATIONS

Issue 26 | Summer 2021

dtcenter.org/news/

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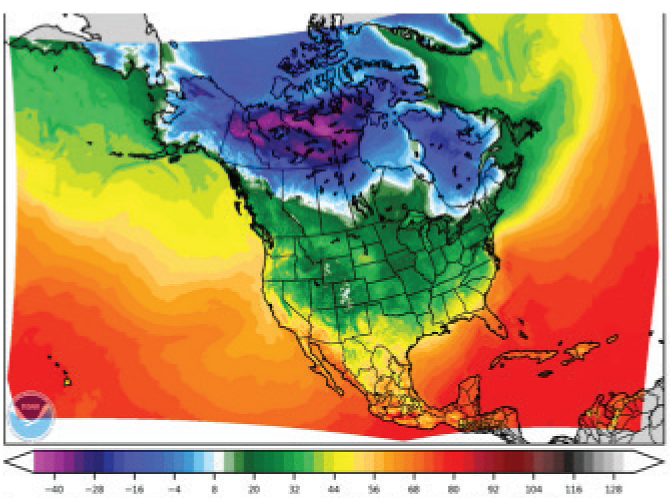
Accelerating Progress Of The Unified Forecast System Through Community Infrastructure

The goals of the Unified Forecast System (UFS) are ambitious: construct a unified modeling system capable of replacing dozens of independently developed and maintained operational prediction systems, while simultaneously paving the way for researchers in NOAA labs and the broader NWP community to access and use that system, improve it, and contribute their own innovations.

Toward these goals, the UFS Research-to-Operations (UFS-R2O) project began contributing to the UFS just over a year ago aiming to deliver several systems ready to move into operational mode under a unified framework, including a global coupled ensemble-based system for medium-range and sub-seasonal to season prediction (Global (Ensemble) Forecast System - G(E)FS); an hourly-updating, ensemble-based, high resolution short-range prediction system (Rapid Refresh Forecast System - RRFS); and a hurricane prediction system (Hurricane Application Forecast System - HAFS).



he UFS R2O Project has advanced NOAA's Rapid Refresh Forecast ystem (RRFS) prediction of temperatures over the continental USA.

Developing multiple modeling applications under a single, coordinated project is a new way of doing business for NOAA & NWS, and one that is starting to pay off. A key driver of success for the first year of the UFS-R2O project is a commitment to leveraging community infrastructure packages that form the backbone of the entire system. Infrastructure packages span the applications listed above and provide core functions: model coupling, interface between atmospheric physics and dynamics, data assimilation, hierarchical model development and testing, post-processing, and model verification. The

(Lead Article continued page 3.)

Director's Corner

By Louisa Nance

DTC Outlook for the Future

Over the years, a major component of the DTC's approach to facilitating the transition of research innovations into operations has been its support for distributed development of community software that includes the capabilities of the current operational systems. This software support has provided the foundation for conducting testing and evaluation that can inform the research to operations (R2O) process. The DTC's software support responsibilities have involved, to varying degrees,

Louisa Nance, DTC Director

(Director's Corner continued on next page.)

Director's Corner

(Director's Corner *continued from page one.)*

"With the award of the contract for EPIC, the DTC is on the cusp of an exciting evolution."

the Gridpoint Statistical Interpolation (GSI) and Ensemble Kalman Filter (EnKF) data assimilation systems, the Weather Research and Forecasting (WRF) model, the Hurricane WRF, the Unified Post Processor (UPP), the advanced Model Evaluation Tools (METplus), and more recently the Common Community Physics Package (CCPP) with its companion Single-Column Model (SCM) capability and the Unified Forecast System (UFS) Medium Range Weather (MRW), Short Range Weather (SRW) and Hurricane Applications.

These software support activities range from code management efforts that include code reviews and regression testing to user and developer support activities that include documentation, Users' Guides, help desk support and training. Supporting all aspects of an end-to-end numerical weather prediction (NWP) system requires substantial resources such that some years as much as 75% of the DTC's annual budget has been dedicated to its software support activities, leaving limited resources to dedicate to actually testing innovations, a role that should be central to a testbed. With the award of the contract for the Earth Prediction Innovation Center (EPIC), the DTC is on the cusp of an exciting evolution. EPIC represents a significant infusion of funding that will address the code management and support needs for the UFS. The UFS is envisioned to be a community-based, coupled, comprehensive Earth modeling system that supports applications spanning local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. Over the next few years, the DTC will be working closely with the EPIC Program Office to transition aspects of its software support activities to the EPIC contractor. Stepping back from these software support activities will free up resources to increase the DTC's investment in testing and evaluation activities, which will be a dream come true. While the DTC will be stepping back from some of its software support activities, we envision the DTC will continue to play a key role in the development and support of two software tools that are central to a hierarchical testing framework (HTF) — CCPP and METplus. The DTC is looking forward to working closely with the NWP community to engage in in-depth testing and evaluation activities that will include more diagnostic information on model performance to inform the development process. ■

Louisa Nance is the Director of Developmental Testbed Center. She has been with the DTC since it's inception in 2003, as its first official hire when Bob Gall was the Director and Steve Koch the Deputy Director. She has served in many leadership roles in the DTC, including the DTC Assistant Director.

(Lead Story *continued from page one.*)

infrastructure packages are backed by teams with substantial expertise, each focused on providing robust solutions to some of the most complex challenges in building Earth system models. Examples of community-developed infrastructure used in UFS include the Model Evaluation Tools verification system (METplus), the Earth System Modeling Framework (ESMF), the Community Mediator for Earth Prediction Systems (CMEPS), the Community Data Models for Earth Prediction Systems (CDEPS), the Common Community Physics Package (CCPP), and the Joint Effort for Data assimilation Integration (JEDI).

Use of community infrastructure software has accelerated progress within the UFS. One way this has happened is through greater sharing and reuse of code. Another way is through specialized, focused teams solving complex problems in a generalized way such that multiple applications reap the benefits. For example, the UFS has teamed with ESMF to provide a unified coupling framework capable of supporting a range of different UFS application requirements, from single component configurations to fully coupled. ESMF has been leveraged in a collaborative effort between NCAR and NOAA to develop the CMEPS (a coupler to handle information exchange across different earth system models) as a shared coupler and the new CDEPS (a data model functionality). Both CMEPS and CDEPS are used in NCAR's Community Earth System Model, and in the UFS Medium Range Weather and Hurricane applications. This approach represents a substantial consolidation of effort. Code optimizations, as well as problems resolved within one system, have been immediately leveraged by another. The use of CMEPS and CDEPS in multiple contexts and by a large user base has increased its flexibility--needed for experimentation by the research community--and robustness--required for reliability when run in operational environments.

Use of the CCPP has accelerated the progress of coupling atmospheric physics and dynamics. The CCPP is a collection of atmospheric physical parameterizations (CCPP Physics) and a framework that couples the physics for use in Earth system models. The CCPP-Physics is designed to contain operational and developmental parameterizations for weather through seasonal prediction timescales. Today the CCPP is used in the UFS and in the Navy's next generation model NEPTUNE (Navy Environmental Prediction sysTem Utilizing the NUMA corE). Additionally, the CCPP Framework is being extended for use with the NCAR Model for Prediction Across Scales (MPAS) and Community Atmospheric Model (CAM). Because it enables host models to assemble parameterizations in flexible suites, and is distributed with a single-column model that permits tests in which physics and dynamics are decoupled, the CCPP facilitates hierarchical system development and is appropriate for both research and operations.

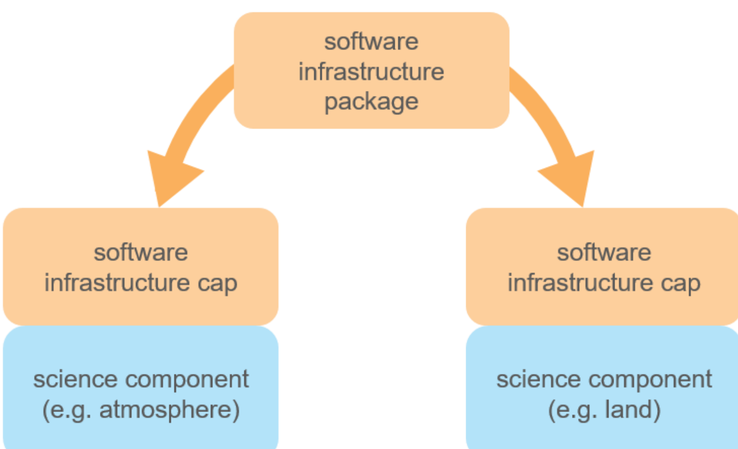


Figure. Schematic of two components interacting through a software infrastructure package. Each component has a "cap" that calls into scientific code. The caps translate that scientific code to data structures and metadata that are understandable by the infrastructure package that connects them.

The infrastructure not only includes the physics, model, and coupling framework, but also the pre-processing, post-processing, and verification and diagnostics tools. METplus is the UFS verification and validation tool that draws contributions from within the community, including academia, laboratories, and operational centers. It has a full suite of traditional statistics and is now being expanded to support diagnostics used in model development at all spatial and temporal time scales. These enhancements are being driven by the findings of the 2021 DTC UFS Metrics Workshop, held in February 2021. METplus is also being integrated into the UFS application workflows to be run after the Unified Post Processor (UPP) interpolates the model output onto standard grids. Finally, it has also been extended to leverage the output of JEDI for evaluations using the observation dataset ingested by JEDI.

Overall, the interdependency of the infrastructure packages are beginning to show a maturity and robustness that will lead to efficient model improvement for the UFS over the next few years. The second year of the UFS-R2O project is staged to continue to accelerate the development of an efficient, flexible, and well supported cross-cutting infrastructure.

Contributed by Rocky Dunlap, Tara Jensen, Arun Chawla, Mariana Vertenstein, Ligia Bernardet. ■

DTC VISITOR

William Gallus, Jr

Evaluating CCPP Physics Across Scales For Severe Convective Events

The DTC Visitor Program offers a unique means of gaining experience with state-of-the-art modeling and visualization approaches. During my visits with the DTC through this program the previous three times, I explored these diverse areas of study, and was able to provide several graduate students with unique opportunities in these areas:

1. The DTC's first convection-allowing model (CAM) ensembles run back in the mid-2000s,
2. The Method for Object-based Diagnostic Evaluation (MODE) verification approach (which was new at that time), and
3. The Community Leveraged Unified Ensemble (CLUE).

The new FV3-LAM model is a limited-area version of the nonhydrostatic Finite Volume Cubed Sphere dynamic core already running in the operational GFS model. This dynamic core is to replace most, or all, of the current models running operationally in the next few years, including those with convection-allowing grid spacing. Because my research has long focused on improved understanding and forecasting of convective- system evolution, I was invited to join an effort studying the impact of two different physics suites on several convective events. I am currently examining the output from my FV3-LAM runs using 3-, 13-, and 25- km horizontal grid spacing with physics packages closely matching the Rapid Refresh Forecast System (RRFS) and Global Forecast System (GFS), for three cases. The first case occurred in the northern Plains in May 2015, which was poorly predicted in my previous WRF runs. A second case that occurred in Texas during May 2019 was generally predicted well by CAM models. The third case, the infamous Midwestern Derecho of August 2020 that was the costliest single thunderstorm event in U.S. history, was poorly predicted by most CAMs, although some of the High Resolution Rapid Refresh (HRRR) and experimental HRRR runs from the evening before captured the event surprisingly well. The goal of the project is to see how well the physics suites perform through a range of horizontal grid spacing.

Observed reflectivity at 18 UTC 10 August 2020 (upper left, from UCAR archive), compared to simulated reflectivity in a run with 25 km horizontal grid spacing (upper right), 13 km (lower left), and 3 km (lower right).

One of the more interesting findings involves the derecho event. By accident, 13- and 25- km horizontal grid spacing runs were performed without using convective schemes, and these runs did a surprisingly

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DTC Visitor Article (Continued.)

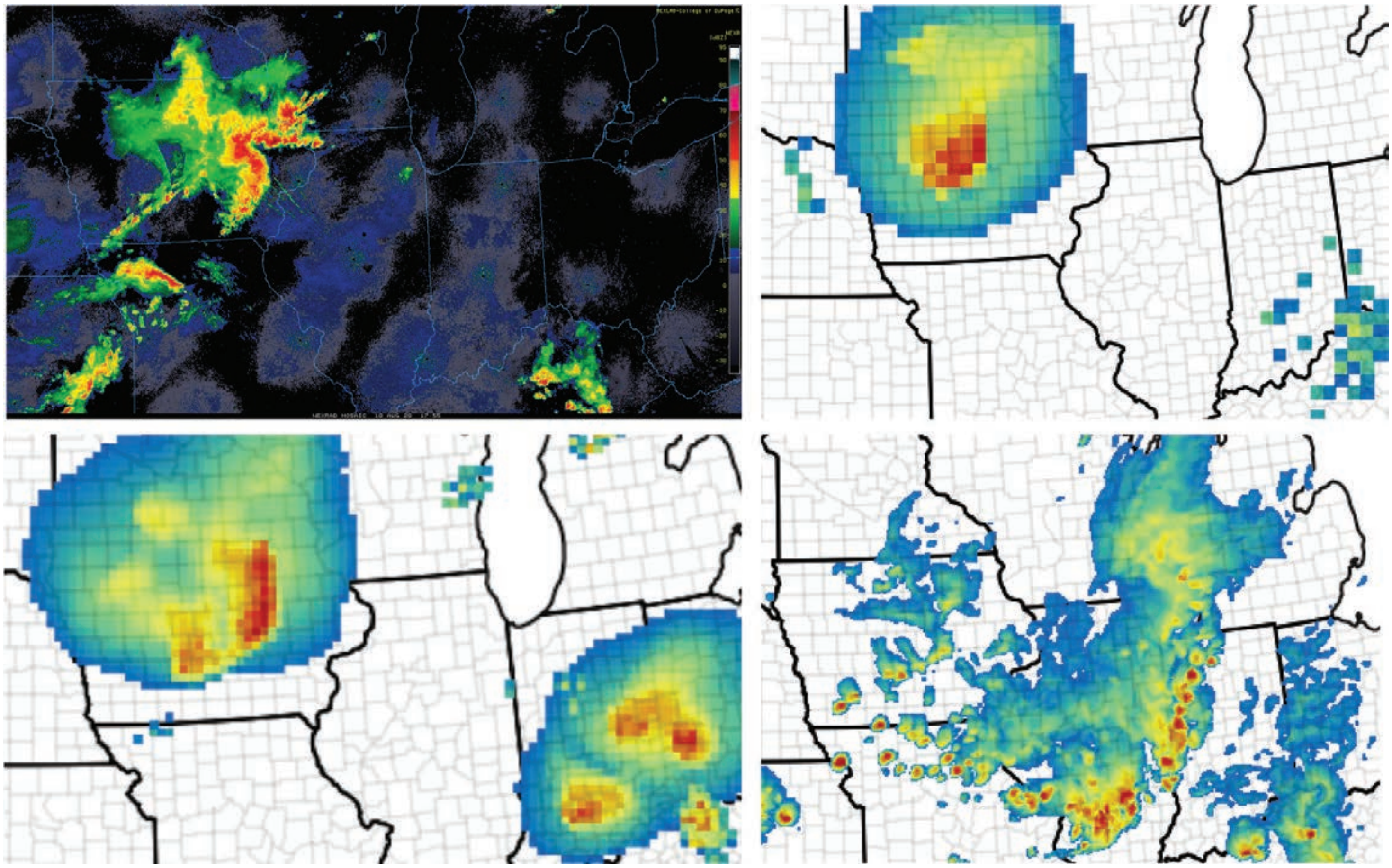

Figure above: Observed reflectivity at 18 UTC 10 August 2020 (upper left, from UCAR archive), compared to simulated reflectivity in a run with 25 km horizontal grid spacing (upper right), 13 km (lower left), and 3 km (lower right).

good job of showing the derecho in Iowa around 18 UTC 10 August (see Figure). However, the 3- km run performed very poorly because too much convection developed the night before, eliminating nearly all of the Convective Available Potential Energy (CAPE) in Iowa when the actual event occurred. This result is surprising because the FV3-LAM run was driven by initial and lateral boundary conditions from the successful 00 UTC HRRR-experimental run that did not experience this problem. When convective schemes were turned on, the 13-km results did not change noticeably, but the 25-km results were much worse, suggesting the schemes were very active at 25 km but inactive at 13 km.

More quantitative comparisons will soon be performed using MET to obtain some traditional skill measures, and MODE to focus on the convective systems of interest. I also plan to implement FV3-LAM on the supercomputer at my own university, and will be using it to explore upscale convective growth and morphology evolution in my own research.

Contributed by William A. Gallus, Jr. Iowa State University. ■

William Gallus is a professor of meteorology at Iowa State University, where he has been since 1995. His research focuses on improved understanding and forecasting of convective systems, particularly their rainfall and evolution, through the use of convection-allowing model simulations. He teaches courses on synoptic and mesoscale meteorology and has won several teaching awards at Iowa State. When he isn't studying thunderstorms and severe weather, he can be found tending his garden, playing piano, hiking, and chasing tornadoes.

WHO'S WHO IN THE DTC

Mrinal Biswas NCAR

Mrinal Biswas was born and raised in Durgapur, West Bengal, India, a small industrial town. He was raised by a Civil Engineer father while his mother took care of him and his sister. He enjoyed school but even more enjoyable was the time he played outdoors with his friends late into the evening. He was fascinated with anything electronic from radios to vinyl record players, even watches, disassembling them while his mom took his sister to school and quickly re-assembling them before she returned. It made him feel like an "engineer." Once, he was playing with a speaker and connected the two ends of the wires from the speaker to a 1.5 V battery (DC). It made such a feeble sound, he decided instead to connect them to a 220 V electrical outlet (AC). Although the experiment was successful in that it was certainly louder, he didn't expect the explosion of sparks from the short circuit he'd caused.

So, it comes as no surprise that Biswas entertained the notion of becoming an engineer. He often visited the Durgapur Steel Plant where his father worked, awed by the towering blast furnaces that served as the backbone of the factory.

Ultimately, he attended Banaras Hindu University in Varanasi, India and studied Physics, Geology, and Mathematics for his Bachelor's degree. During that period, he became attracted to Geophysics because it was an applied field, and soon after, he enrolled in their M.Sc (Tech) program. But a drastic turn of events would shift his educational focus to meteorology.

A severe cyclone made landfall in Odisha in the eastern part of India, during which ten thousand people lost their lives. At that time, local area managers were unprepared for a cyclone of that magnitude. The disaster and emergency management teams were not able to grapple with the damage. And, because the forecasting was so poor, no one had time to prepare an effective strategy for evacuation. The overwhelming damage and loss caused by this event had a significant impact on Biswas, and he knew that meteorology was a discipline where he could make a difference. Coincidentally, his meteorology teacher held a class on tropical cyclones which further honed his interest, and tropical cyclones became his new passion.

After earning his Masters degree, he was hired as a Research Associate at the Center for Atmospheric Sciences, Indian Institute of Technology, New Delhi, India. It was there that he was introduced to supercomputers and learned to run MM5. He then moved on to the Indian Institute of Tropical Meteorology, Pune, India in 2002 to pursue a PhD. He was working on a project to study the nonlinear interaction in the energetics of monsoon, but fate had other plans. He was offered the opportunity to work with the renowned (late) Prof T. N. Krishnamurti of Florida State University (FSU), Tallahassee to work on multimodel superensemble for hurricanes, which was irresistible. His dream of studying tropical cyclones was finally becoming a reality.

After moving to the USA in 2003, he performed real-time hurricane forecasting over the Atlantic basin, passing the FSU superensemble outputs to the National Hurricane Center (NHC) in Miami. His team was able to provide the most accurate forecasts for the 2004 hurricane season, which still stands as the highlight of his early career. He continued to improve the quality and usability of the model. The HFIP-Corrected Consensus Approach (HCCA) model developed by NHC is based on superensemble methodology.

Biswas was first introduced to NCAR when he attended a WRF tutorial, and then the first Hurricane WRF (HWRF) tutorial in 2010. He was so impressed with the knowledge and dedication of the scientists at NCAR that he made the decision to join the group in 2011. He continued to hone his expertise with the HWRF model. Growing his expertise and collaborating at the DTC provided him an unique opportunity to feel he was helping people in a tangible way. As a result of this career trajectory,

(Continued on next page.)

Mrinal Biswas (Continued.)

he was asked to join the teaching team for the second HWRF tutorial.

He now answers questions from the user community, replying to all the questions for the HWRF and GFDL vortex tracker public release codes. A great deal of testing and evaluation work continues as well. Biswas became involved in the Model Evaluation Tool (MET) plus software and contributed to use cases. He is currently working on the Hurricane Analysis and Forecast System (HAFS), which involves regression testing, testing with different physics options, and diagnostic evaluation. Bringing research innovations into operations and vice versa continues to be the most rewarding aspect of his work.

When not evaluating model performance, he and his wife enjoy their two daughters (7 & 2), kitchen adventures with risky recipes, and digging into the occasional DIY project. Traveling, once COVID-19 concerns recede, will be a welcome diversion. ■

COMMUNITY CONNECTIONS

DTC Workshop On Integrating Cloud And Container Technologies Into University NWP Curriculum: The Recap

The DTC convened a live, virtual three-day workshop 7-9 June 2021 tailored toward university faculty interested in integrating software container and cloud technologies into new or existing Numerical Weather Prediction (NWP) curricula. Of the nearly 40 interested registrants from over 25 different institutions, approximately 16 active participants attended the three-day event. The majority of attendees were either professors of NWP courses or interested in teaching NWP in the future, along with a few industry and researcher participants.

The workshop was inspired by recent partnerships with university programs to incorporate a containerized end-to-end NWP system online tutorial, recently established by the DTC, into their course. The success of these partnerships prompted an eagerness to solicit further input from faculty to enhance and refine the system, based on the needs and constraints of university professors. The goals of the workshop were two-fold; first, to inform the target audience about the tools made available by the DTC and how these technologies have been used in university classrooms; and second, to solicit feedback and facilitate dialogue with faculty about the existing content and how it may be incorporated into their curriculum.

The workshop held a variety of session types to provide a broad spectrum of information and experiences to encourage engagement and thoughtful discussions. The workshop kicked off with an overview of the NWP systems established by the DTC, after which participants were given access to Amazon Web Services (AWS) to practice the online tutorial and become familiar with the containerized NWP system. Additional demonstrations and practice sessions were provided later in the workshop as well, including a focus on modifying and customizing the system. DTC invited two of the participants, Thomas Guinn from Embry Riddle

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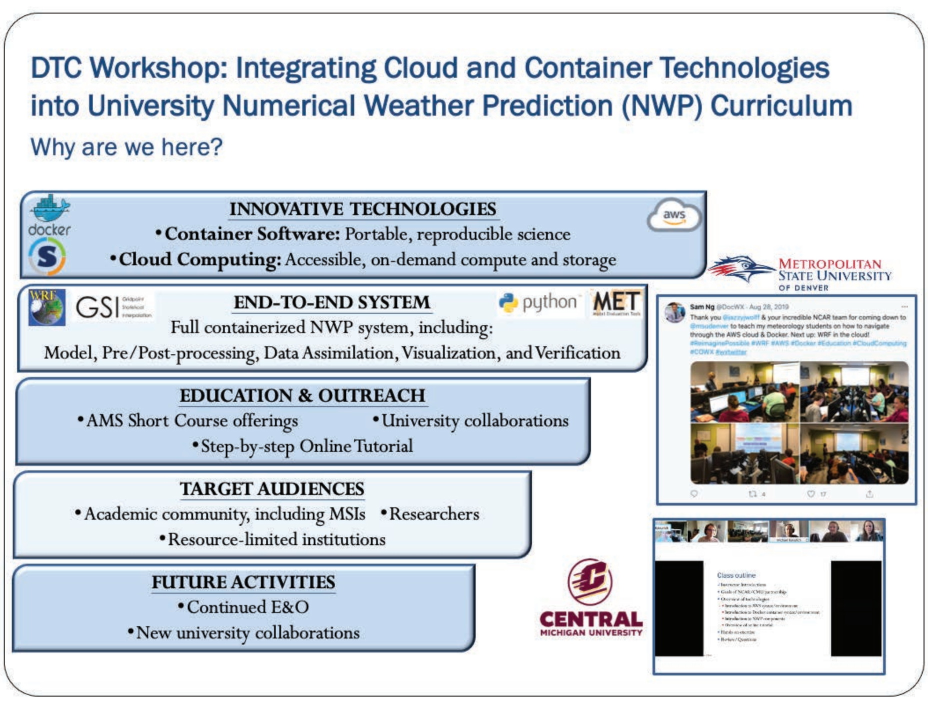


DTC Workshop Diagram

The Recap (Continued.)

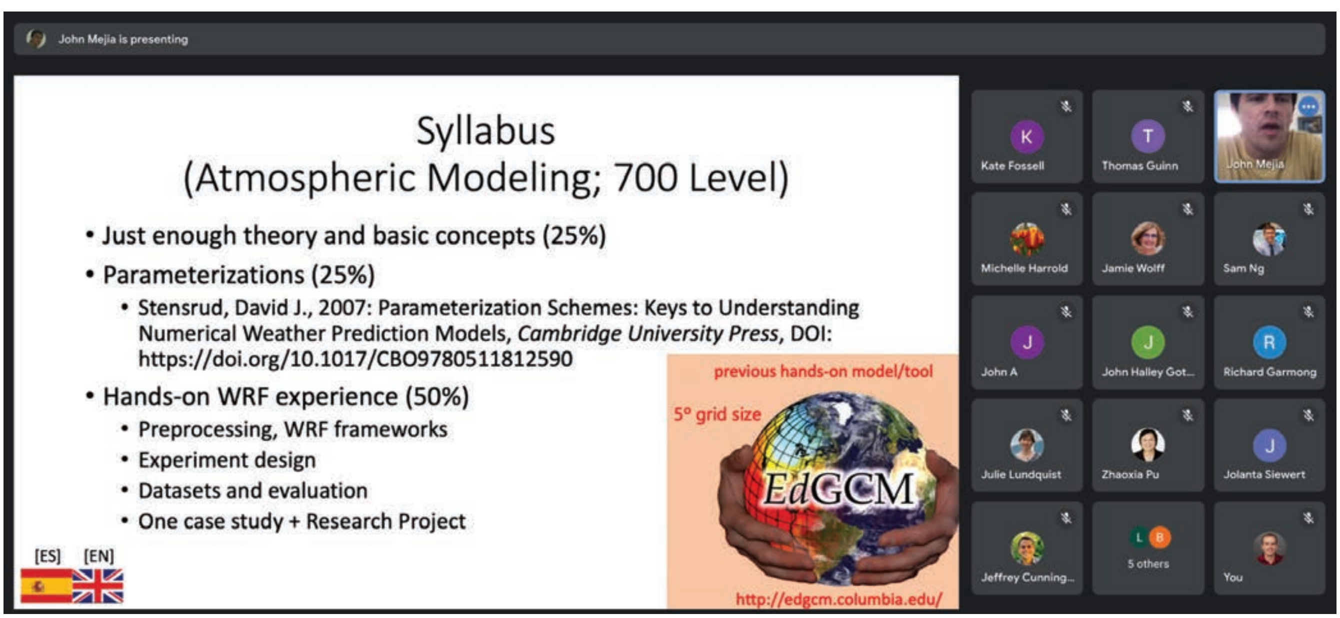
Aeronautical University and John Mejia from the Desert Research Institute, to share an overview of their current NWP coursework to set the stage for opportunities and challenges that exist in current curriculum approaches. Following these presentations, Sam Ng from Metropolitan State University - Denver and John Allen from Central Michigan University gave testimonial talks about their recent experience working with the DTC to incorporate the end-to-end containerized NWP system into their classes, which provided practical examples and experiences to seed further discussion. Additionally, a representative from AWS presented information on the AWS Academy as an opportunity for faculty to train in AWS resources.

At the core of the workshop were the breakout group discussions in which participants had the opportunity to think critically about the feasibility of using this content in their classes, share concerns or limitations, potential solutions, and pose questions to the DTC to consider for future improvements and enhancements. The feedback was quite positive and encouraging; overall, participants realized the benefit of containers and felt the integration into the classroom curriculum can foster excitement for NWP! Some of the specific takeaways and suggestions expressed were :

- Broad interest in using AWS or cloud computing for NWP components, imbuing students with new technical skills (e.g., cloud computing, containers) applicable to non-meteorology jobs as well;
- Need for more options to better align the detail of NWP components, containers, and cloud computing to the appropriate course level and skill sets;
- Desire to coordinate with the DTC to implement NWP containers in class curricula, including getting started with AWS and providing guest lectures;
- Requests for more tutorials, instructional videos, etc., as well as expand case types;
- Recognition of potential hurdles, including heterogeneity of operating systems (e.g. Mac, Linux, Windows) used by students and accompanying user instructions, spin-up time for instructors and students to learn about cloud computing and NWP, and costs associated with cloud computing;
- Excitement for containerized MET and METviewer for easier verification; and
- Interest in participating in an AMS or AGU education conference or short course

For anyone interested in learning more about this effort or potential collaboration, please reach out to Kate Fossell at fossell@ucar.edu. The DTC is looking to connect with interested parties to continue the conversations begun at the workshop and facilitate new collaborations. Those who express interest will be invited to a newly established Slack workspace. Workshop presentations are now available on the workshop website.

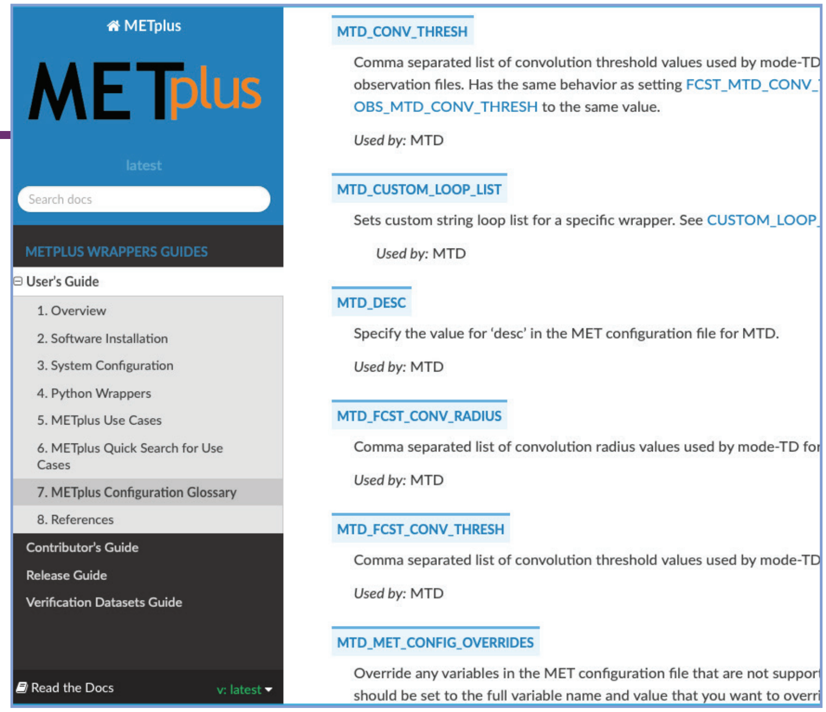
Contributed by Kate Fossell, with Michelle Harrold, Mike Kavulich, John Halley Gotway, and Jamie Wolff. ■



Syllabus 700 level course

BRIDGES TO OPERATIONS

METplus For Operational Verification And Diagnostics



METplus Online Documentation screenshot

The idea of including the enhanced Model Evaluation Tools (METplus) in NOAA operations for the verification and validation of Environmental Modeling Center (EMC)'s suite of environmental prediction models has been a decade in the making. METplus is the DTC-developed verification framework that spans a wide range of temporal (warn-on-forecast to climate) and spatial (storm to global) scales. It is intended to be extensible through additional capability developed by the community and the transition of this framework to NOAA's Weather and Climate Operational Supercomputing System (WCOSS) was a major accomplishment. This partnership project between DTC, NOAA's EMC, and the National Centers for Environmental Prediction (NCEP) Central Operations (NCO) is an on-going engagement. Through its development, METplus has become an integral part in the verification work of NOAA's modeling operations because of the robust software, suite of capabilities, ease of use and documentation, and the fact that METplus is continually evolving. METplus has made the desire to have reliable, consistent statistical output a reality and will help bolster the next generation of numerical models to higher forecast prediction accuracy. As a result of this hand-in-hand partnership and cooperation to build and test the latest versions of METplus, less time is needed by numerical weather prediction (NWP) model developers to assess how a NWP model can be improved. METplus has the statistical and graphical verification output they need to diagnose shortcomings efficiently and optimize NWP settings for the next generation of NWP models. METplus' output has been tested against real-time datasets from NOAA and compared to in-house calculations for precision and ease of use.

DTC, EMC, and NCO worked collaboratively and iteratively to install METplus-3.1 and MET-9.1 on the WCOSS developmental system to test and optimize the software between August 2020 and March 2021, with the goal of installing the METplus system into real-time operations once WCOSS2 is available to EMC scientists. METplus-4.0.0 is planned to be the foundation of the burgeoning EMC Verification System (EVS).

In April 2021, the software was officially installed into 24/7 operations at NCO on WCOSS (soon to be WCOSS2). This milestone will now allow EMC to run operational METplus verification tasks and continue to build METplus into real-time Unified Forecast System (UFS) applications. This represents a major achievement in the UFS Research to Operations to Research (R2O2R) paradigm, as verification metrics developed within the UFS community now have a direct pathway to operations.

One part of the change METplus brings as an operational companion to numerical weather forecasting is in its support and documentation. METplus is fully supported: METplus has a User's Guide for each of its components (with additional information available on the METplus Website). The documentation is continuously updated and refined as needed for operability and understanding. Configuration options and keywords can be easily searched in each guide, eliminating the need to bookmark a specific page for reference. With community support through a GitHub Discussions board, all documented user issues in METplus will receive the direct attention of the METplus scientists,engineers, and the METplus community at large. If an opportunity for enhancing METplus is brought forward from these help sources, a METplus team member will create a Github issue, allowing users to track the progress.

METplus is not only a component of NOAA's Unified Forecast System (UFS) cross-cutting infrastructure but will also be an evaluation and diagnostic capability for NCAR's System for Integrated Modeling of the Atmosphere (SIMA). METplus is actively being developed by NCAR/Research Applications Laboratory (RAL), NOAA Global Systems Laboratory (GSL), EMC, several US Department of Defense agencies and departments, and the Unified Modeling partners led by the Met Office of the United Kingdom. Finally, METplus is a community resource via the DTC and is open for community contributions to the transition of successful ideas from research to operations.

Contributed by Julie Prestopnik, John Opatz, and Tara Jensen. ■

DID YOU KNOW

UFS Short-Range Weather Training

The Developmental Testbed Center (DTC), in cooperation with Subject Matter Experts (SMEs) from NOAA's Environmental Modeling Center (EMC), National Severe Storms Laboratory (NSSL), and Geophysical Fluid Dynamics Laboratory (GFDL), will host a live, virtual training session for the Unified Forecast System (UFS) Short-Range Weather (SRW) Application from September 20-24, 2021. This training will focus on teaching community users how to set up and run the first officially released SRW Application for their own experiments. The SRW Application targets predictions of regional atmospheric behavior out to several days; more details on the first SRW App release can be found here.

Contributors: Jamie Wolff. ■

NEWS FROM THE DTC

Announcements, Events and More

UPCOMING WORKSHOP

20-24 Sept 2021 | UFS Short-Range Weather Training. See article above.

SOFTWARE RELEASES:

14 May 2021 | The DTC announced the release of the multi-component verification framework called the enhanced Model Evaluation Tools (METplus). METplus contains a suite of Python wrappers and ancillary scripts to enhance the user's ability to quickly set-up and run MET. METplus also has an analysis suite including METviewer and METexpress user interfaces and METdatadb, METcalcpy, and METplotpy as shared packages for loading and storing MET output as well as aggregating and plotting results.… Read more.

Sponsors

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