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UFS QUARTERLY

Bulletin of the UFS Community

The UFS Short-Range Weather App Release

Photo: Mike Coniglio - NOAA NSSL

IN THIS ISSUE

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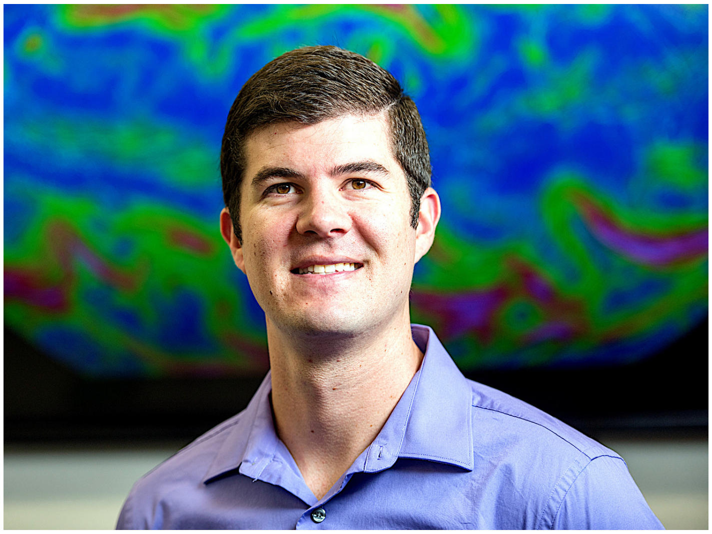
THE BRIGHT UFS FUTURE

By Victor Gensini

A New Chapter in Short-Range Extreme Weather Prediction



It would be an understatement to say that I'm excited about the future of short-range extreme weather prediction in the Unified Forecast System (UFS) framework. The release of the UFS short-range weather (SRW) application, adding a convection-allowing, limited area configuration to the UFS suite, marks a new chapter for predicting meso-γ weather phenomena. This is an important milestone, as most extreme weather phenomena remain below the horizontal grid spacing of the parent FV3 operational nest — and will likely stay that way for the near future.

The UFS SRW app was designed to permit FV3 to run in a limited area model framework at convection-allowing horizontal grid spacings, using modest computational resources. Most modern laptops would even be sufficient for many applications. That flexibility has opened the door for ours and other research groups to propose new ideas and techniques that can be used in NOAA's operational weather models. We became early academic adopters of the UFS framework for teaching and research and are grateful for this opportunity.

Perhaps the most appealing feature of the UFS framework is the community-driven, open-source nature of the suite. This is paramount for educational endeavors and allows students to seamlessly transition into future workflows that are transparent while developing coding skillsets that are highly relevant and in demand. Git-based open development repositories allow for better code management, making it simple for community members to contribute new code through pull requests. In addition, UFS-SRW community forum discussions are open and especially helpful for our group in identifying potential obstacles and solutions.

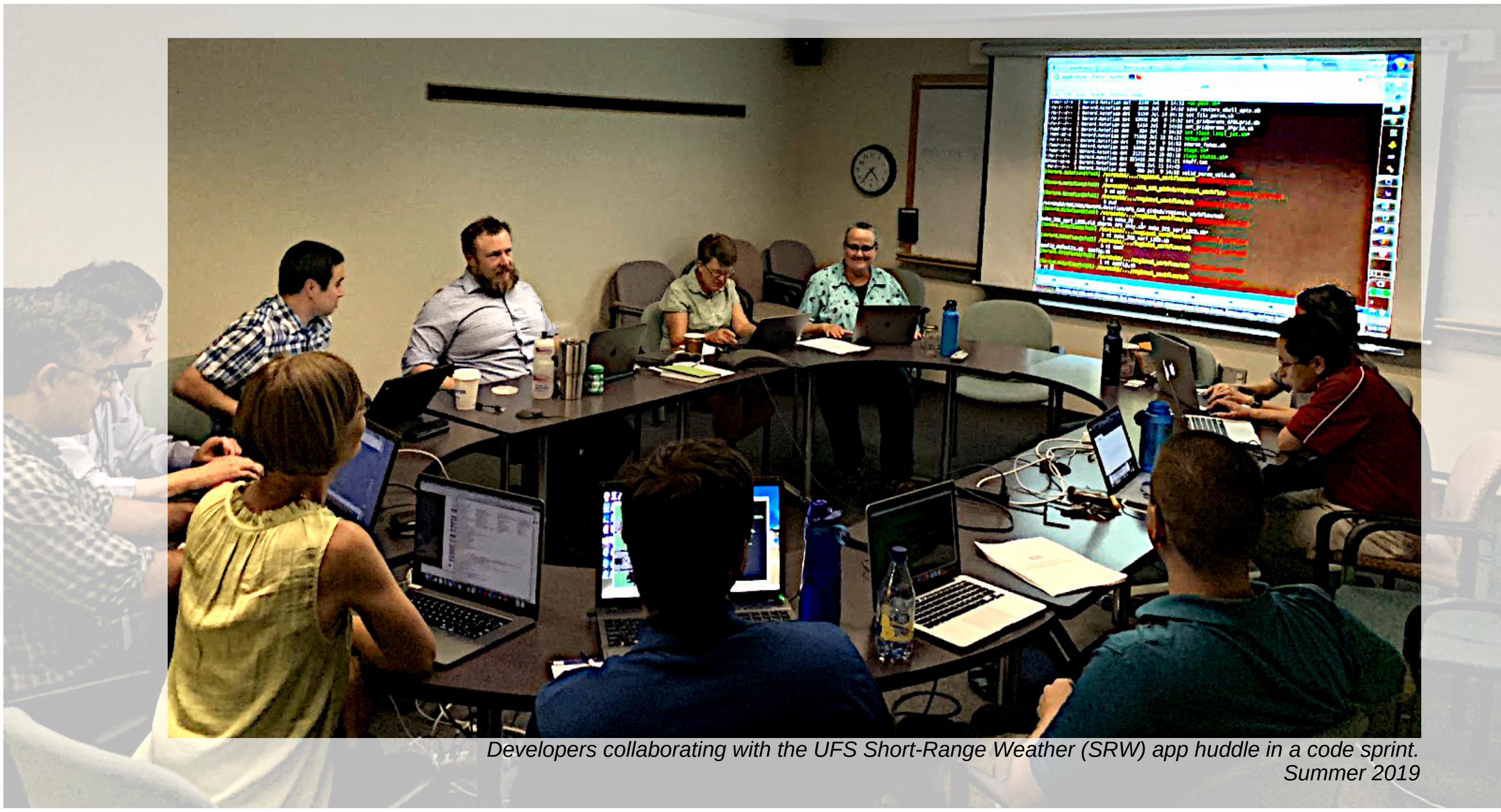
The bright future of extreme weather prediction using the UFS SRW app is just getting started. I like to think that we have a new, more computationally-efficient engine running the vehicle — the FV3 dynamical core. Our community is now tasked with tuning its suspension, brakes, and transmission — implementing properly-scaled parameterizations. We are excited to be contributing to the tuning of this new vehicle!

Dr. Victor Gensini is an Associate Professor at the Department of Geographic and Atmospheric Sciences, Northern Illinois University (NIU), and Deputy Director for NIU's Center for Research Computing and Data.

Editorial Board: *Jose-Henrique Alves, Susan Jasko, Curtis Alexander, Jeff Beck, Jacob Carley, Lauren Gaches, Jamie Wolff.*
Collaborators: *Victor Gensini, Chris Franks, Russell Schneider.*
We are thankful for the support from the UFS Steering Committee and the UFS Communications and Outreach Team.
Thank you, and forgive us if we forgot someone!

THE UFS SHORT-RANGE WEATHER APP

By Jamie Wolff and Jeff Beck



Developers collaborating with the UFS Short-Range Weather (SRW) app huddle in a code sprint. Summer 2019

Fostering Collaboration to Improve Near-Term Weather Prediction

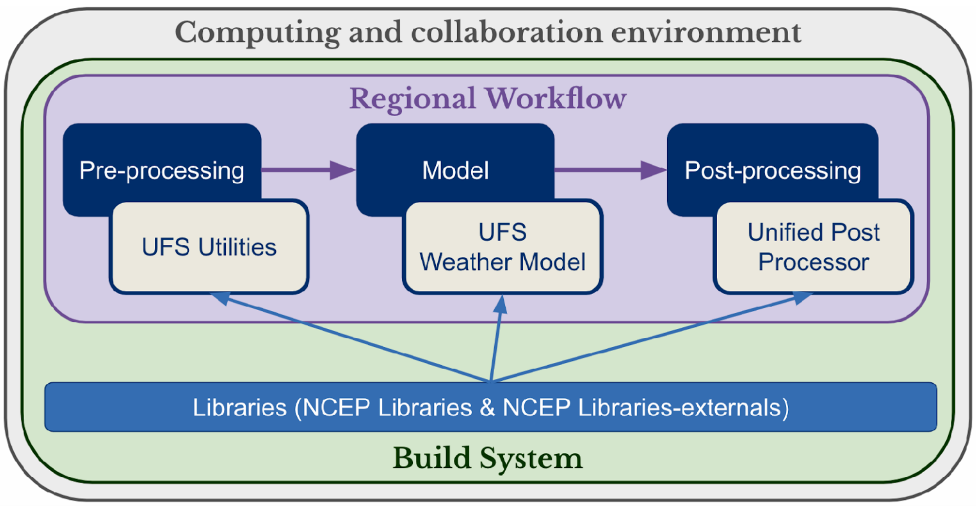
Weather impacts our daily lives, and accurate forecasts are critical to planning whether we can enjoy the outdoors or prepare for a major storm. However, hazardous events such as thunderstorms, blizzards, and floods present a challenge to our weather forecast models and ability to plan safely ahead. The Unified Forecast System (UFS) framework is shifting the balance in our favor towards improving the ability to predict such threatening events by accelerating Earth system model advancement. Taking a big step in that direction, the UFS Short-Range Weather (SRW) Application was released this week, targeting near-term forecasts critical to saving life and property.

The first public release of the SRW App results from a collaboration between several cooperative institutes and universities, the Developmental Testbed Center (DTC), and the National Oceanic and Atmospheric Administration (NOAA). The new UFS App is the foundation for building NOAA's future convection-allowing ensemble forecast system, known as the Rapid Refresh Forecast System (RRFS). It launches a new approach where a version of the code becomes publicly available several years before the operational implementation of the RRFS. This path allows for active engagement across the community, streamlining the transition of research innovations into NOAA's next-generation flagship high-resolution forecast system as the system matures.

In addition to being the modeling system for NOAA's operational forecasts on a day-to-day basis, the UFS is designed to support an active research program through a flexible framework. The SRW is one of seven application areas within the UFS that specifically targets near-term weather forecasts, spanning time frames from less than an hour out to several days. The driving force behind the formation of the UFS and the subsequent development of the SRW and other UFS Apps was feedback provided by the UCACN Model Advisory Committee (UMAC) in 2015.

The UMAC was composed of community members with a wide range of expertise across the weather enterprise, working together to provide a technical and strategic review of the major modeling components in the National Weather Service (NWS) operational suite. The Committee recommended a strategic evolution of those systems over the next 5-10 years, emphasizing collaborations with the academic community and private sector to support technology transfer based on research within or outside of NOAA. Ultimately, UMAC identified that the NOAA operational suite's unification was urgently needed to invite innovation and facilitate maintenance of the systems, improving and streamlining research to operations (R2O).

While it is critical to have this open access in place it is important to recognize that the needs of the research and operational communities are distinctly different. The research community needs flexible and simple tools that support basic research to promote advancement through innovations. Operations require software infrastructures that minimize performance impacts and failures. Reconciling requirements is made possible by a unified workflow established for the SRW App that can be used seamlessly in research or operational modes. The research community can now test code that will eventually become operational. As a result, scientists can focus research efforts that may ultimately be committed back to the authoritative code repositories to facilitate effective R2O.



Components of the UFS SRW Application

The SRW App will improve scientists' ability across the weather enterprise to contribute to the RRFS in ways that have never been done before for an operational convection-allowing model. This success results from using a streamlined model suite consolidated around a common dynamic core and workflow. The open-source nature of the UFS is being further strengthened by dynamics and physics development efforts supported by the UFS R2O Project and by new opportunities for collaboration across private, academic, and government sectors.

A fundamental aspect of the UFS that addressed the feedback from the UMAC was placing the code in open-access repositories through GitHub. In this collaborative development environment, the broader scientific community is enabled and encouraged to contribute to the future operational weather forecast system. The open development paradigm aggregates scientists who can help improve the system while not limiting these advancements to coming from only within NOAA. For example, the SRW App is engaging model developers and subject matter experts in model physics (particularly for convective-scale processes but more broadly across scales), data assimilation, ensemble design, verification, and process-level diagnostics. Such an effort, using collaborative code development, will help continually improve forecast accuracy.

As we continue to move into the UFS era, we are tapping into a yet unrealized wealth of scientific community knowledge. The goal is to enhance pathways between innovations and operations to accelerate model improvements. Ultimately, the success of the SRW App and the RRFS will be measured by their benefits to society through enhanced forecast guidance, leading to better decision-making and protection of the country.

Jamie Wolff is an Associate Scientist at NCAR's Research Applications Lab (RAL)
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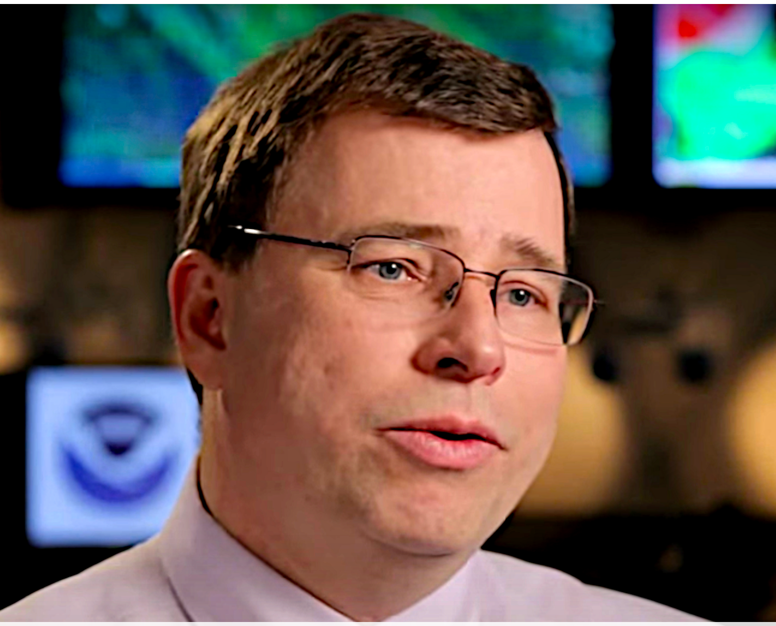


"The ultimate goal is to extend predictive capabilities to finer scales and better forecast the range of potential severe-storm outcomes for every endangered community."

UFS PEOPLE

RUSSELL SCHNEIDER

Dr. Russell Schneider has served as Director of the NOAA-NWS Storm Prediction Center since August 2010, and led the Center through the historic 2011 tornado season. The Storm Prediction Center is responsible for protection of life and property through official 24x7 nationwide forecasts and warnings for hazardous mesoscale weather phenomena including tornadoes, severe thunderstorms and wildfires. His passion for understanding weather comes from a series tornado outbreaks that devastated communities in the Chicago area during his childhood. "Many school children of similar age to me were killed when their school buses were destroyed by a violent tornado," remembers Russ. The experience directed his career aspirations towards atmospheric sciences, and a successful tenure leading NOAA's Storm Prediction Center. Russ earned a B.S., M.S., and Ph.D. in Atmospheric Sciences from the University of Wisconsin at Madison. In 2007, he received a Department of Commerce Bronze Medal for contributions to U.S. weather services, and in 2011, the American Meteorological Society Kenneth C. Spengler Award for bringing diverse communities together within the collaborative environment of NOAA's Hazardous Weather Testbed.

C&O: *What does the UFS Short-Range Weather app release mean for your work at NOAA's Storm Prediction Center (SPC)?*

Russ: The SRW app is helping advance operational numerical modeling forecasting on scales that more accurately represent individual thunderstorms. That is essential to providing communities and families the forewarning they need to make effective decisions in advance of potentially deadly storms. They are also fundamental to advance our operational high-resolution forecast systems skill during severe storms, supporting a Weather-Ready Nation.

C&O: *How do you see the inclusion of convection-allowing models in the UFS will transform NOAA's forecasting capabilities, fostering cultural change toward a community-modeling paradigm?*

Russ: The promise of numerical modeling at these scales has been an active area of research within our community since the late 1970's. Fundamental advances toward a Weather-Ready Nation require the realization of this potential in our operational high-resolution forecast systems for a wide variety of extreme events including severe thunderstorms and tornadoes. Many of the advances in convection-allowing numerical weather prediction have been galvanized by the now twenty-year series of Spring forecast experiments within the NOAA Hazardous Weather Testbed (HWT) in Norman, Oklahoma. These collaborations, led by SPC and OAR National Severe Storms Laboratory have involved scientists from the Environmental Modeling Center, Global Systems Laboratory, National Center for Atmospheric Research, and diverse university and government partners from around the Nation and the world. These experiments forged a dynamic learning community focused on key scientific and societal challenges, collaborating to understand and forecast more effectively severe storms.

C&O: *You've said the SPC use of CAMs has helped develop an effective approach to transition innovations to operations. Can you explain?*

Russ: The SPC focuses on specialized post-processing of uniquely tailored CAM NWP output into probabilistic forecast information, which is combined with national forecast expertise to support effective societal decision-making prior to extreme weather events. Within the broader collaborations organized by the HWT, experiments span a wide range of readiness levels (RLs), from basic research supported by NSF grants, through applied NOAA research, and its ultimate transition into forecast information and tools within NWS Severe Weather Operations led nationally from the SPC. Within these experiments, SPC national severe weather forecast experts are active participants and share their real-time practical insights into the strengths, weaknesses, and operational utility of the next generation CAM NWP guidance directly with developers and researchers. We also work extensively within the UFS community to develop objective metrics that effectively describe the attributes that next-generation NWP must improve to advance severe storm forecasting. This has effectively provided a path for transitioning innovations to operations.

C&O: *What are the implications of the SRW app release to the establishment of the Earth Prediction Innovation Center (EPIC)?*

Russ: I believe it is an important step to further strengthening the virtuous cycle between the research community and our next generation operational forecast services. Many of the scientific modeling advances over the past decade have been realized in a mixture of WRF, ARP, and EMC modeling systems. This diversity in dynamic cores has slowly evolved into a focus on the FV3-based UFS core application. Supporting broader community adoption of a NOAA-supported central code set, will support quicker integration of research modeling advances into NOAA operational forecast improvements.

C&O: *How do you see the evolution of operational short-range weather prediction at NOAA, and what will be the benefits of that to society?*

Russ: Some of these benefits have already been realized with our first generations of operational deterministic and ensemble CAM forecast systems. There is an enormous potential benefit to society from further improving these systems by including advances such as data assimilation at the storm scale, including radar information to better initialize ongoing convective systems. The ultimate goal is to extend predictive capabilities to finer scales and better forecast the range of potential severe-storm outcomes, including their relative likelihood, using ensemble forecast systems from days in advance, through hours, and ultimately minutes prior to all severe weather events, for every endangered community.

April 2011 set a record for the most tornadoes observed in the U.S. during a calendar month. NOAA's SPC provided outlooks predicting the major tornado outbreaks up to five days in advance, helping attenuate the loss of life and property. The outbreak struck the southeastern U.S on April 27th, causing $11 billion in damages, leaving an estimated 321 people dead, and 2,753 injured. After visiting impacted families, President Barack Obama met SPC staff, NWS forecast officers, broadcasters, and emergency managers to support their work. In tandem with high-resolution ensembles, UFS convection-allowing capabilities will help improve the predictability of severe storms, helping attenuate risks to endangered communities.

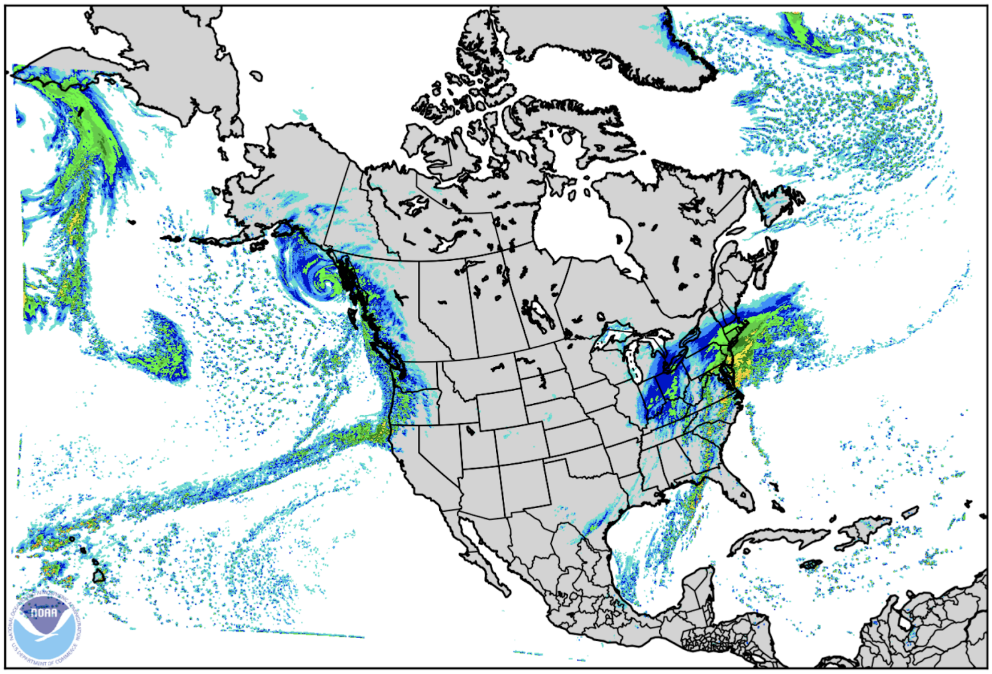
President Obama shakes hands with Russ Schneider after visiting families affected by the 2011 tornado outbreak

SHORT-RANGE WEATHER IN OPERATIONS

By Curtis Alexander and Jacob Carley

Unifying Convection Allowing Models to Improve Short-Range Weather Prediction

The UFS Short-Range Weather App is the first release of a limited area, convection-allowing model capability in the UFS framework. The release is a significant milestone in the early life of the UFS, underpinning the future high-resolution operational weather prediction system of the United States, known as the Rapid Refresh Forecast System (RRFS).



Simulated composite radar reflectivity from a prototype RRFS forecast

The next-generation RRFS is a Convection-Allowing Model (CAM) that will facilitate the retirement of all existing operational CAMs in NOAA's National Centers for Environmental Prediction (NCEP) production suite. It follows the unification footsteps of NCEP's Global Ensemble Forecast System (GEFSv12) and those planned for the Global Forecast System (GFSv16), paving the way for further unification of NOAA's weather forecast system in the 2023-2024 timeframe. While the present suite of CAMs in operations serves a critical role, it has grown quite complex.

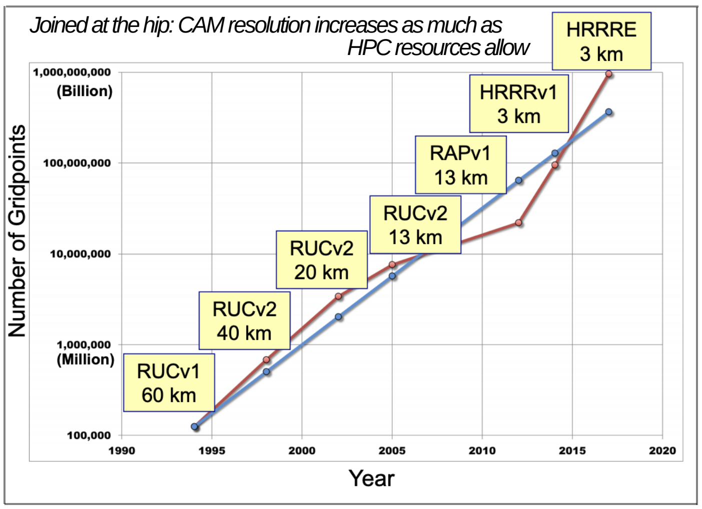
The SRW App release and the subsequent unification of CAMs are major accomplishments that bring the modeling community together, focusing on the same system rather than a handful. The unification should lead to significant improvements across the board in the RRFS over the years, extending beyond its first version. Expected improvements include measurable skill impacts and all the societal benefits one would associate with improved, high-resolution forecasts: severe weather, rainfall, winter weather, renewable energy applications, and aviation forecasting, to name a few.

The RRFS will feature a convective-scale, hybrid ensemble-variational data assimilation system with hourly updates and ensemble forecasts every hour, with longer extensions 2-4 times per day. The domain will also be expanded considerably, transitioning from location-specific regions of high resolution to a North American domain with uniform 3-km grid spacing. In 2005, when NCEP introduced the first CAMs into NOAA's operational forecasting suite, such a configuration was a distant dream with only 7.8 teraFLOPS available on our supercomputers (see more in the Whats, Whys, and Hows of CAMs section below).

A bit over fifteen years and 12.1 petaFLOPS later, the RRFS is on its way to becoming a reality. It is a possibility enabled by a growing commitment to community development and the UFS alongside significant advances in high-performance computing. This combination provides a foundation to implement innovative science to fulfill the NWS operational mission to protect lives and property.

Whats, Whys, and Hows of CAMs

Convection-Allowing Models are numerical weather prediction systems run at a sufficiently fine resolution to allow for convective processes, i.e., thunderstorms, to be simulated explicitly. In practice, this typically refers to models with grid-spacing of 3-4 km and finer. At such resolutions, the bulk properties of many hazardous convective weather systems can be captured, including features such as rotating updrafts in supercells. Such a capability allows us to better forecast weather conditions in which such hazardous storms may occur. As a result, CAMs have been a critical component of the forecaster toolkit in the severe weather community for well over a decade.



CAM systems are most often employed in a regional or limited area modeling framework. Such a framework is advantageous as it allows a modeler to run over a local area without the expense or complication typically associated with running over the entire globe at CAM resolution. While some solutions do exist under the context of variable resolution or nesting methods - they still require the maintenance of a global modeling framework. When one is only concerned with short-range forecasts, a limited area modeling approach has been preferred for decades.

CAM applications are also those that feature rapid updates with very low-latency. Global modeling systems typically operate with more latency, on the order of a couple hours or more, to assimilate as much late-arriving observational data as possible to provide the best initial conditions for medium range weather forecasts. Therefore, these systems can't be combined without introducing a prohibitive amount of latency for the CAM application or reducing the number of observations ingested into the global model. Hence, a need for limited area applications persists.

The first CAMs became operational at NCEP in 2005, with around 5.5 km grid-spacing over small regions covering ⅓ CONUS and limited vertical resolution. This grid-spacing was too coarse by today's standards. Still, it was a necessary compromise to make these CAMs fit on our high-performance computing system, which then had a theoretical peak capacity of 7.8 teraFLOPS.

Further complicating matters, operational CAM runs would occasionally be preempted if tropical storms were present, requiring instead running a hurricane model. Simply put, computer resources were not available to run both. Despite these compromises, it was clear that CAMs could provide realistic depictions of convective storms — and improved forecasts in complex terrain and coasts, where resolving topographic details is necessary.

As our compute capacity has increased over the years, so has the spatial coverage, resolution, and sophistication of operational CAMs. Today, the North American Mesoscale forecast system (NAM) has 3 km nests and an on-demand 1.5 km nest. In December 2020, version 4 of the High-Resolution Rapid Refresh (HRRR) became operational. Notably, HRRRv4 includes the first ensemble-based data assimilation system at the convective-scale, reflecting the synthesis of years of collaborative research-to-operations efforts.

Forecasts from these systems with additional CAM forecasts are combined as members of the current High-Resolution Ensemble Forecast system (HREF). What began as a handful of experimental efforts in the early 2000s has resulted in the maturation of several operational CAM systems regularly used by the forecast community.

Thanks to the UFS community effort, the plethora of CAMs in operations will be replaced by a single convective-allowing, high-resolution ensemble system. The RRFS starts a new chapter in short-range extreme weather prediction — the opening statement is the UFS SRW App release.

***Curtis Alexander** is Chief of the Assimilation and Verification Innovation Division at NOAA's Global Systems Lab (GSL)*
***Jacob Carley** is RRFS Project Lead at NOAA/NCEP's Environmental Modeling Center (EMC) and Physical Scientist with EMC's Data Assimilation and Quality Control Group*

THE UFS GRADUATE STUDENT TEST

By Chris Franks and Jose-Henrique Alves

Coding to Inspire a New Generation of Earth Scientists

Are you the type of person that likes to take on challenges and find creative solutions to conquer them? We think you are! Consider this your official invitation to begin working with the UFS and become a contributor. We are inviting you to take our Graduate Student Test (GST).

The GST was introduced as a way to measure the usability of the UFS code. It has become a gauge on how successful we are at engaging the broader community in the UFS development process. Its name borrows from the idea that a student or graduate-level professional should be able to quickly get, change and run UFS code, test it for correct operation, and use standard diagnostic packages to evaluate results.

Since the first GST was published in 2019, we've inspired not only graduate students, but scientists of all ages, professors, undergraduate and high-school students, who have all provided great feedback about the usability of our codes. More than that, their experiences returned great stories about taking on challenges and solving problems.

As part of the Short-Range Weather (SRW) App release, we are publishing a GST that will take the challenge of running the UFS to a new level. Participants in the SRW GST will be asked to run a high-resolution version of the UFS (a 3km limited-area nest), using boundary conditions from two alternative sets of operational model runs. In addition, GST takers will be able to compare results from two physics packages, one of them more forward-looking towards the next-gen convective-allowing system that will become operational in 2023-2024 timeframe.

We think you have what it takes to get involved and help us ensure that UFS materials and processes are clear and understandable for everyone who wants to work with the UFS code.

Visit the UFS Community GST page to register!