Upcoming UFS Release: Description of the Short-Range Weather Application

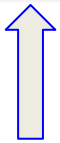
Jeff Beck[1,3,7], Jamie Wolff[2,3], Curtis Alexander[1], Jacob Carley[4], Todd Arbetter[2,3], Laurie Carson[2,3], Mike Kavulich[2,3], Gerard Ketefian[1,3,6], Larissa Reames[5,8], Dom Heinzeller[1,3,6], Julie Schramm[2,3], and Lou Wicker[5]

[1]NOAA/GSL, [2]NCAR, [3]DTC, [4]NOAA/EMC, [5]NOAA/NSSL, [6]CIRES, [7]CIRA, [8]CIMMS

UFS MRW Training, November 06, 2020

UFS Applications

	Atm	Land	Ocean	Sea Ice	Aerosol	Ionosphere	Storm Surge	Wave
Medium-Range Weather	1	0						0
S2S	0	0	0	0	0			
Hurricane	0	0	0					0
Short-Range Weather	0	0						
Space Weather	0	0				0		
Coastal							0	0
Air Quality	0	0			0			



UFS Applications

- Applications are UFS configurations that support particular forecast requirements
- Each application can combine a numerical model, data assimilation, pre- and post-processing, a workflow, and other elements

SRW App: Covers short-range weather/convection-allowing atmospheric phenomena from less than an hour to several days

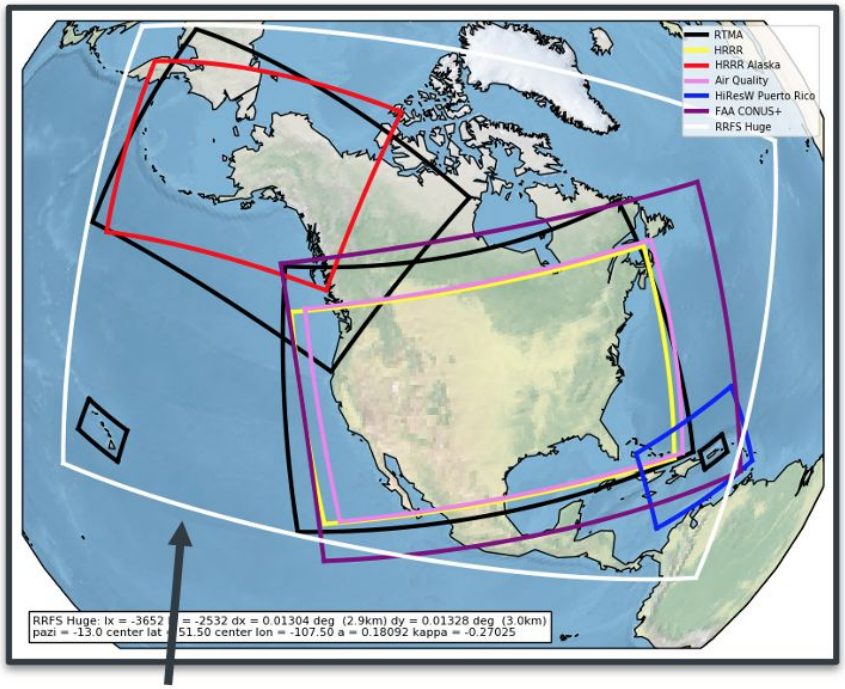
Transition of Regional Systems to FV3 Core

- Transitions planned to SRW App/FV3 dycore for all regional CAM/near-CAM deterministic and ensemble applications (SREF, GEFS, HREF, NAM, RAP, HRRR)
- Goal is to design a CAM-scale ensemble DA and prediction system based on the FV3-Local Area Model (LAM) called the Rapid-Refresh Forecast System (RRFS)
- Target operational implementation: FY23

NPS Modeling System	Current Version	Q3 FY 20	Q4 FY 20	Q1 FY 21	Q2 FY 21	Q3FY21 - Q2FY22 MORATORIUM	Q3 FY 22	Q4 FY 22	Q1 FY 23	Q2 FY 23	Q3 FY 23	Q4 FY 23	Q1 FY 24	Q2 FY 24	Q3 FY 24	Q4 FY 24	UFS Application
Global Weather & Global Analysis	GFS/ GDASv15				GFSv16									GFSv17/ GEFSv13			UFS Medium Range & Sub-Seasonal
Global Waves	GWMv3																
Global Weather Ensembles	GEFSv11		GEFSv12														
Global Wave Ensembles	GWESv3																
Global Aerosols	NGAC v2																
Short-Range Regional Ensembles	SREFv7																
Global Ocean & Sea-Ice	RTOFSv1.2			RTOFSv2					RTOFSv3								UFS Marine & Cryosphere
Global Ocean Analysis	GODASv2								GODASv3								
Seasonal Climate	CDAS/CFSv2															SFSv1	UFS Seasonal
Regional Hurricane 1	HWRFv12		HWRFv13				HAFSv1				HAFSv2				HAFSv3		UFS Hurricane
Regional Hurricane 2	HMONv2	HMONv3															
Regional High Resolution CAM 1	HiRes Window v7			HIRESWv8						RRFSv1	RRFSv2			RRFSv2			UFS Short-Range Regional HiRes CAM & Regional Air Quality
Regional High Resolution CAM 2	NAM nests/ Fire Wxv4																
Regional High Resolution CAM 3	RAPv4/ HRRRv3			RAPv5/ HRRRv4													
Regional HiRes CAM Ensemble	HREFv2			HREFv3													
Regional Mesoscale Weather	NAMv4																
Regional Air Quality	CMAQv5						CMAQv6										
Regional Surface Weather Analysis	RTMA/ URMA v2.7		RTMA/ URMA v2.8								3DRTMA/ URMAv3						
Atmospheric Transport & Dispersion	HySPLITv7						HySPLITv8								HySPLITv9		UFS Air Quality & Dispersion
Coastal & Regional Waves	NWPSv1.2			NWPS v1.3			NWPS v1.4						RWPSv1				UFS Coastal
Great Lakes	GLWUv3.4						GLWUv4								GLWUv5		UFS Lakes
Regional Hydrology	NWMv2			NWMv3							NWMv4						UFS Hydrology
Space Weather 1	WAM/IPEv1															WAMv2	UFS Space Weather
Space Weather 2	ENLILv1																

Rapid Refresh Forecast System (RRFS)

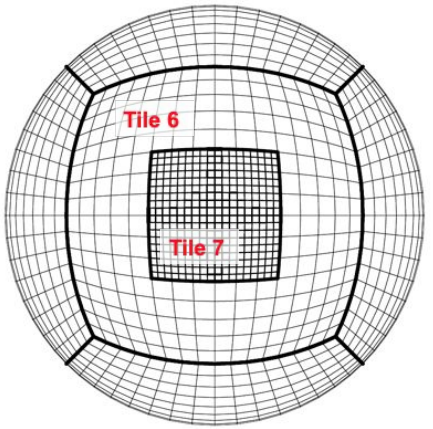
- Based on the FV3-LAM
- Rapidly updated
- Convection-allowing (~3 km)
- Ensemble data assimilation (RRDAS? with JEDI, est. 30 or 40 members)
- Ensemble forecasts (est. 10 members)
  - 18h+ hourly
  - 60h every 6 to 12 hours



3 km RRFS domain (notional)

A Limited Area Model Capability: Background Information

- FV3 Cubed-Sphere (Global Configuration)
  - Uses a gnomonic projection where great circles serve as model coordinates
  - Global coverage consists of six tiles
  - Offers grid uniformity (widest cell only √2 wider than narrowest), but only for standard six-tile global setup
  - Provides refinement through Schmidt transformation and nesting, but requires execution of a global domain
- New Limited Area Model (LAM) capability
  - Leveraged the nesting capability (tile seven) in the FV3 to act as a regional domain, and removed tiles 1-5
  - Incorporates necessary modifications to FV3 code to include a halo around tile seven in which LBCs are transferred to the regional domain
  - Tile six is discarded and all calculations are made on the regional domain with the halo
  - Still allows for Schmidt stretching of the gnomonic grid for flexible domain sizes



UFS Short-Range Weather (SRW) Application

- Model
  - Finite-Volume Cubed-Sphere Dynamical Core (FV3)
    - Limited Area Model (LAM) capability
  - Common Community Physics Package (CCPP)
- End-to-end workflow
  - Pre-processing, model execution, post-processing
  - Support for the ROCOTO workflow manager or stand-alone scripts
- Documentation
- User support forum
  - https://forums.ufscommunity.org/

Target release date: 7 December 2020

Release Teams

- Leads: J. Beck (NOAA/GSL/DTC), J. Wolff (NCAR/DTC), J. Carley (NOAA/EMC), C. Alexander (NOAA/GSL/DTC)
- Participation: DTC, NOAA (GFDL, EMC, GSL, NSSL, GLERL), NCAR, CIRA/CIRES/CIMMS
- Focus teams
  - Model code (lead: Jeff Beck/Laurie Carson)
  - Pre-processing (lead: Larissa Reames)
  - Build system (lead: Mike Kavulich)
  - Workflow (lead: Jeff Beck)
  - Testing (lead: Dom Heinzeller)
  - Documentation (lead: Jamie Wolff)
  - Support Forum (lead: Jamie Wolff)
- Graduate Student Test: Defined by the UFS Release Team and distributed by the UFS Communications and Outreach Working Group

Release Goals

- The SRW Application (version 1.0) will include a prognostic atmospheric model, pre- and post-processing, and a community workflow for running the end-to-end system
  - The inclusion of data assimilation and a verification package (METplus) will follow in future releases
- The aim of the release is to introduce the atmospheric limited area version of the UFS to the broader scientific community, with the following features:
  - Ports easily to multiple platforms
  - Allows users to run experiments with a user-friendly workflow
  - Contains detailed documentation of the entire system
  - Provides support through forums

Platform Support

Level 1: Preconfigured platforms
- Prerequisites and libraries installed
- Workflow & model build/run out of the box
- Comprehensive testing before release

- NCAR Cheyenne (Intel & GNU)
- NOAA Hera, Jet, WCOSS Cray and Dell (Intel)
- MSU Orion (Intel)

Level 2: Configurable platforms
- Prerequisites and libraries expected to install
- Workflow and model expected to build/run
- Comprehensive testing before release

- Odin (Intel)
- TACC Stampede (Intel)

Level 3: Limited-test platforms
- Prerequisites and libraries expected to install
- Workflow and model should build and run
- Limited testing

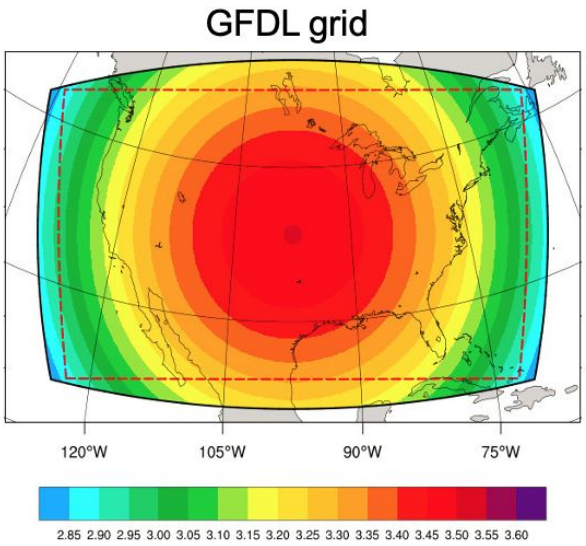
- macOS
- Ubuntu
- RedHat

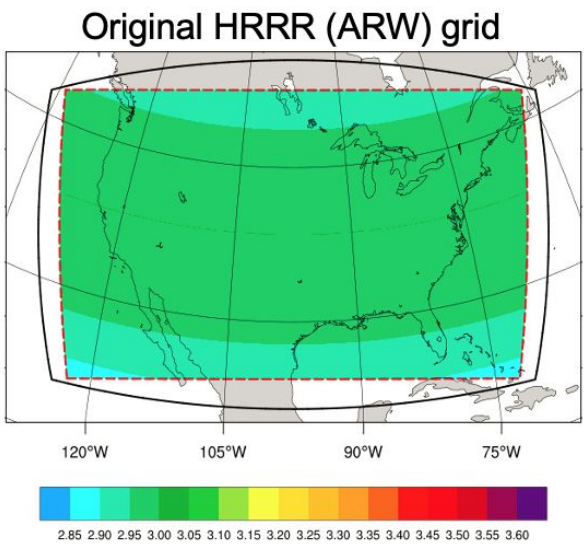
Level 4: Build-only platforms
- Prerequisites and libraries expected to install
- Workflow and model should build
- Very limited tests of running the model

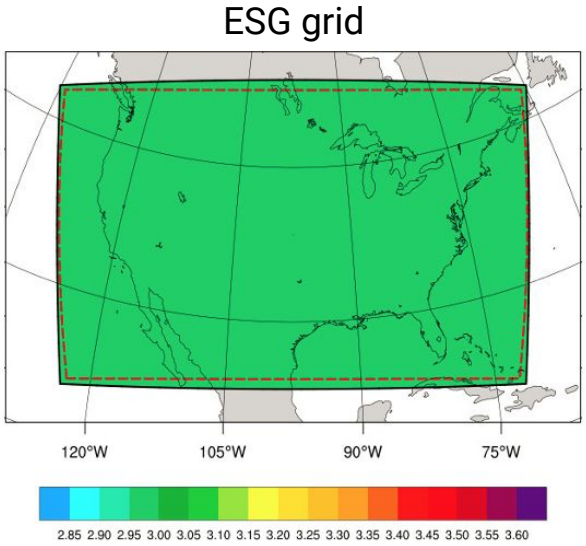
- All generic platforms with GNU
- Pre-configured AMIs on AWS

Domains and Resolutions

- 3-km, 13-km and 25-km predefined Contiguous U.S. (CONUS) domain
- New, highly uniform Extended Schmidt Gnomonic grid
- Preliminary tools for users to define their own domain will also be included in the release but not fully supported (use at your own risk!)







Physics

- **Two supported configurations through CCPP**

	GFS_v15p2	RRFS_v1beta
Microphysics	GFDL	Thompson-Eidhammer
PBL	K-EDMF	MYNN
Surface Layer	GFS	MYNN
Deep Convection	SAS	-
Shallow Convection	SAS	-
Radiation	RRTMG	RRTMG
Gravity Wave Drag	uGWP	GFS GWD
Land Surface	Noah	Noah-MP
Ozone	NRL 2015	NRL 2015
H2O	NRL	NRL

Build System

- User-friendly build system that invokes CMake
  - Standardized platform-dependent set of environment variables and modules used to build all repositories, then sourced at run time by the workflow
- Linux and Mac operating systems are supported
- Options exist between Intel and GNU compilers
- **Prerequisite Libraries**
  - Straight-forward to build all software libraries required by the model, pre-processing, and post-processing utilities (mainly relies on NCEPLIBS)
  - Libraries are already installed on preconfigured platforms

Pre-Processing Utilities

- regional_esg_grid or make_hgrid, orog, filter_topo, and shave
  - Generates the initial ESG or GFDL grid based on a user-defined namelist, orography from fixed files, then filters the topography based on resolution, and shaves the excess halo rows down to what is required for the LBCs
- sfc_climo
  - Creates climatology fields from fixed files for use in chgres_cube
  - Fields include: max snow albedo, snowfree albedo, vegetation greenness, vegetation type, substrate temperature, slope type, and soil type
- chgres_cube
  - Reads in raw external model (global or regional) and sfc_climo data to create initial conditions for the UFS Weather Model
  - IC/LBCs from: GFS, NAM, RAP, and HRRR

Post-Processing - UPP

- Converts model output on the native model grid (in netCDF format) to standard isobaric coordinates (in GRIB2 format)
  - For the SRW App, write component netCDF files (phyf*.nc and dynf*.nc) are generated based on a user-defined projection, not the direct gnomonic output of FV3
- Calculates additional diagnostic fields that are not part of model output
- Allows customization of the fields in the output files
  - An option has been added to the community workflow which allows users to specify their own flat file for use with UPP

End-to-end SRW App System Overview

- Build and compile
  - Umbrella CMake-based build system for all the code components to run the end-to-end regional workflow
- Create an experiment
  - Many customization options available
  - Script then builds configuration/namelists
- End-to-end execution with task management using Rocoto workflow or stand-alone scripts
  - Pre-processing
  - Model execution
  - Post-processing with the Unified Post Processor
- Python scripts for basic graphics from UPP grib2 files

Community/Operational Workflow Merger

- Originally, two FV3-LAM workflows were being developed in parallel at GSL/DTC and EMC
- Community, collaborative efforts are fundamental to advancement of the UFS and the RRFS
- Code sprint in Summer of 2019
  - Participants from DTC, EMC, GSL, and NSSL
  - Defined requirements to incorporate EMC/NCO standards into the community workflow
- Created a single, flexible, expandable experiment and workflow generation tool that can be used in both operational and research environments
  - Either the community or NCO configuration can be invoked at workflow generation time

SRW App Workflow

- The **config.sh** file represents a single location where the user sets all applicable variables/settings for their experiment
  - Templates (to copy/modify) are provided for different configurations
- Once all settings are defined, the user runs the **generate_FV3LAM_wflow.sh** script to produce the work directory and the Rocoto workflow XML file (the user can also run the stand-alone scripts at this time too)
  - Error checking is conducted to ensure user-defined variables have valid values and requirements are met for FV3 grid decomposition
- The workflow allows users the option to stage external model data and skip grid/orog/sfc_climo steps (or only run it once), so it can be implemented in retrospective or real-time environments

SRW App Workflow Tasks

Run once per expt (optional)

1. **`make_grid`**: Generates grid files
2. **`make_orog`**: Generates filtered orography files
3. **`make_sfc_climo`**: Generates surface climatology files (used if fields are not available in external model output)

Run once for each cycle

4. **`get_extrn_ics`**: Retrieves output files from the external model needed for generating ICs, surface fields, and the 0-th hour LBC
5. **`get_extrn_lbcs`**: Retrieves output files from the extrenal model, needed for generating LBCs
6. **`make_ics`**: Creates ICs on the native FV3-LAM grid (including surface fields and the 0-th hour LBC)
7. **`make_lbcs`**: Creates LBCs for each boundary condition interval on the FV3-LAM grid
8. **`run_fcst`**: Runs a forecast (cycle) with the FV3-LAM
9. **`run_post`**: Processes write-component forecast output files through UPP to generate grib2 files

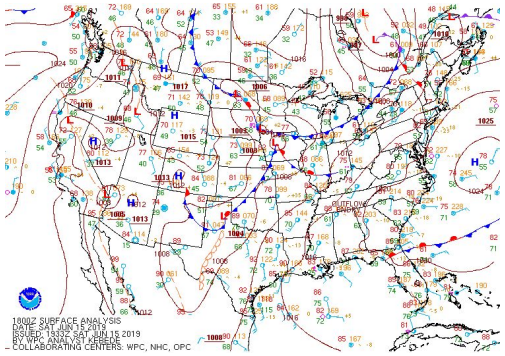
Graduate Student Test (GST)

Similar to the MRW Application, a GST is being established for the SRW App. The GST is considered a measure of success for each release by illustrating code availability and development processes to the broader community.

Assesses whether a student can do the following (easily) in under six hours:

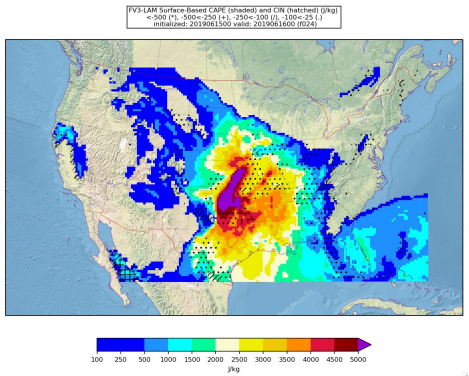
- Get, build, run, and change code, test code for correct operation
- Evaluate code with standard diagnostic packages
- Locate documentation, user support, and training

You don't have to be a graduate student to take the GST!



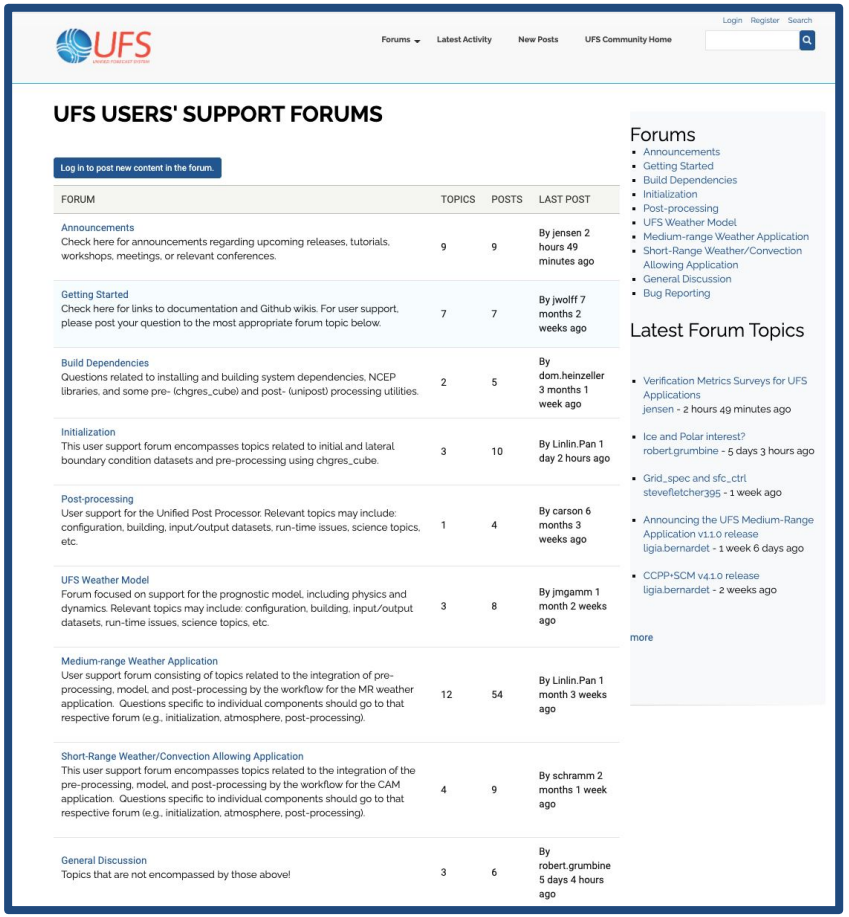
Short-Range Weather App GST

- Includes a severe weather example case (15 June 2019) as a default, plus allows the user to change the physics suite and resolution in multiple iterations
- Visually compare a number of output fields through use of Python scripts
- Fill out a questionnaire about the experience
- Coming soon: Get involved! Register!



User Support

- Documentation
  - All components included:
    - SRW App, UFS weather model, UFS utilities, FV3, CCPP, UPP
    - Will be available within the repos and online
- Python GRIB2 scripts
  - Plot GRIB2 output for 15 standard fields for any of the three pre-defined domains
  - Plot difference graphics between two separate experiments
- Forums
  - https://forums.ufscommunity.org
  - Participation from SMEs
  - Build knowledge within the community



App Code Repositories

Repository Description	Authoritative repository URL
Umbrella for the UFS SRW Weather App	https://github.com/ufs-community/ufs-srweather-app
Umbrella for the UFS Weather Model	https://github.com/ufs-community/ufs-weather-model
Regional Workflow	https://github.com/NOAA-EMC/regional_workflow
Libraries	https://github.com/NOAA-EMC/NCEPLIBS https://github.com/NOAA-EMC/NCEPLIBS-external
UFS Utilities	https://github.com/NOAA-EMC/UFS_UTILS
Unified Post Processor	https://github.com/NOAA-EMC/EMC_post

All components are in public repositories on GitHub
Posting of issues and submission of pull requests encouraged

Wiki pages on GitHub include helpful/getting started information

Join the UFS Community

- Conduct scientific research by running the code and analyzing output, resulting in feedback to the UFS community (via Forum etc.), presentations, or publications
- Report bugs - via Forum
- Ask and answer questions in the Forum
- Take the Graduate Student Test
- Participate in NOAA Notice of Funding Opportunities
- Participate in the DTC Visitor Program
- Read the UFS Newsletter and the DTC Newsletter
- Attend the annual UFS Users Workshop
- Develop code in one or more components (open issues/PRs)

Looking Forward

- Continued development of different UFS applications
- In addition to the SRW App, future releases of applications and capabilities are being planned as they reach mature levels of development. These include:
  - S2S App
  - Hurricane App
  - Coupled modeling capability (ocean, sea ice, and waves)
  - Data assimilation and verification capability