AMS Town Hall: Jan 12, 2023

NOAA Unified Forecast System (UFS) Research to Operation (R2O) Project

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UFS R2O Project Leads

NOAA's Unified Forecast System Research to Operations Project (confex.com)

Panelists

NWS Remarks

Dr. Stephen Smith
NOAA/NWS/OSTI
Director

OAR Remarks

Dr. Dorothy Koch
NOAA/OAR/WPO
Director

Program Overview

Mr. Kevin Garrett
NOAA/NWS/OSTI
Modeling Program Director

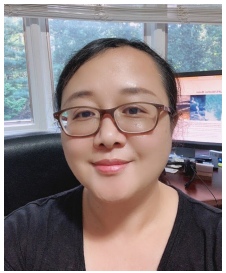
Dr. Jim Kinter
George Mason University
COLA Director

Dr. Vijay Tallapragada
NOAA/NWS/EMC
Senior Scientist

Dr. Jeff Whitaker
NOAA/OAR/PSL
Model and DA
Chief

Technical Overview

Dr. Yan Xue
NOAA/NWS/OSTI
Program Manager



Dr. Maoyi Huang
NOAA/OAR/WPO
EPIC Program
Program Manager

Engaging with UFS-R2O

UFS-R2O Project Overview

https://vlab.noaa.gov/web/ufs-r2o

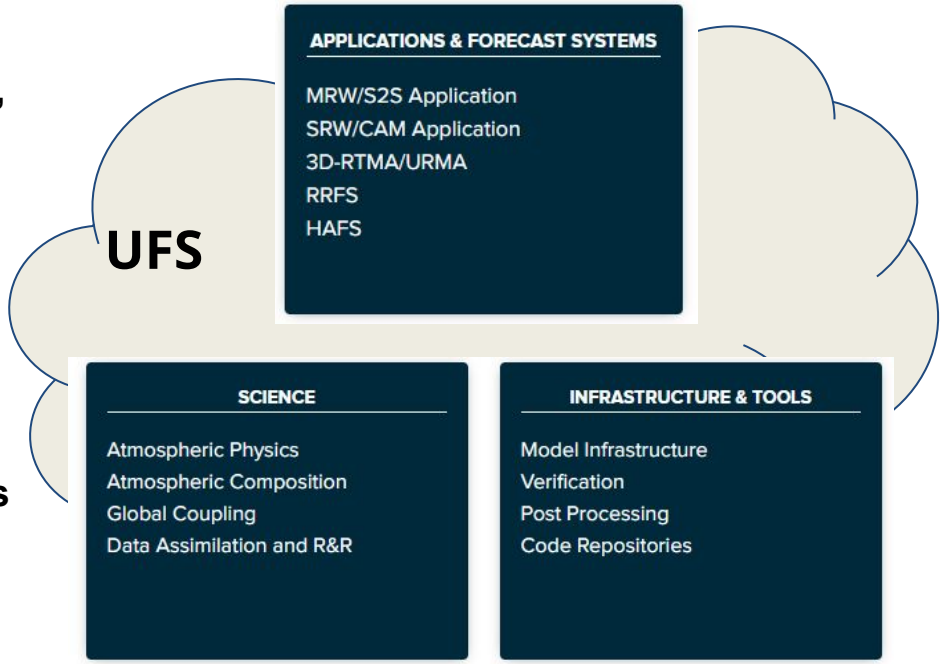
Kevin Garrett

Director, NOAA/NWS/OSTI Modeling Program

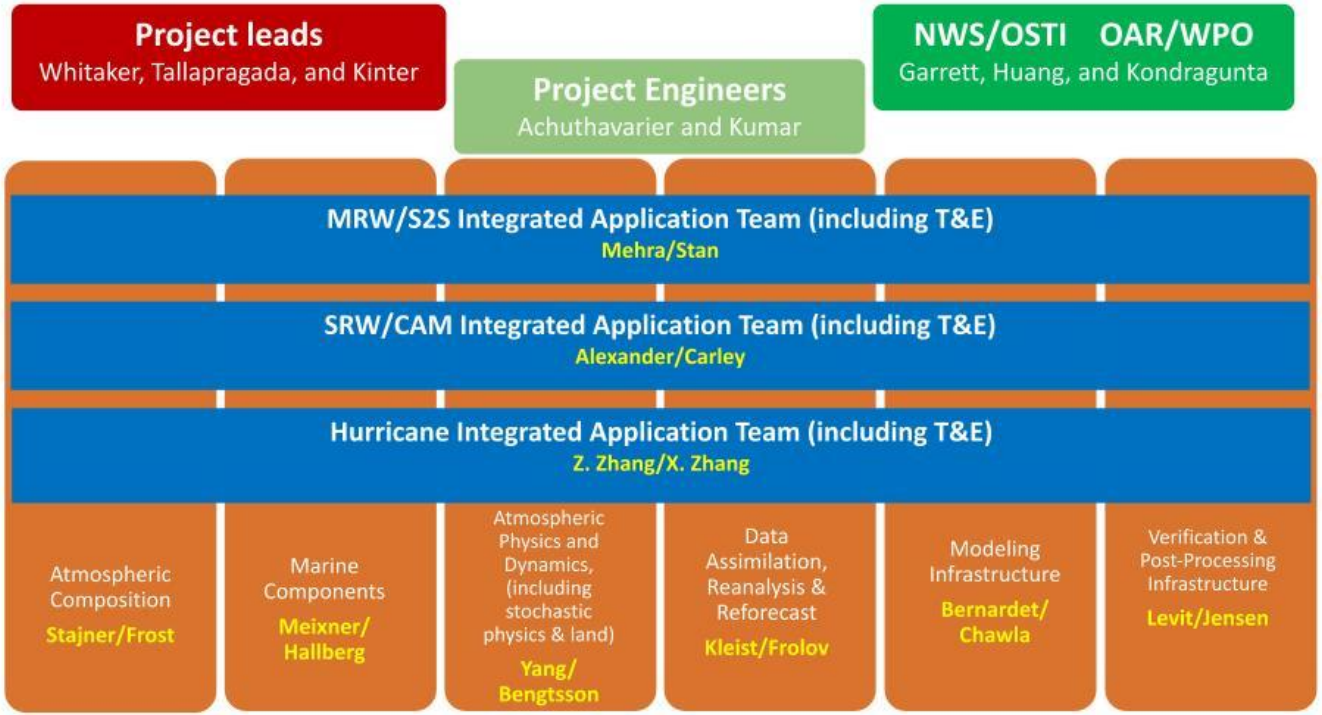
What is the *UFS-R2O* project?

UFS R2O

- **Formal kickoff in 2020**
- **Transition UFS applications, components, and infrastructure into NWS operations (integrated, fully-coupled Earth system model)**
- **Direct partnerships with UFS community members and Earth Prediction Innovation Center (EPIC)**
- **Focus on high readiness-level capabilities**
- **Co-managed by NWS/Office of Science and Technology Integration and OAR/Weather Program Office**



UFS-R2O Project Structure



Interfaces to UFS Working Groups

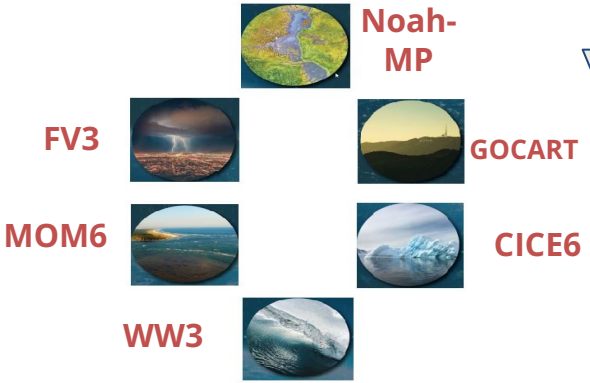
Application Teams

Cross-Cutting Teams

Focus and Accomplishments

UFS R2O

Medium-range Weather/S2S



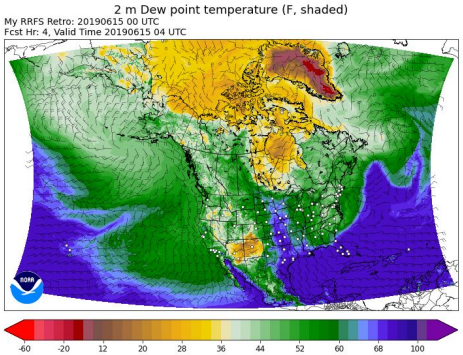
Global (Ensemble) Forecast System

- 6-way weakly coupled model
  - w/aerosol via CCPP
- 1-deg ocean reanalysis
  - JEDI
- GEFS R&R, online coupled DA
- GFSv17/GEFSv13 T2O (Q4FY24)

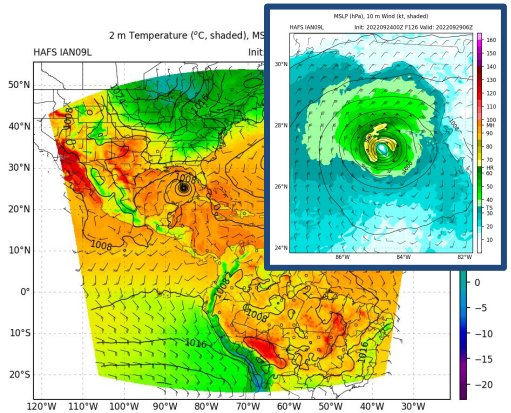
Short-range Weather

Rapid Refresh Forecast System

- FV3-LAM T2O (2021)
- RRFS port to cloud
- HWT Spring Experiment
  - Evaluation
- RRFS improvements
- RRFS v1 T2O (Q2 FY24)
  - *Retire HRRR, HiResWs, NAM Nests, HREF*



Hurricane



Hurricane Analysis and Forecast System

- HAFS v0.3 Configurations
  - Physics/Coupling/DA/Nests
- HAFS Real-time parallels
  - Product dissemination
- HAFS Retrospective
  - Evaluation
- ***HAFS v1 T2O (June 2023)***
  - *Retire HWRF/HMON*

Current Project Planning

UFS R2O

- Phase II of the project starting Q3 FY23 (through 2026)
- Support multiple transitions for HAFS, RRFS, 3D-RTMA, GFS, GEFS
- Prioritize activities supporting transition of externally funded projects (Disaster suppl., JTTI, NOFOs)
- Ensure transition of capabilities that address forecasters feedback

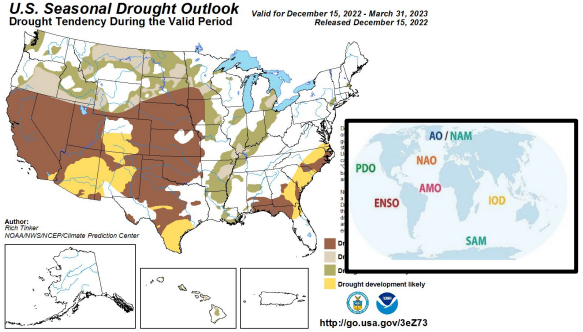
Issue / request	Description of the issue / request	MRW/S 2S AT	SRW/C AM AT	Hurr. AT	Atm. Comp. CCT	Atm. Phy. Dyn. CCT	DA & RR CCT	Infra. CCT	Veri. & PP CCT	Marin e CCT
CAPE issues	GFS had a long-standing low bias for CAPE that was made worse with GFSv15. Initial struggles seemed to be tied to weak lapse rates aloft; v15 introduced a late-day warm-season low-level cool, dry bias that seemed to worsen the low CAPE bias. GFSv16 over-mixes the PBL in the warm season (seemingly tied to dry soil), making the low bias even worse. Low CAPE does not appear to affect frequency of convection (resolved or parameterized)	☑	☐	☐	☐	☑	☐	☐	☐	☐
Extreme heat index episodes	Extreme heat/heat index episodes underforecast by GFS in medium range.	☑	☐	☐	☐	☑	☐	☐	☐	☐
Extreme heat index episodes	CAMs tend to be too cool in extreme western heat events, connected to the challenges of representing terrain-driven circulations and the marine layer	☐	☑	☐	☐	☑	☐	☐	☐	☐
Visibility, ceiling, clouds and fog	Prediction of onset and lifting of fog and low cloud cover associated with shallow cold air masses is a challenge. FV3 models have very little fog and low cloud cover.	☐	☐	☐	☐	☐	☐	☐	☐	☐
Visibility, ceiling, clouds and fog	Ceilings in CAMs (especially HRRR) during precip events drop too low. Cloud information in CAMs is too binary; need more prediction of BKN and SCT cloud cover; CAMs predict too much IFR along the west coast in summer. CAMs can struggle to varying degrees with retaining shallow, cloudy airmasses	☐	☑	☐	☑	☑	☐	☐	☐	☐
Temperature on complex terrain	Downslopes warming and/or drying often not captured well in global models (high RH bias)	☑	☐	☐	☐	☐	☐	☐	☐	☐
Temperature on complex terrain	CAMs struggle to generate and maintain convectively-induced cold pools of the proper magnitude and spatial extent - these features are critical to storm evolution.	☐	☑	☐	☐	☑	☐	☐	☐	☐

Alignment of UFS-R2O project scope to forecasters' needs

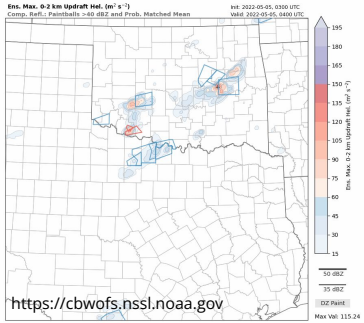
Emerging Opportunities

UFS R2O

Accelerate development of a Seasonal Forecast System

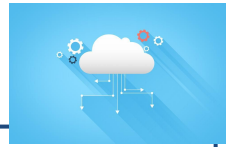


Warn-on-Forecast System



Value-added

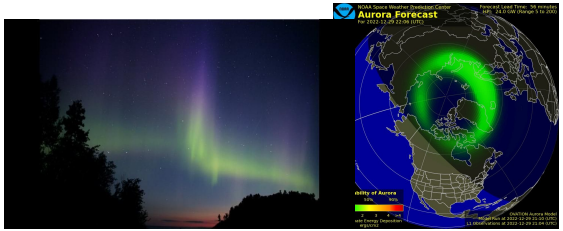
METplus



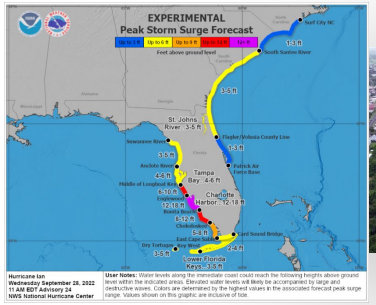
EPIC

- Coupled DA
- Cloud
- AI/ML
- O2R/efficiency
- Evaluation/ verification

Space Weather



Coastal and Surge Modeling



UFS-R2O Technical Overview

https://vlab.noaa.gov/web/ufs-r2o

Project Leads

Jim Kinter, Vijay Tallapragada, Jeff Whitaker

Technical Approach/Guiding Principles

UFS R2O

- **Evidence-driven development motivated by forecast (stakeholder) priorities and guided by scientific requirements**
- **Coordinated development of shared modelling and data assimilation infrastructure and algorithms (across Earth prediction enterprise)**
- **Open source, community accessible code with agile development**
- **Prototyping and testing (unit, regression, and scientific tests)**
- **Continuous evaluation of results**

MRW/S2S Application Team Scope

MRW/S2S -- Medium-Range Weather / Subseasonal to Seasonal

Three Applications with Global Coupled Models:

- **Global Forecast System (GFSv17)**: deterministic medium-range forecast guidance for up to 2 weeks lead-time
- **Global Ensemble Forecast System (GEFSv13)**: probabilistic sub-seasonal forecast guidance up to 6 weeks
- **Seasonal Forecast System (SFSv1)**: probabilistic seasonal forecast guidance up to 1 year

Coupled UFS Prototypes 1–8

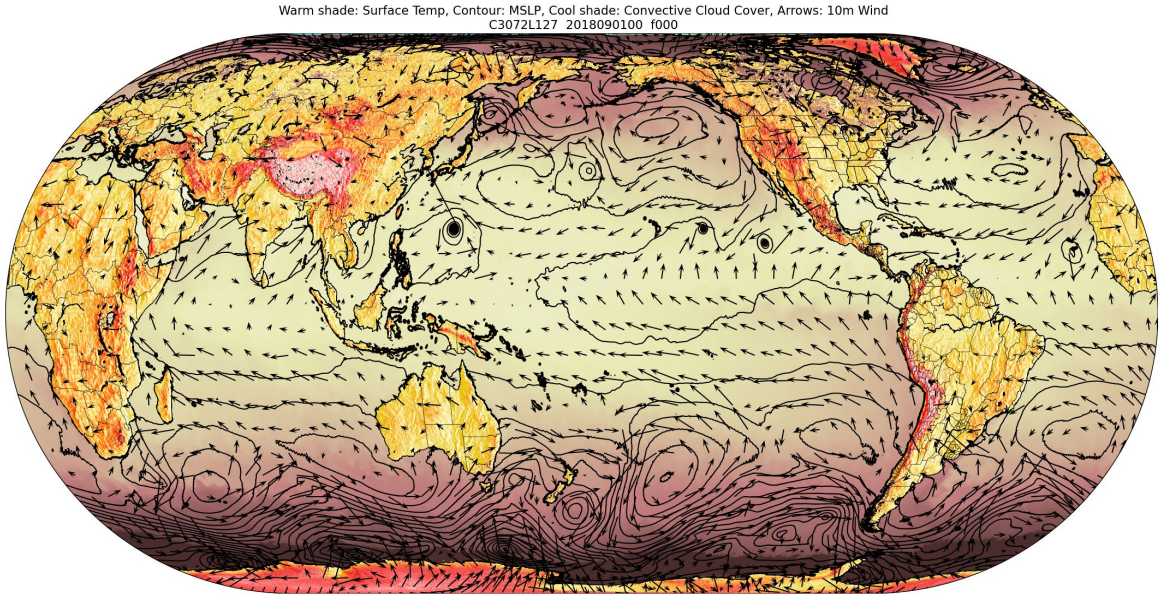
UFS R2O

Prototype	Atmospheric Model C384 (~0.25 degree) horizontal resolution			Ocean Model Tripolar ~0.25 degree horizontal resolution	Wave Model Regular lat/lon 0.5 degree grid	Ice Model Tripolar ~0.25 degree horizontal resolution	Mediator
	Dynamical Model	Physics Settings & Driver	Land Model				
P1	FV3 64 layers, Non-Fractional grid (model top at 54km)	GFSv15.2, IPD driver	Noah LSM	MOM6	N/A	CICE5	NEMS
P2							
P3.1							
P4		GFSv15.2, CCPP driver			WW3		
P5						CICE6 (Mushy TD not turned on)	CMEPS
P6	FV3 127 layers, Fractional grid (model top at 80km)	GFSv16					
P7		Modified GFSv16	Noah-MP LSM			CICE6 (Mushy TD turned on)	
P8		Further Modified GFSv16	Modified Noah-MP LSM				

(P8+ includes one-way coupled aerosols)

A Six-Way Global Coupled Unified Forecast System (UFS) -- a first for NOAA/NWS

UFS R2O



UFS Earth System Model Components:

- FV3 (Atmosphere)
- MOM6 (Ocean)
- CICE6 (Sea Ice)
- WW3 (Waves)
- NOAH-MP (Land)
- GOCART (Aerosols)

A fully coupled UFS serves as a foundation for future operational global forecast systems at NOAA/NWS/NCEP ranging from weather to subseasonal to seasonal scales.

Animation Courtesy:
S. Moorthi and Keqin Wu, NWS/NCEP/EMC

Planned GFSv17 Implementation

GFSv17 Configuration:

- 5-way coupled system: C768L127 or C1152L127 Atmospheric Model, ¼ degree MOM6 with 75 levels, unstructured grids for WW3, CICE6, and Noah-MP
- Physics upgrades: sa*-TKE-EDMF PBL; Noah-MP* LSM w/ VIIRS veg type, modified surface layer; sa-convection; Thompson MP*; UGWD; MERRA2 Aerosol Climatology, IMS-NIC Ice fields;
- 3-year full resolution retrospectives prior to operational implementation

GDASv17 Configuration:

- Ensemble perturbation generation using JEDI G-LETKF
- JEDI UFO
- Scale-dependent localization
- Additional obs: NOAA20 OMOS-NP; NOAA21 VIIRS, OMPS-NP, OMPS-TC, ATMS, CrIS; MetopC GOME, GOES-18 AMVs/ABI, Himawari AHI/AMVs, Sentinel-6, Metop 2nd Gen, Meteosat 3rd Gen, GMI, saildrones etc.
- Marine JEDI (SOCA)
- Land DA using JEDI
- JEDI-3DVar-FGAT for Aerosol DA

* "sa" = scale-aware
"Noah-MP" = Noah multi-physics
"Thompson MP" = Thompson microphysics

Planned GEFSv13 Implementation

GEFSv13 Ensemble Configuration:

- 6-way coupled system: C384L127 Atmospheric Model, ¼ degree MOM6 with 75 levels, unstructured grids for WW3, CICE6, Noah-MP and GOCART*
- Stochastic physics in atmos, ocean and land
- Perturbations in initial conditions
- 31-member* ensemble out to 35 days+
- Weakly coupled DA
- 3-year full resolution retrospectives prior to operational implementation

- *Possible to increase ensemble size
- +Possible extension of forecast length to 48 days
- ****Coupling to aerosols (GOCART) is done only for one member of GEFSv13***

Reanalysis (Replay) & Reforecast:

- CPC/OWP requires 30-year reforecast data (1991-2022) for calibration and validation
- Reforecast will be initialized by a replay of UFS to ERA5 atmos. and ORAS5 ocean, CPC sea ice analysis, Noah-MP spin up, snow DA
- Every Monday and Thursday, 35 days, 11 ensemble members
- Every day, 16 days, 6 members
- To ensure a smooth transition from reforecast to operation, a test dataset of reforecasts initialized by the replay will be run and used to assess its similarity with reforecasts initialized from a prototype pre-operational weakly coupled ensemble DA system.

Hurricane Application Team Scope

HAFS -- Hurricane Analysis and Forecast System

To create more accurate high-resolution forecast guidance for tropical cyclones across the globe.

Hurricane Integrated Application Team goals:

- Develop Hurricane Analysis and Forecast System (HAFS) based on UFS
- Finalize two configurations for implementation to replace operational HWRF and HMON in FY23

SRW/CAM Application Team Scope

SRW/CAM -- Short-Range Weather / Convection Allowing Modeling

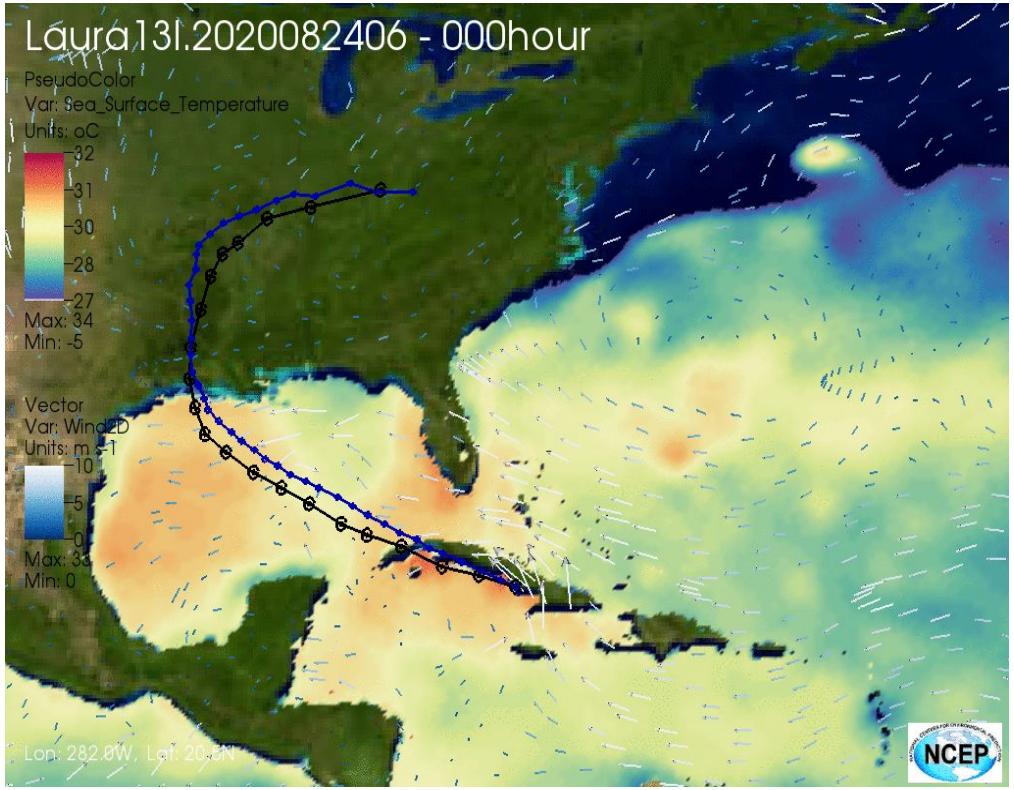
To create more accurate high-resolution forecast guidance using applications that span the regional domains (CONUS and OCONUS) and time scales from about nowcasting to about three days.

SRW/CAM encompasses three applications

- **3-Dimensional Real Time Mesoscale Analysis (3DRTMA)**
  - 15-minute 2.5-to 1.25 km analysis system
- **Rapid Refresh Forecast System (RRFS)**
  - Based on the FV3-Limited Area Model (LAM)*, Rapidly updated, Convection-allowing (~3 km), Hybrid EnVar assimilation (~ 36 mem), Ensemble forecasts (~9 mem), Stochastic and multiphysics suite, 18h+ hourly, 60h every 6 hours
- **Warn on Forecast System (WoFS)**
  - 18 member forecasts provide probabilistic output; 6-hr fcsts every 30 min (available@T+30 min); Will nest **inside** the RRFS ensemble

Hurricane Analysis and Forecast System

UFS R2O

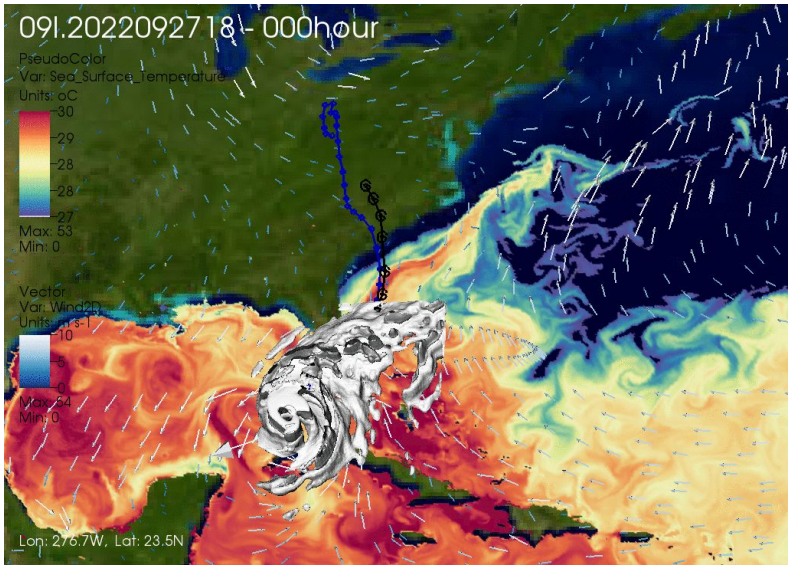


HAFS Development Objectives

- Use cloud resolving resolutions within nests (static, telescopic and moving) and coupled domains
- Improve physics schemes by using observations to enhance the accuracy of coupled simulation of physical processes for TC's
- Advance inner-core and satellite DA algorithms for TCs; ingest new observations and adopt advanced DA algorithms

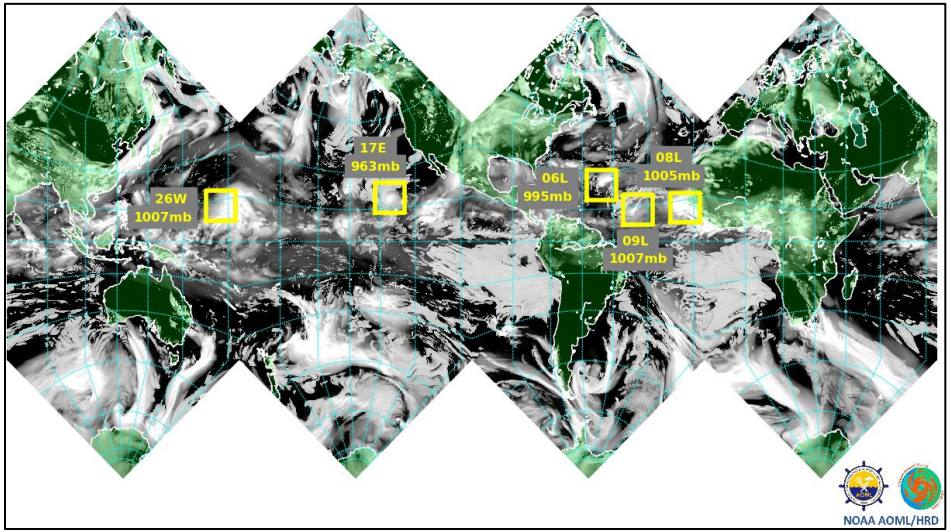
Future Evolution of HAFS Configurations

UFS R2O



Current: HAFS single storm-centric configuration targeted for operational implementation in FY23

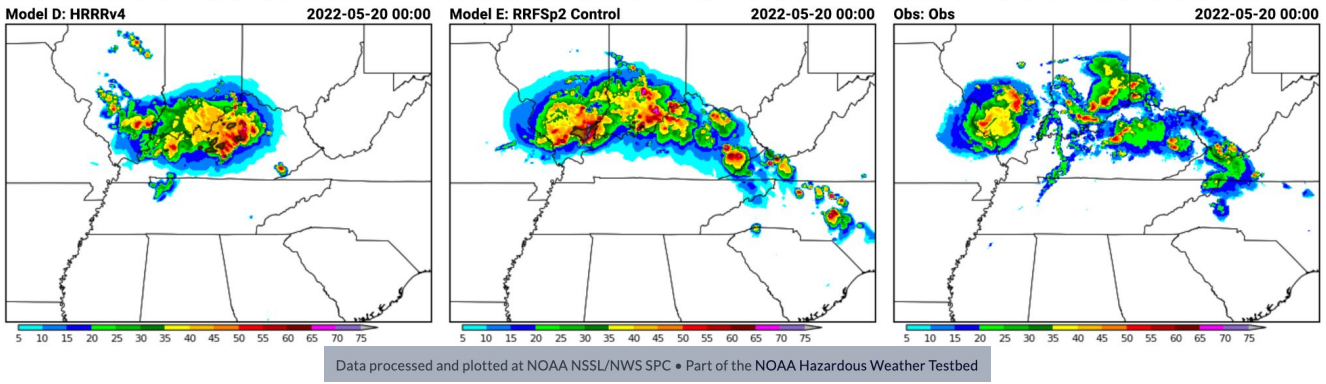
Future: Merged GFS-HAFS with multiple moving high resolution nests following multiple storms embedded in a global domain



CAM/SRW Application Team

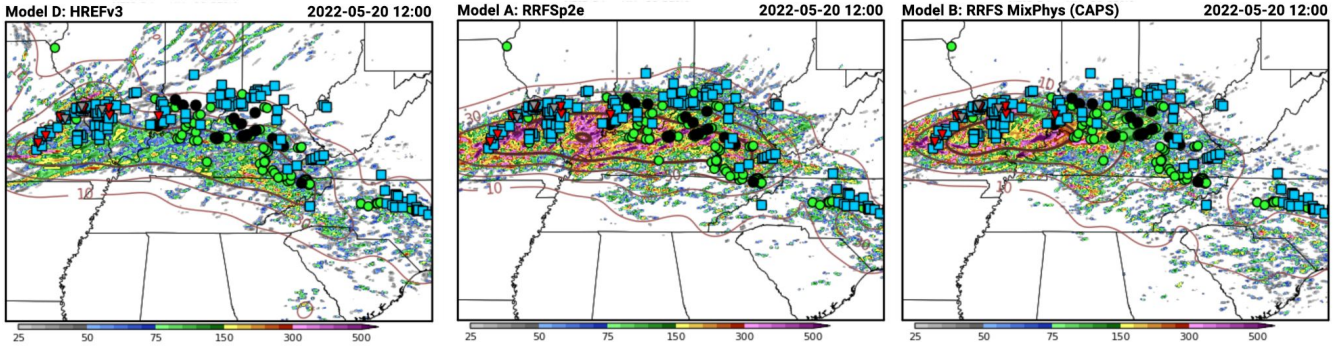
UFS R2O

Hazardous Weather Testbed Spring Forecast Experiment Demonstration
19 May 2022 RRFS Prototype Deterministic and Ensemble Forecasts



24 hr Deterministic Reflectivity Forecasts
Valid 00 UTC 20 May 2022

HRRRv4 Operational Baseline (left)
RRFSp2 Experimental Prototype (center)
MRMS Truth Observations (right)

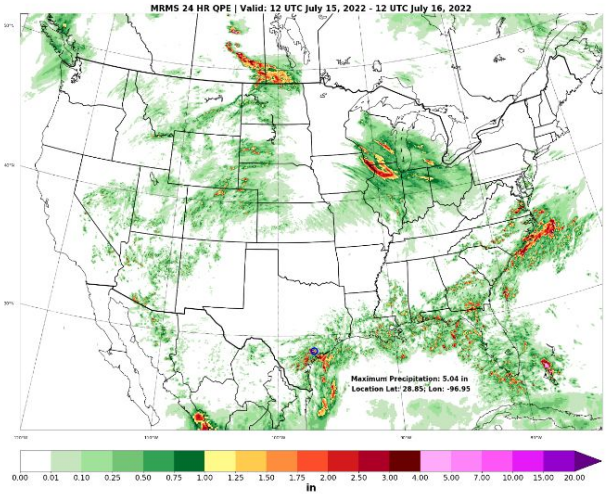


36 hr Ensemble Probability Updraft Helicity Forecasts
Valid 12 UTC 20 May 2022

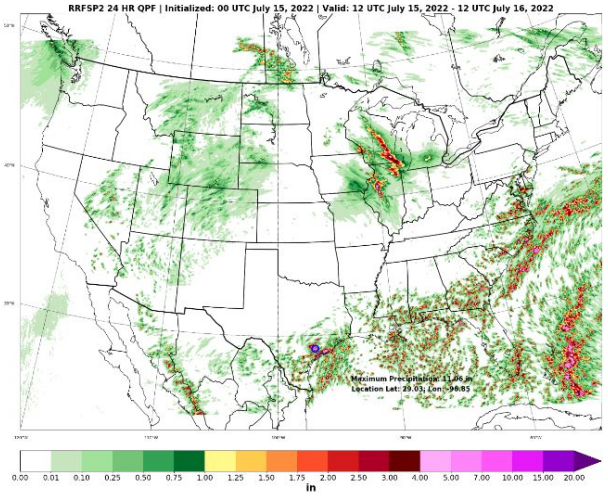
HREFv3 Operational Baseline (left)
RRFSp2 Experimental Prototype (center)
RRFSp3 Experimental Prototype (right)
Severe Storm Report Observations
(Red Triangle = Tornado,
Blue Square = Wind,
Green Circle = Hail)

WPC Hydrometeorological Testbed Flash Flood and Intense Rainfall Experiment 2022
15 July 2022 RRFS Prototype Deterministic QPF

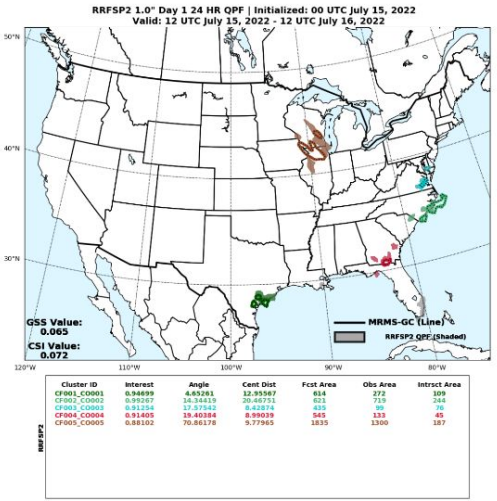
MRMS 24hr QPE



RRFS 24hr QPF



MODE 1” Objects



https://origin.wpc.ncep.noaa.gov/hmt/hmt_webpages/mode/ffair/ffairmode2022.php

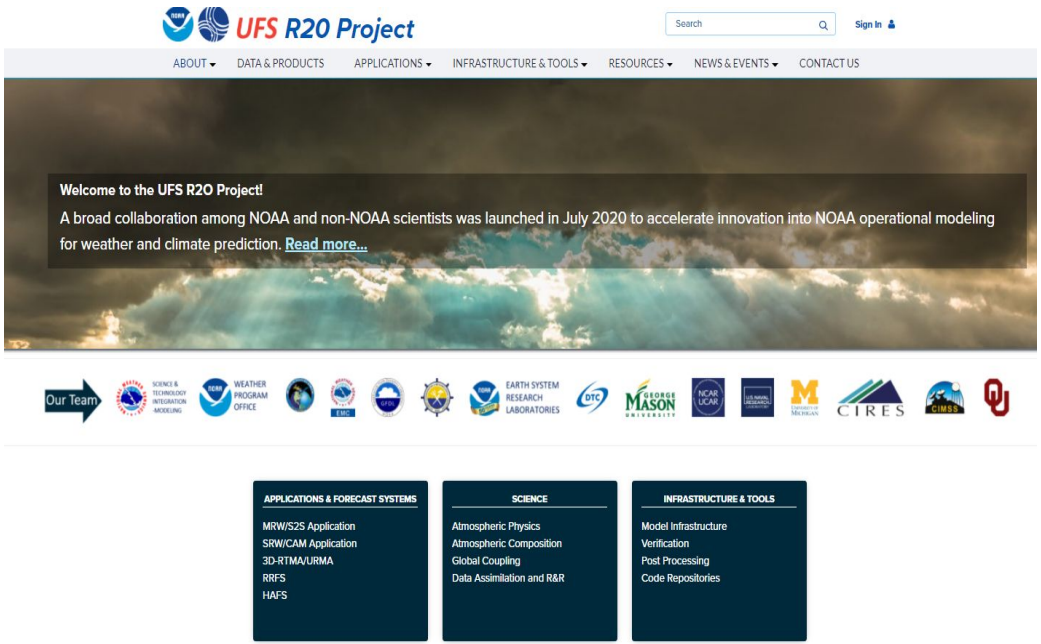
Engaging with the UFS-R2O Project

Yan Xue[1], Maoyi Huang[2]

[1]NOAA/NWS/OSTI, [2]NOAA/OAR/WPO

UFS R2O Website: At Your Service!

- Project structure
  - Application Teams
  - Cross-cutting Teams
- Project scope and deliverables
- Data products and prototypes
- UFS R2O Town Hall
- UFS R2O Annual meeting
- Contact information



How to Collaborate with the UFS-R2O Team?

UFS R2O

Get support from Notice of Funding Opportunity (NOFO)

- WPO/JTTI
- WPO/EPIC
- WPO/S2S
- USWRP - Testbed program
- OSTI/Modeling Program (HFIP, NGGPS, Weeks 3-4)

Contribute to UFS Weather Model Github (Open Source)

https://github.com/ufs-community/ufs-weather-model

Share science ideas and explore collaboration with the UFS-R2O Team

- Application Teams
  - MRW/S2S
  - RRFS/3DRTMA/WoF
  - HAFS
- Cross-Cutting Teams
  - Atmospheric Composition
  - Marine Component
  - Physics/Dynamics/Land
  - Data Assimilation, Reanalysis & Reforecast
  - Modeling Infrastructure
  - Verification & Post-processing

UFS Community Site: At Your Service!

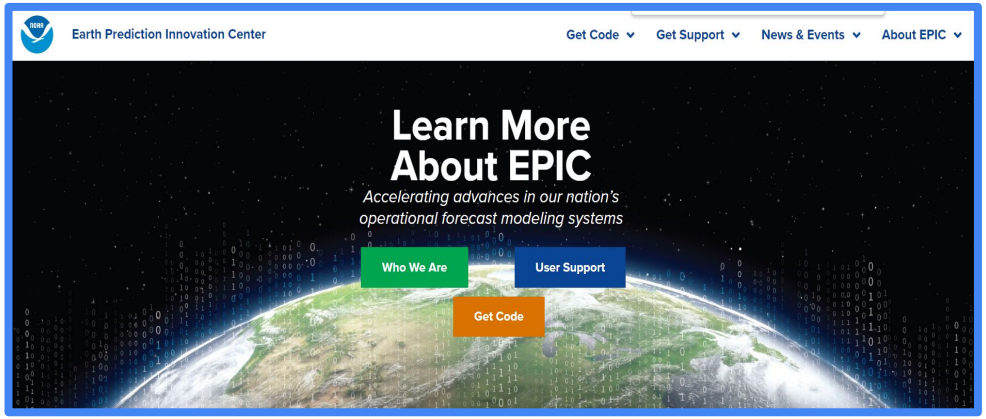
https://ufscommunity.org

- **UFS code and governance**
- **UFS Teams & Working Groups**
- Community news
- Archived newsletters, videos, etc.
- **UFS Webinars**
- **Weeks 3-4/S2S Webinar**

Town Hall of Unified Forecast System Modeling Forum
Jan 10, Tues, 6:00-7:15PM MST

- **Application Teams**
  - Medium-Range Weather (MRW)
  - **Sub-seasonal to Seasonal (S2S)**
  - Hurricane
  - Short-Range Weather/Convection Allowing Model (SRW/CAM)
  - Space Weather
  - Coastal
  - Air Quality
- **Cross-Cutting Teams**
  - Verification and Validation (V&V)
  - Systems Architecture and Infrastructure
  - Communications and Outreach (C&O)
  - Release Coordination
- **Component Working Group Teams**
  - Aerosols and Atmospheric Composition
  - Data Assimilation (DA) and Ensembles
  - Dynamics & Nesting
  - Land
  - Post Processing (PP)
  - Physics
  - Marine

EPIC Community Portal and UFS User Support



[Town Hall of The NOAA Earth Prediction Innovation Center Program]

Jan 10, Tues, 12:15-1:15PM MST

- Quarterly code sprints and hackathons;
- **2nd Unifying Innovations in Forecasting Capabilities Workshop, Jul 24-28, 2023, Boulder, CO**
- Release additional UFS capabilities: RRFS-on-cloud, Land-DA, UFS Use Cases;
- Incorporate support for fire weather, S2S and coastal applications;

Why UFS?

- UFS is a good (soon to be great) platform for forecasting and forecasting research;
- UFS is already in operations;
- There is a clear, steadily-supported R2O path, so using UFS for research can impact operations;
- NOAA is all-in on UFS for forecasting.

Questions?

For more information:

- UFS-R2O Project: **https://vlab.noaa.gov/web/ufs-r2o**
  - Kevin Garrett (NWS OSTI) kevin.garrett@noaa.gov
  - Yan Xue (NWS OSTI) yan.xue@noaa.gov
  - Chandra Kondragunta (OAR WPO) chandra.kondragunta@noaa.gov
  - Maoyi Huang (OAR WPO) maoyi.huang@noaa.gov
  - Vijay Tallapragada (NWS EMC) vijay.tallapragada@noaa.gov
  - Jeff Whitaker (OAR PSL) jeff.whitaker@noaa.gov
  - Jim Kinter (GMU) ikinter@gmu.edu

Backup

UFS S2S Application Team (AT)

https://vlab.noaa.gov/web/ufs-r2o/ufs-s2s-applications-team

UFS S2S AT Co-Leads

Cristiana Stan, GMU; **Fanglin Yang**, NWS/EMC; **Lucas Harris**, OAR/GFDL; **Wanqiu Wang**, NWS/CPC

S2S AT - Goals

- Collect and prioritize **forecast objectives** working with NWS forecasters and model users in general
- Establish **scientific goals** for the model development and ensure that they meet the NWS forecast priorities
- Promote or conduct **model evaluations** and comparisons in order to stay abreast on model performance and deficiencies

UFS S2S AT All-Hands Monthly Meetings

- **Model Evaluation** on S2S Time Scales including prediction skill of the UFS and other models
- **New diagnostics** designed to advance the understanding of Earth system variability in the S2S timescale
- **Identify projects** that can be spun up to **fill the gap** in the model evaluation
- Meeting format will be informal presentations and discussions
- Sign-up link

UFS Coupled model prototype data sets are available on the **AWS S3 Bucket** **for community access**. Community volunteers are invited for model evaluations, diagnosis and comparisons with other models.

Investing in the Future

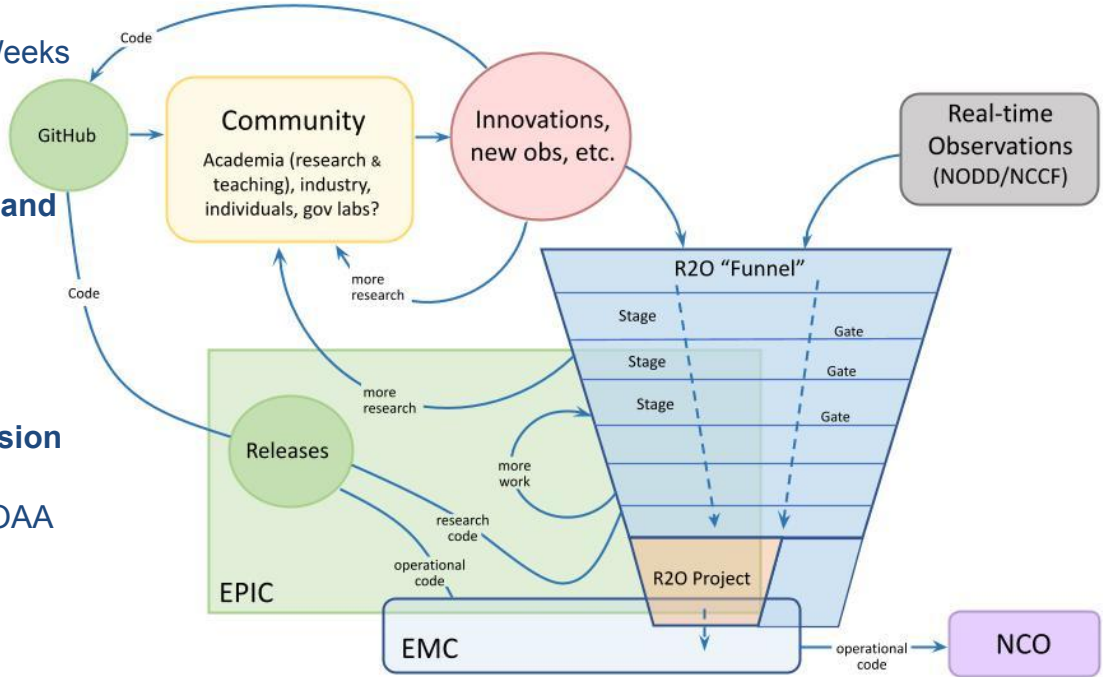
UFS R2O

NOAA Programs that Support UFS

- **NWS/OSTI Modeling Programs:** NGGPS, Weeks 3&4, HFIP
- **OAR/WPO Programs:** EPIC, JTTI, S2S, Atmospheric Composition
- **Disaster Supplementals FY18, FY19, FY22 and Bipartisan Infrastructure Legislation FY22**

UFS Research-to-Operations (UFS R2O) Project

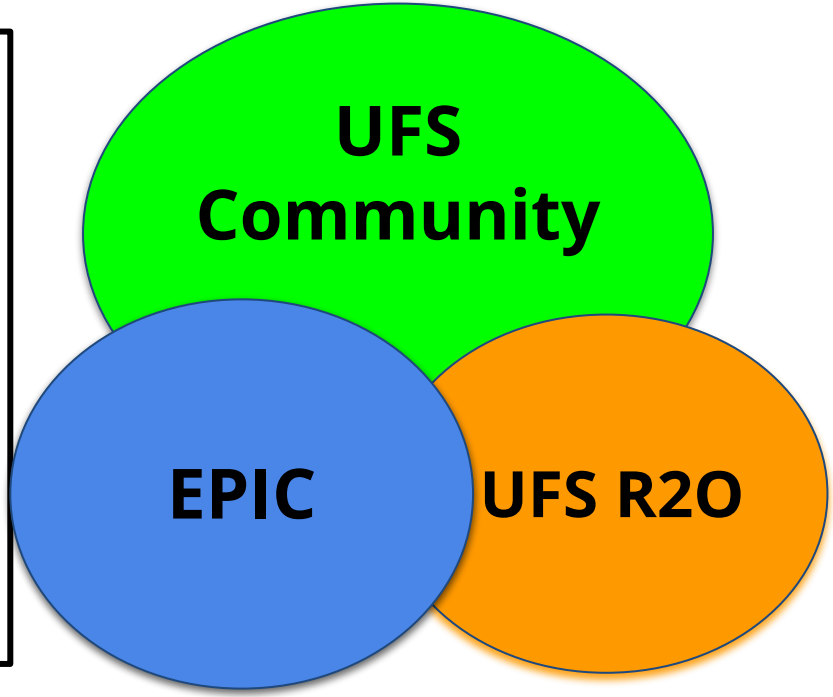
- **Three year project (FY20-23) with 5-year vision**
- Developing the next-generation global and regional forecast systems and transition to NOAA operations in **FY23 and beyond**
- Jointly supported by NOAA NWS and OAR
- Community team (NOAA, NCAR, JCSDA, Academia)
- Website: **https://vlab.noaa.gov/web/ufs-r2o**



UFS Community

EPIC:

- Nurture an inclusive and diverse UFS community
- Develop a publicly accessible end-to-end testing and development environment
- Bring innovations to improve UFS performance



UFS-R2O:

- Applications teams
- Cross-cutting teams
- NOAA-supported grants
- Inter-agency partnerships (ICAMS, JCSDA, etc)
- Responsive to forecast priorities
- Transition plans

Sign Up for the UFS Mailing List! →

UFS-R2O Project Goals

Medium-Range Weather (MRW)/Subseasonal-to-Seasonal (S2S) Applications:
Global Forecast System (GFS v17); Global Ensemble Forecast System (GEFS v13)

Regional Short-Range Weather (SRW)/Convection Allowing Model (CAM) Applications:
Rapid-Refresh Ensemble Forecast System (RRFS v1); Three-Dimensional Real-Time Mesoscale Analysis (3DRTMA); Hurricane Analysis and Forecast System (HAFS v1)

- Data Assimilation (DA):
  - Coupled: Allow observations of one component (e.g. atmosphere) to update all components.
  - Community JEDI for initialization of all forecast systems
  - Advanced ensemble, hybrid and 4D-Var algorithms, enhanced use of satellite radiances.
- Physics: Next-gen moist physics suite unified from convective-allowing to global
- Atmospheric Composition: high-resolution inline air quality prediction and direct aerosol feedback
- Hurricane Analysis & Forecast System (HAFS) with multiple moving nests

Future Plans

- **Community and cloud, expand partnerships for:**
  - Development & simulation
  - Model evaluation
- **Increase forecaster engagement:**
  - Model developments driven by forecaster needs
  - Partners on code retirement plans and process
- **Phase II (2024-2025):**
  - Transition first generation UFS applications to operations
  - **Strengthen bridge from research to operations**

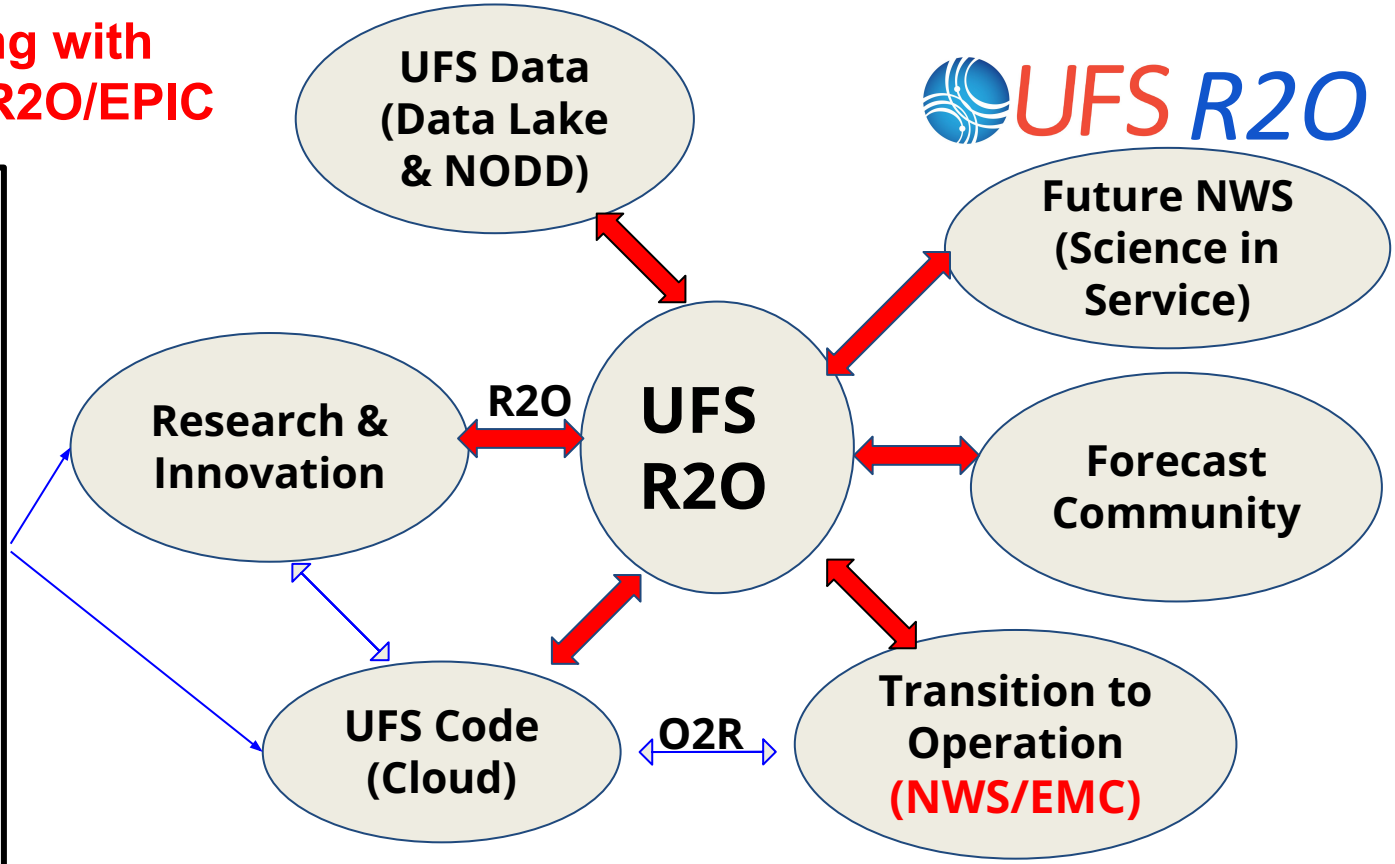
Gaps and Needs of UFS R2O

- Understanding of Earth system predictability in UFS
- Diagnosing and understanding of model biases
- Reducing model biases
- Improving representation of model uncertainty in ensemble capability
- Improving data assimilation and use of observation
- Aligning R&D efforts to address forecaster needs
- Accelerating transition of R&D into operations

Engaging with UFS/UFS-R2O/EPIC

EPIC:

- Public Release
- Cloud environment
- User support
- Code Springs & Training
- 2nd Unifying Innovations in Forecasting Capabilities Workshop (summer 2023)
- Student support
- Fire weather, S2S and coastal app.



https://github.com/ufs-community/ufs-weather-model

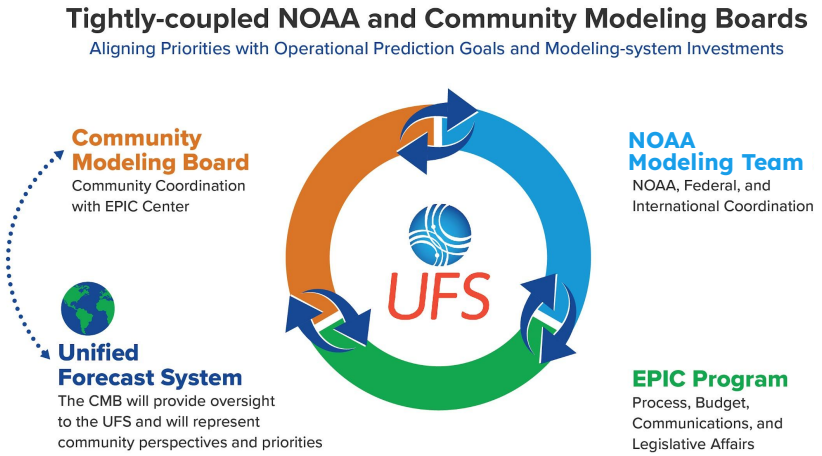
How to Engage with the UFS-R2O Teams

- For specific interests contact Application Team and Development Cross Cutting Team Leads
- For sustained collaborations with the UFS R2O Project on the developing systems, partners are encouraged to contribute to UFS development code on Github

  https://github.com/ufs-community/ufs-weather-model
- For support on public released codes, please go to the EPIC Community Portal

Upcoming EPIC Events and Opportunities

- Quarterly code sprints and hackathons;
- Establish a Community Modeling Board;
- EPIC Symposium & Student Workshop at AMS;
- 2nd Unifying Innovations in Forecasting Capabilities Workshop;
- Release additional UFS capabilities: RRFS-on-cloud, Land-DA, UFS Use Cases;
- Incorporate support for fire weather, MRW/S2S/HAFS/coastal applications;



2023 UIFCW
A UFS Collaboration Powered by EPIC

Date: July 24th - 28th

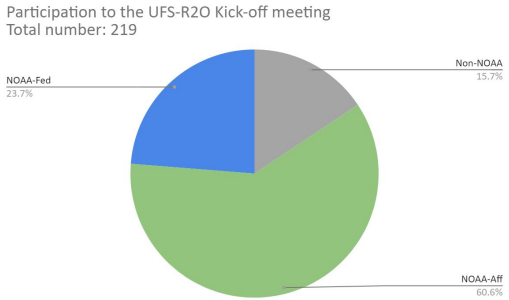
Location:
Center Green, Boulder, CO

Path Forward

- **Integrate with EPIC**
  - Engagement on software, infrastructure and user support
- **Community support (enhanced by EPIC)**
  - Support multiple compute-platforms and community collaborators
- **Organization**
  - Coordinate across multiple institutions using contemporary software management and communication tools; integrate other funded NOAA projects
- **Make model output available to the community**
  - NOAA Data Lake & NOAA Open Data Dissemination (NODD)

UFS-R2O Project History

- **Winter 2019-2020**:
  - Proposal invited (2-year project)
  - Project team and proposal assembled
- **March 12-13, 2020**: Face-to-face peer-review
- **April-May 2020**: Funding finalized
  - **$13M/yr: NWS-OSTI $10M and OAR-EPIC & JTTI $3M**
- **July 2020**: Project launch, Kick-off meeting (July 9-10), **200+ attended**
- **October 2020**: First Quarterly Program Review
- **July 2021**: Year 2 kick off
- **July 2021:** First Annual Meeting
- **December 2021:** Year 3 extension review



Near and Future Plans for Physics/Dynamics Development

Phase-two overarching goals:

- Address systematic biases found in GFSv17/GEFSv13/HAFS/RRFS prototype simulations related to physical process descriptions.
- Seek improvements for low frequency phenomena in extended forecasts related to physical process descriptions.
- Continue to unify physical process descriptions across applications to the extent feasible.
- Continue development of scale-adaptive and unified process descriptions.
  - Optimize physics for the sub 10km range in global simulations.
  - Develop a unified prognostic cloud fraction scheme that connects microphysics, convection and planetary turbulent processes.
- Continue development of process level stochastic physics, ensuring conservation of energy and moisture, and consistency in perturbations across component interfaces.
- Address physics-dynamics interface issues, time-step sensitivity in physics, diffusion property impact on near grid-scale phenomena, numerical solutions in physics leading to unphysical solutions (e.g. negative tracers).
- Continue testing and evaluation of current prototype systems and new physics innovation in land and atmosphere processes using process level diagnostics and hierarchical test framework.

Stretched goals

- Research physics innovations needed for sub 1 km range in turbulence and shallow convection.
- Include aerosol-microphysics-radiation interaction in short and medium-range weather forecast models
- Apply neural network based correction to the state variables for machine learned in-line bias correction.

Physics for MRW/S2S Applications

	GFS.v16	UFS
Cumulus Convection (Shallow & Deep)	sa-SAS	Positive definite mass flux; stochastic convective organization; Improved CAPE
Surface Layer	GFS	Sea spray; optimization
PBL	sa-TKE-EDMF	Positive definite tracer advection; optimization
Non-orographic GWD	uGWP v0	uGWP.v1 (Yudin et al., 2021)
Orographic Gravity Wave Drag Small-scale gravity-wave drag (new) Turbulence Form drag (new)	Kim & Arakawa (1995)	uGWP.v1 Kim and Doyle (2005) Tsiringakis et al. (2017) Beljaars et al. (2004)
Land	Noah LSM	NOAH MP and VIIRS veg type
Aerosol	OPAC	MERRA2
Fractional grid	N/A	compositing albedo and emissivity; fractional grid enabled surface cycle; z_bot calculation for coupling stability etc

Updated

New

Physics for MRW/S2S Applications (cont'd)

	GFS.v16	UFS
Microphysics	GFDL MP	**Thompson MP** • improve computational stability (inner-loop), • optimize cloud cover and radiative fluxes • use Semi-Lagrangian sedimentation for rain and graupel • develop cloud-aerosol interaction scheme
Radiation (LW &SW)	RRTMG	RRTMGp *(pending on improvement in computational efficiency)*
Ice climatology	CFSR (model)	IMS-NIC (observation & retrievals)
land/sea/lake masks	MODIS	VIIRS

New

- **Some of the schemes have also been tested and evaluated in RRFS and HAFS for physics unification.**

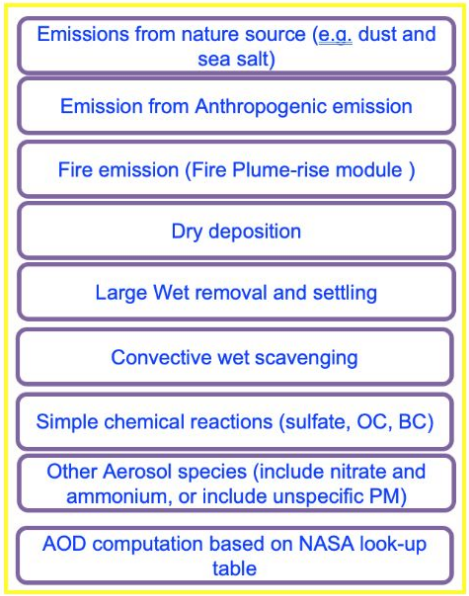
NOAA's next-generation global aerosol forecast: UFS-Aerosol

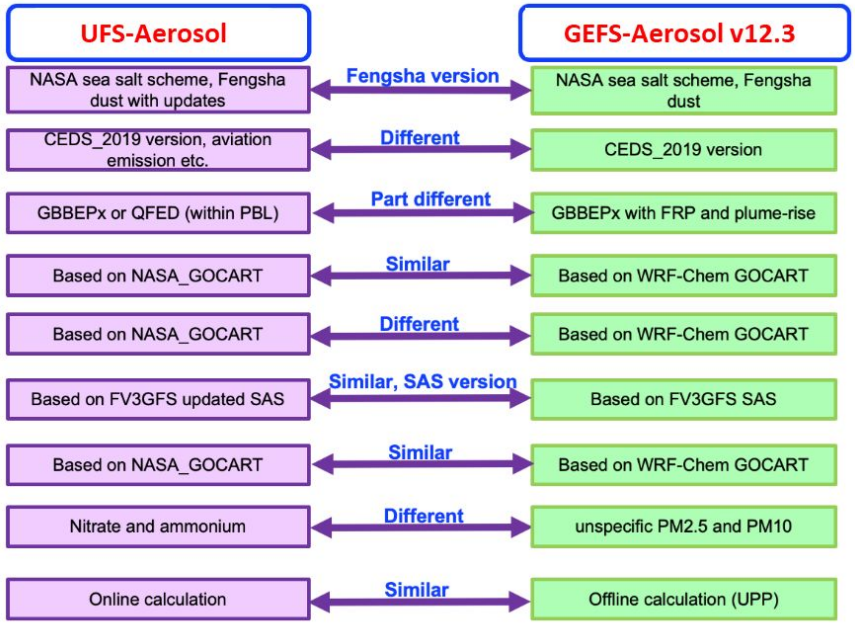
UFS R2O

UFS-Aerosol = Prognostic aerosol component of UFS 6-way coupled system developed within UFS R2O Program as a prototype for global subseasonal prediction targeted for GEFSv13

Expected benefits:

- Improved aerosol process descriptions
- Realistic aerosol spatial distributions and temporal variability
- Realistic representation of aerosol radiative impacts on meteorology
- Solid foundation for NOAA's next-generation operational S2S forecast system





Overview of UFS-Aerosol Development

UFS R2O

Planning

- Concept of operations
- Evaluation plan

Processes

- Improved dust treatment
- Convective wet scavenging
- Aerosol precipitation flux
- Aerosol-radiation interactions

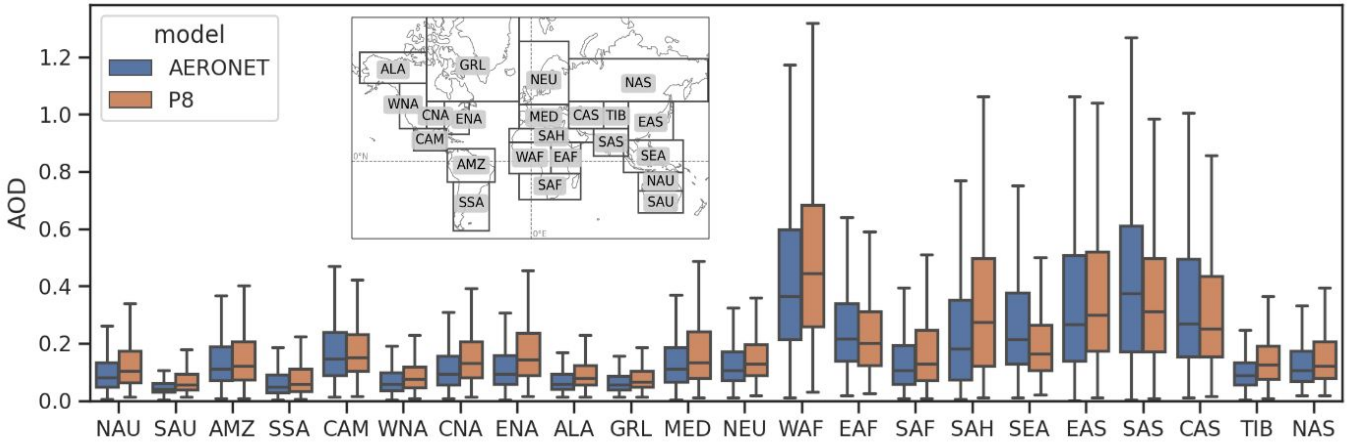
Evaluation

- Aerosol spatial/temporal distributions, speciation, size, optical properties
- Impacts of aerosol-radiative interactions on meteorology

Architecture

- NUOPC-compliant
- Latest GOCART version on NASA repository
- Coupled to UFS atmospheric component
- UFS global workflow extended to include aerosols

Regional comparisons of **P8 Weeks 1-4 UFS-Aerosol** to **AERONET Total AOD**



Analysis by Jian He, Zach Moon, and Barry Baker

Physics for HAFS.v1

	Suite A	Suite B
Land/ocean Surface	NOAH, HYCOM	NOAH, HYCOM
Surface Layer	GFS , TC-related Z0	GFS, TC-related Z0
Boundary Layer	Sa-TKE-EDMF, TC-related tuning (L) Lmax=300,300	Sa-TKE-EDMF, TC-related tuning (H, L, mass flux..) Lmax=300,75
Microphysics	**GFDL single-moment**	**Thompson double-moment**
Radiation	RRTMG (every 900s)	RRTMG (**every 1800s)**
Deep & shallow CU	Scale-aware-SAS	Scale-aware-SAS
Gravity wave drag	Unified GWD	Unified GWD

Physics for RRFS.v1

Physics	SCHEME	REFERENCE
PBL/Turbulence	MYNN-EDMF	Olson et al. (2019)
Surface Layer	MYNN	Olson et al. (2021)
Microphysics	Thompson-Eidhammer	Thompson and Eidhammer (2014)
Climatological Aerosols	Thompson-Eidhammer	Thompson and Eidhammer (2014)
Smoke and Dust	RAVE fire data, FENGSA scheme for dust	Ahmadov et al., Freitas et al., 2010
Shallow Convection	MYNN-EDMF	Olson et al. (2019) Angevine et al. (2020)
Gravity Wave Physics	Small Scale and Turbulent Orographic Gravity-Wave & Form Drag	Beljaars et al. (2004) Tsiringakis et al. (2017) Toy et al. (2021)
Land Model	RUC --> Noah-MP	Niu et al. (2011)
Large Lakes	FVCOM	Fujisaki-Manome et al. (2020)
Small Lakes	FLake/CLM Lake	Mironov (2008)/Subin et al. (2012), Mallard et al. (2015)
Near-Surface Sea Temperature	NSST	Fairall et al. (1996), Derber and Li (2018)
Long and Short Wave Radiation	RRTMG	Iacono et al. (2008), Mlawer (1997)

Primary HAFS IOC Configurations

HAFSv1.0	Domain*	Resolution*	DA/VI	Ocean/Wave Coupling	Physics	Basins
Config. 1 (HAFS-A)	Storm-centric with one moving nest, parent: ~81x81 degree, nest: ~12x12 degree	Regional (regular Gnomonic), ~6/2 km, ~L81, ~2 hPa model top	VI and DA	Two-way HYCOM, one-way WW3 coupling for NHC AOR	Physics suite-1	All global Basins NHC/CPHC/JTWC Max 7 Storms Replace HWRF
Config. 2 (HAFS-S)	Storm-centric with one moving nest, parent: ~81x81 degree, nest: ~12x12 degree	Regional (ESG), ~6/2 km, ~L81, ~2 hPa model top	Adaptive VI and/or DA	Two-way HYCOM No Wave	Physics suite-2	NHC/CPHC Max 5 Storms Replace HMON

*Subject to change based on T&E and available computer resources

Primary configuration (HAFS v0.3A), storm- centric with moving nest in all global oceanic basins.

Secondary configuration (HAFS v0.3S) uses alternate physics in NHC/CPHC basins.