AMS Town Hall: Jan 27 2022

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

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UFS R2O Project Leads

EMC, PSL, GSL, CSL, NSSL, ARL, GFDL, AOML, NESDIS

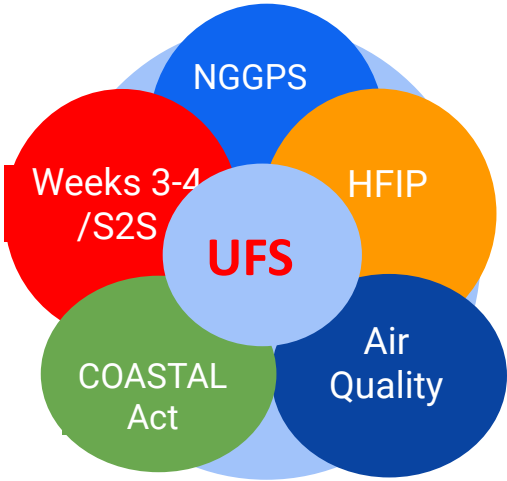
Agenda

- Opening Remarks from OAR - Dr. Dorothy Koch
- Opening Remarks from NWS - Dr. Steve Smith
- Programmatic Overview - Dr. Jamese Sims
- Technical Overview - Dr. Jim Kinter
- Engaging with the UFS R2O Project - Dr. Jamese Sims
- NOFO opportunities to collaborate with UFS - Dr. Yan Xue
- Q&A Session

NWS/OSTI-Modeling Programs

UFS R2O

- **Next Generation Global Prediction System (NGGPS)**
  POCs: Jamese Sims, Farida Adimi
- **Weeks 3-4/ Subseasonal to Seasonal Prediction (Weeks 3-4/S2S)**
  POCs: Yan Xue, Deepthi Achuthavarier
- **Hurricane Forecast Improvement Program (HFIP)**
  POCs: Youngsun Jung, Sikchya Upadhayay
- **National Air Quality Forecast Capability (NAQFC)**
  POCs: Youngsun Jung, Jose Tirado-Delgado
- **Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act**
  POCs: Jamese Sims, Stacy Mackell



The Unified Forecast System (UFS) was established in 2014 as part of the NWS/NGGPS Program, to unify forecast "application" systems from weather to climate.

Unified Forecast System (UFS)

UFS R2O

A community-based, coupled Earth modeling system, to support the Weather Enterprise and to serve as the source for NOAA's operational applications.

- First established as part NOAA/NWS/NGGPS program in 2014
- Unify forecast "application" codes and infrastructure, using open, community codes

Engagement opportunities

- Model releases
- Model analysis opportunities
- Annual user tutorials and workshops

Organization

- Steering Committee
- Application Teams
- Working Groups

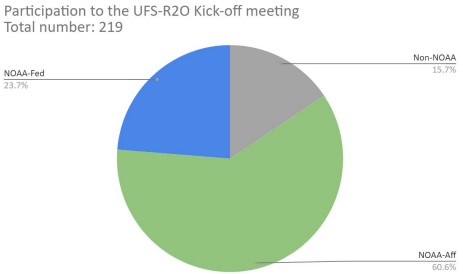
https://ufscommunity.org

UFS Strategic Plan (2021-25); Science Goals:

- Reduce near-surface biases
- Incorporate new data types targeting specific Forecast Skill Priorities
- Test and implement a coupled component capability
- Increase physical consistency of physics and dynamics
- Establish ensemble-based methods to describe uncertainty
- Develop FV3-based Whole Atmosphere Model (for Space Weather application)

UFS-R2O Project History

- **Summer 2019**:
  - EPIC community meeting, need to better organize the UFS community to prepare
- **Fall 2019**:
  - NWS and OAR program managers agree to coordinate and commit resources
  - Program office invited 3-pager ideas from UFS community (approx 60 submitted, $50M/y)
- **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**



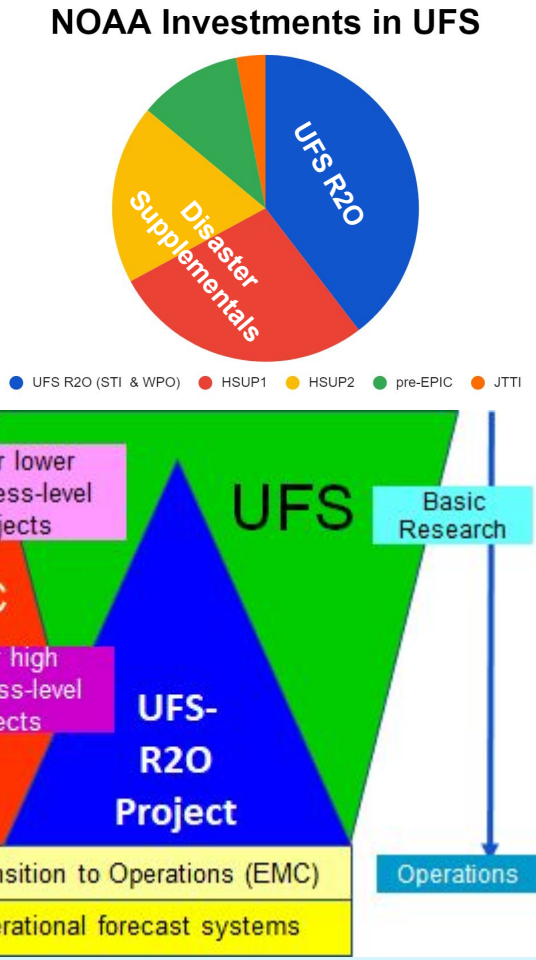
NOAA Investments in UFS

Unified Forecast System (UFS)

- NOAA programs that support the UFS: NGGPS, Weeks 3&4, Air Quality, JTTI, EPIC, and Hurricane and Disaster Supplementals

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 for NOAA's operations by FY24
- NOAA's largest investment in the UFS: $13M/yr, jointly supported by NOAA Operations (NWS) and Research (OAR)
- Community team (NOAA, NCAR, JCSDA, Universities)
- Website: https://vlab.noaa.gov/web/ufs-r2o



OAR/WPO R2O Portfolio

OAR/WPO Programs Supporting NOAA's Unified Forecasting System:

- **Joint Technology Transfer Initiative (JTTI) (RL 4-8)**
  - POC: Chandra.Kondragunta@noaa.gov
  - FY22 JTTI NOFO: $2M (Proposals due on Nov 17, 2021)
  - FY22 JTTI Internal NOFO (NOAA): $3M (Proposals due on Nov 1, 2021)
- **Climate Testbed (RL 5-8)**
  - POC: Jessie.Carman@noaa.gov
  - FY22 CTB NOFO: $1.25M (Proposals due on Nov 17, 2021)
- **Subseasonal to Seasonal Forecasting (RL 2-4)**
  - POC: Jessie.Carman@noaa.gov
  - FY22 S2S NOFO: $1.75M (Proposals due on Nov 17, 2021)
- **EPIC**
  - POC: Maoyi.Huang@noaa.gov

EPIC - Earth Prediction Innovation Center

Partnering with the community for the benefit of the nation

Vision: *Enable* the most accurate and reliable operational numerical forecast model in the world.

Mission: To be the *catalyst* for community research and modeling system advances that continually inform and accelerate advances in our nation's operational forecast modeling systems.

What EPIC is….

- A virtual community model development environment
- Management of cloud- ready code
- Community access to NOAA observations, data & tools
- Community support & engagement
- Clear research & model transition to operations priorities
- Expected expansion to other additional model components
- EPIC: focus on the Unified Forecast System (UFS)

Community Engagement

UFS UNIFIED FORECAST SYSTEM

Cloud Use

Contact: maoyi.huang@noaa.gov

UFS R2O Project Goals

Global Coupled Medium-Range Weather (MRW)/Subseasonal-to-Seasonal (S2S) Applications:
Global Forecast System (GFS v17) and 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), and 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

UFS-R2O Priorities

MRW/S2S Priorities

- **Reduce near-surface biases**
- Improve representation of tropical and stratospheric variability, including **Madden Julian Oscillation (MJO)** and **quasi-biennial oscillation (QBO)**
- Implement a **coupled** ensemble prediction system, including **reanalysis** and **reforecast** capabilities.
- Improve quantification of **model uncertainty**
- **Advance initialization** through improved use of observations and advances in data assimilation algorithms.

SRW/CAM Priorities

- Implement a **Three-Dimensional Real-Time Mesoscale Analysis**, updated every 15 minutes, for real-time nowcasting/situational awareness
- Develop a unified **Rapid-Refresh Ensemble Forecast System** for regional CAM scales to simplify the operational product suite including **Community Multiscale Air Quality (CMAQ)**

Hurricane Priorities

- Establish **Hurricane Analysis and Forecast System (HAFS)**
- Develop **Initial Operational Capability (IOC)** for the **2023 hurricane season**
- Finalize two configurations for implementation to replace operational HWRF and HMON

"Leveraged" NOAA Funded Projects

- **NWS/OSTI Notice of Funding Opportunity (NOFO) Projects**
  - **NGGPS, Weeks 3-4/S2S, HFIP (applications due Feb 7, 2022)**
- **OAR/WPO NOFO Projects**
  - **JTTI, CTB, S2S (applications closed Nov 17, 2021)**
- **Hurricane Supplemental Projects**
  - **FY18/IFAA**: Physics, Hurricane modeling, SAR & FV3-CAM, Infrastructure, DA/JEDI, and observation processing
  - **FY19/DSAP**: Hurricane modeling, RRFS on cloud, wildfire smoke, and satellite products for fire and smoke
  - **FY22**: **Flood and Precipitation, Wildfire, and Hurricane**

Future Plans

- **Community and cloud, expand partnerships for:**
  - Development & simulation
  - Model evaluation
- **Strengthen forecaster engagement:**
  - Model developments driven by forecaster needs
  - Partner on code retirement plans and process
- **Phase 2 (2023-2025?):**
  - Broaden NOAA engagement
  - Include new forecast applications
- **Strengthen interagency partnerships**

UFS-R2O Technical Overview

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

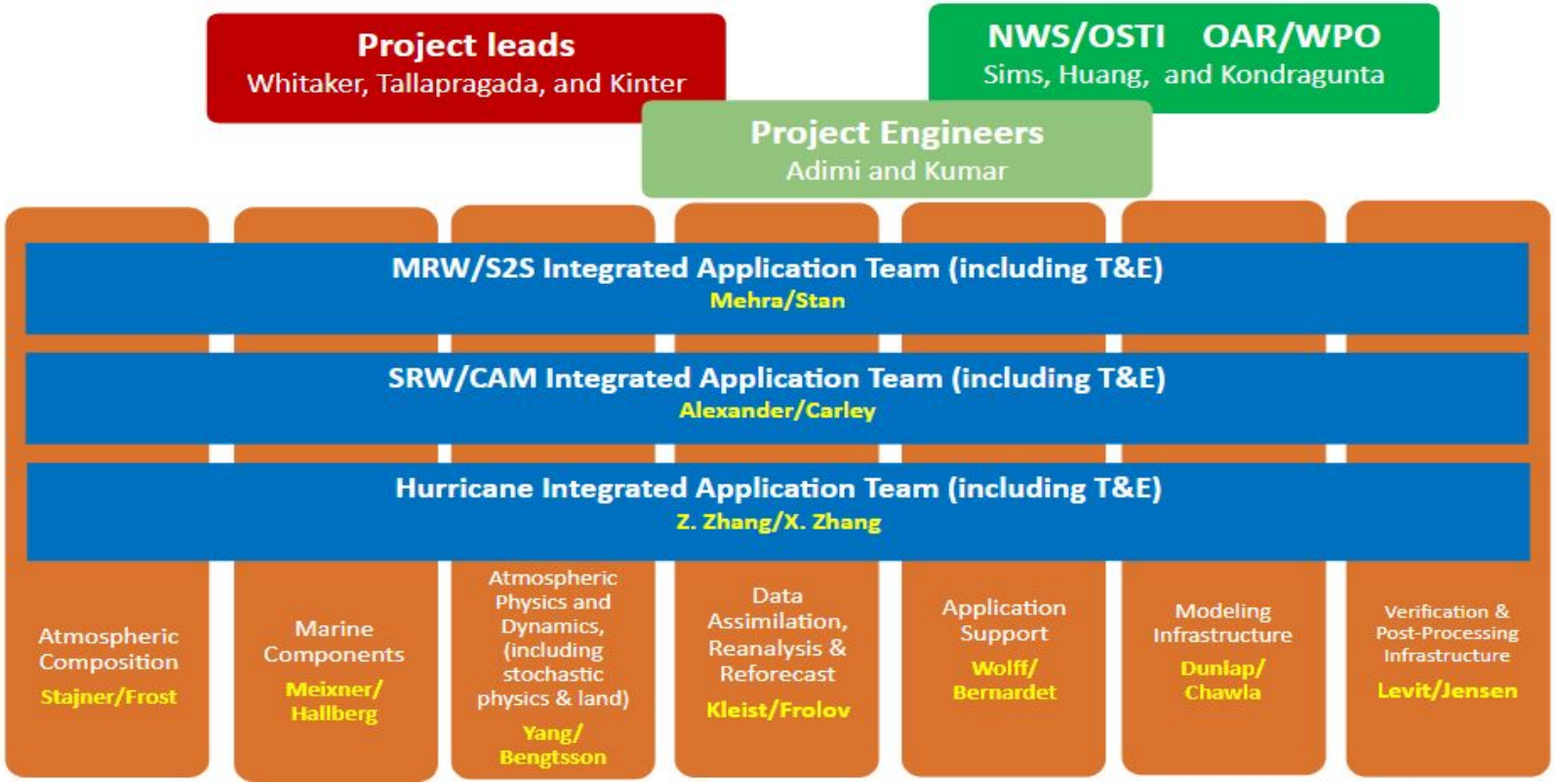
Project Leads

Jim Kinter, Vijay Tallapragada, Jeff Whitaker

EMC, PSL, GSL, CSL, NSSL, ARL, GFDL, AOML, NESDIS

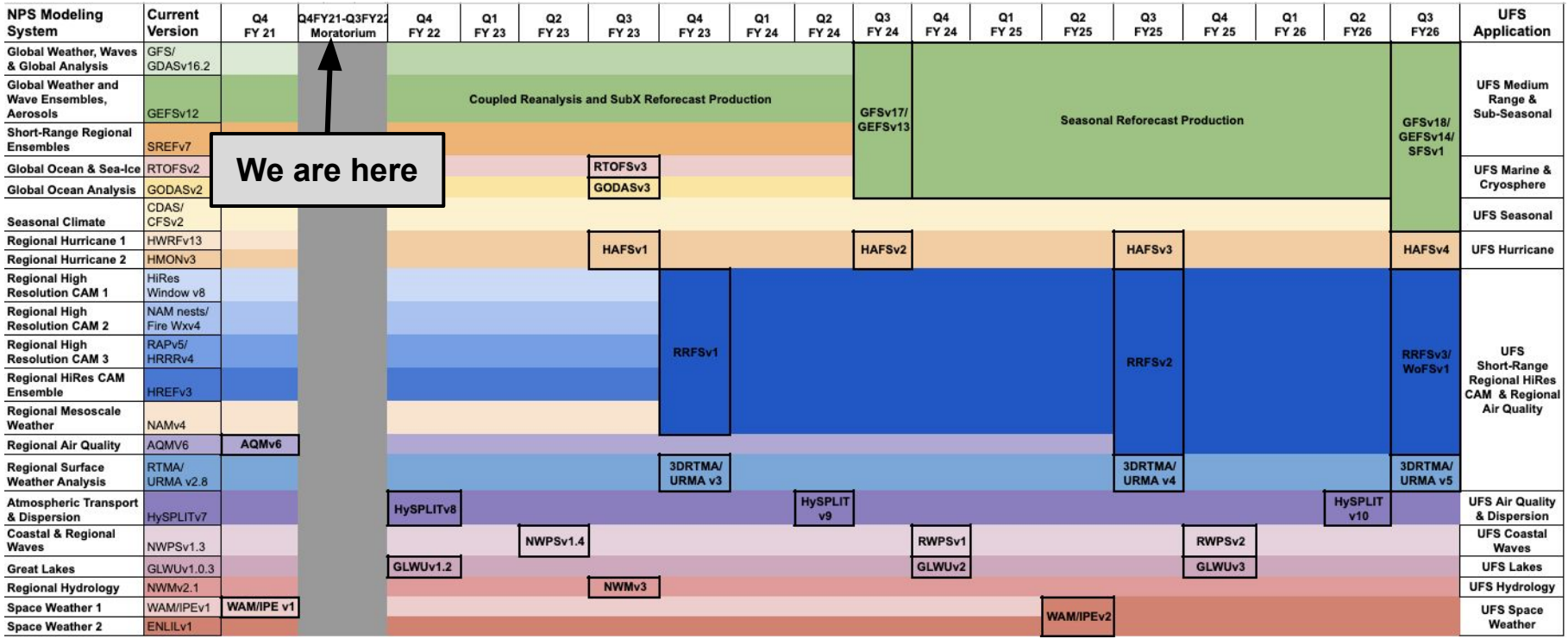
New Project Structure

UFS R2O



Notional Timelines for Operational Implementation

UFS R2O



NPS Modeling System	Current Version	Q4 FY 21	Q4FY21-Q3FY22 Moratorium	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	Q1 FY 25	Q2 FY25	Q3 FY25	Q4 FY 25	Q1 FY 26	Q2 FY26	Q3 FY26	UFS Application
Global Weather, Waves & Global Analysis	GFS/ GDASv16.2																			
Global Weather and Wave Ensembles, Aerosols	GEFSv12																			UFS Medium Range & Sub-Seasonal
Short-Range Regional Ensembles	SREFv7																			
Global Ocean & Sea-Ice	RTOFSv2																			UFS Marine & Cryosphere
Global Ocean Analysis	GODASv2																			
Seasonal Climate	CDAS/ CFSv2																			UFS Seasonal
Regional Hurricane 1	HWRFv13																			UFS Hurricane
Regional Hurricane 2	HMONv3																			
Regional High Resolution CAM 1	HiRes Window v8																			UFS Short-Range Regional HiRes CAM & Regional Air Quality
Regional High Resolution CAM 2	NAM nests/ Fire Wxv4																			
Regional High Resolution CAM 3	RAPv5/ HRRRv4																			
Regional HiRes CAM Ensemble	HREFv3																			
Regional Mesoscale Weather	NAMv4																			
Regional Air Quality	AQMV6																			
Regional Surface Weather Analysis	RTMA/ URMA v2.8																			
Atmospheric Transport & Dispersion	HySPLITv7																			UFS Air Quality & Dispersion
Coastal & Regional Waves	NWPSv1.3																			UFS Coastal Waves
Great Lakes	GLWUv1.0.3																			UFS Lakes
Regional Hydrology	NWMv2.1																			UFS Hydrology
Space Weather 1	WAM/IPEv1																			UFS Space Weather
Space Weather 2	ENLILv1																			

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 / Seasonal to Subseasonal

To create more accurate forecast guidance using applications that span the global domain and time scales from about one week to about two years.

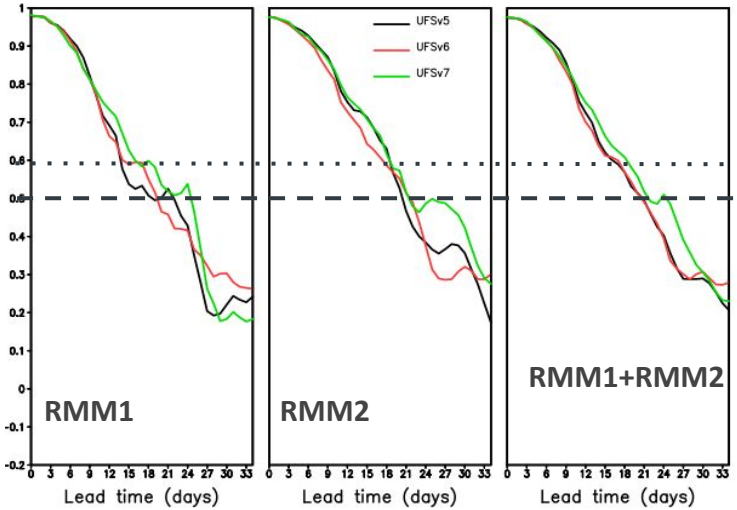
Three Applications with Global, Coupled Models:

- **Global Forecast System (GFS)**: deterministic (v17: 13-km grid) medium-range forecast guidance for up to 2 weeks lead-time
- **Global Ensemble Forecast System (GEFS)**: probabilistic (v13: 25-km) sub-seasonal forecast guidance up to 4 weeks
- **Seasonal Forecast System (SFS)**: probabilistic (v1: 25-km) seasonal forecast guidance for 4 weeks to 2 years

MRW/S2S Integrated Application - Major Accomplishments

- Global coupled system (Atm-Ocean-Ice-Wave) **prototype-7 completed** with candidate GFSv17 physics (including Noah-MP land surface model).
  - Final prototype-8 expected in Q2FY22 **(GFS/MOM6/CICE6/WW3/Noah-MP/GOCART)**
- Prototype forecasts have **skill at target lead-times comparable to or superior to existing operational levels**
- Considerable **improvement in weeks 3-4 of MJO** and basket of standard metrics
- **40-year 1 deg marine reanalysis** using JEDI Sea-ice Ocean and Coupled Analysis (SOCA, https://www.jcsda.org/soca)

AC: All MJO cases



Better MJO AC in P7: approx 1-2 more days of high AC

Focus Areas: Gaps and Challenges - MRW/S2S

Data Assimilation

- 30-year reanalysis by 'replaying' to ERA5/ORAS5; Land surface DA; Utilize all-sky/all-surface radiances

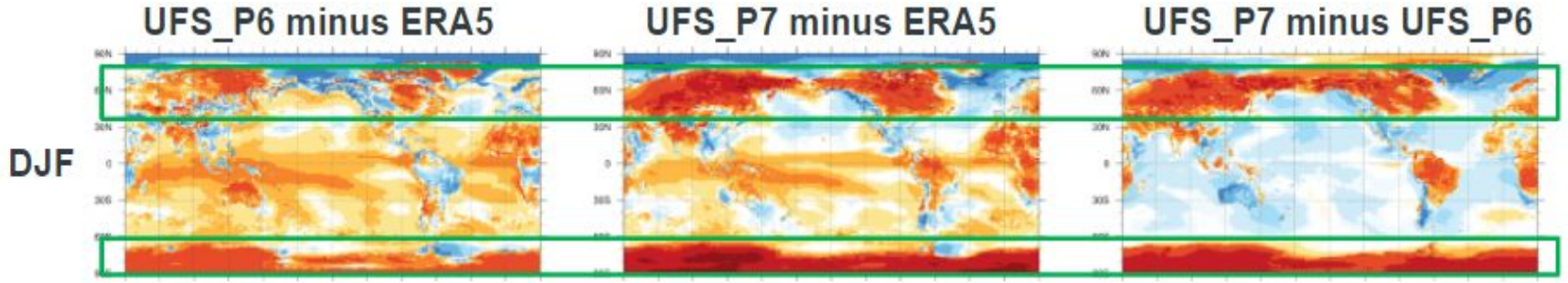
Testing and Evaluation

- Unified, portable, extensible workflow system, including verification and validation with METplus; Process-based analysis to attribute sources of bias and RMS error

Model Development

- Land surface modeling; Aerosol-radiation feedback

Communication among developers and evaluators is essential



In P7, compared to P6, Over ocean: reduction of warm bias, Over land: increase of warm bias

SRW/CAM Application Team Scope

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

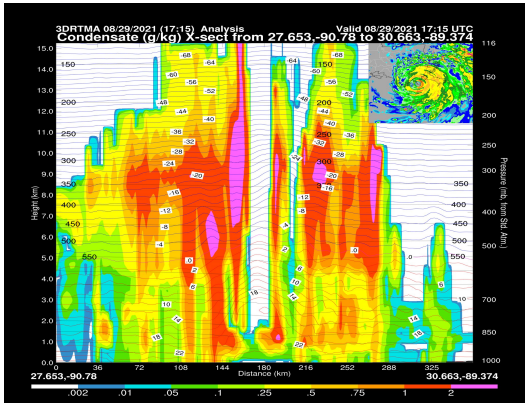
To create more accurate high-resolution forecast guidance using applications that span the regional domains (CONUS and OCONUS) and time scales from about nowcasting to about three days.

SRW/CAM encompasses three applications

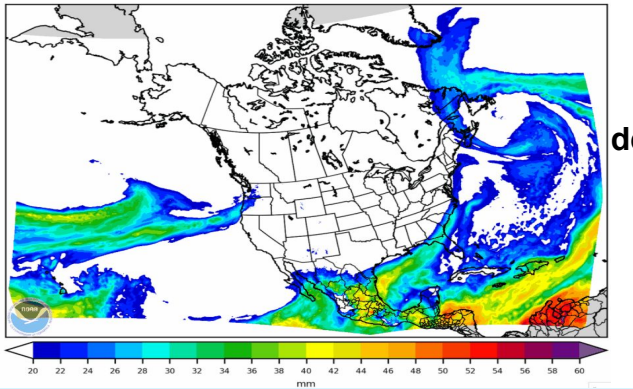
- **3-Dimensional Real Time Mesoscale Analysis (3DRTMA)**
  - 15-minute 2.5-to 1.25 km analysis system
- **Rapid Refresh Forecast System (RRFS)**
  - Based on the FV3-Limited Area Model (LAM)*, Rapidly updated, Convection-allowing (~3 km), Hybrid EnVar assimilation (~ 36 mem), Ensemble forecasts (~9 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

SRW/CAM Integrated Application - Major Accomplishments

- Established 3DRTMA and 3DURMA including support for OCONUS
- FV3-LAM implemented in operations on 5/11/21 (replaces NMMB member in HREFv3).
- Established RRFS model and ensemble configuration
- Multi-physics ensemble tested on cloud HPC



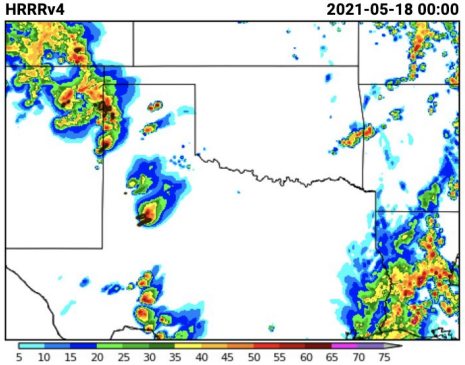
Analyzed 3D Cross-section of Hurricane Ida from 3DRTMA

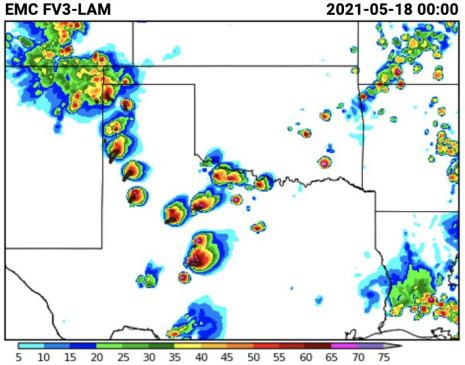


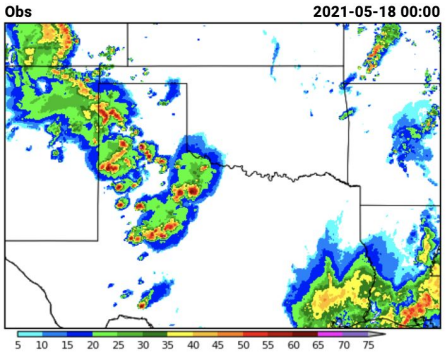
Real-time demonstration of RRFS

Focus Areas: Gaps and Challenges - SRW/CAM

- ***3DRTMA:***
  - *AI/ML, improvement of the 3DRTMA background*
- ***RRFS:***
  - *Convective-scale performance issues with storm structure and extreme precipitation rates*
- ***WoFS:***
  - *Change model core from WRF-ARW to FV3 LAM and retune*







Very intense updrafts for convective storms in RRFS

Hurricane Application Team Scope

HAFS -- Hurricane Analysis and Forecast System

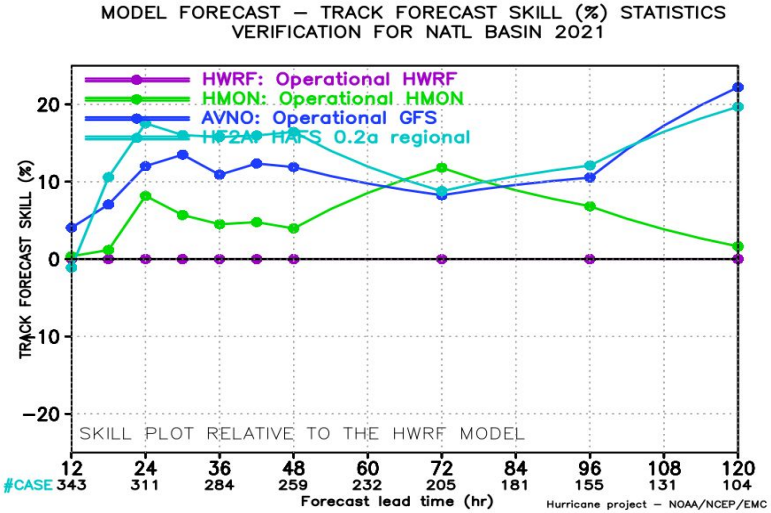
To create more accurate high-resolution forecast guidance for tropical cyclones across the globe.

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

Hurricane Integrated Application - Major Accomplishments

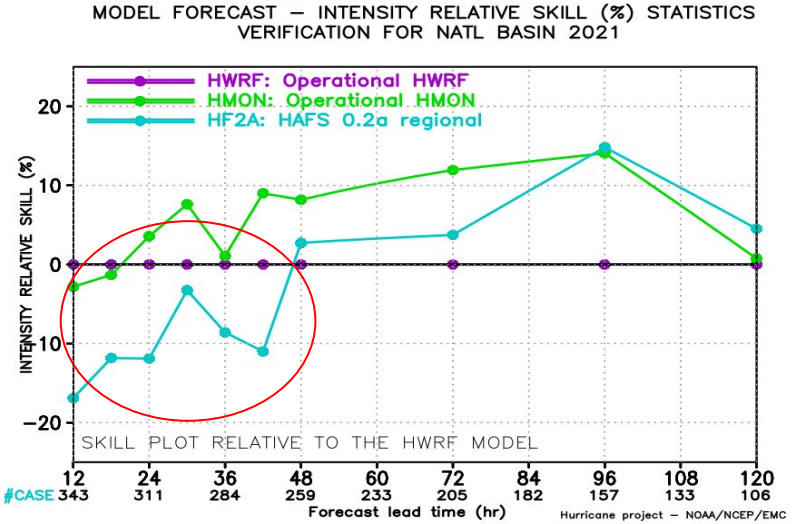
- First version of moving nest in global and regional framework
- Self-cycled hybrid 3D Ensemble Variational Data Assimilation system
- Surface and planetary boundary layer schemes for tropical cyclone forecasts
- Two-way HYCOM ocean model coupling and One-way WaveWatch-3 coupling using Community Modeling of Environmental Prediction System (CMEPS) software
- Several Real-time demo configurations of Hurricane Analysis and Forecast System (HAFS) executed



Track forecast guidance from HAFS-A is more skillful than operational hurricane forecast systems, HWRF/HMON/GFS, i.e. improves 10-20% superior to that from HWRF

Focus Areas: Gaps and Challenges - Hurricane

- Scale-aware physics at different grid resolutions
- Vortex initialization and multi-scale DA
- Improve moving nest: flexible refinement, multiple storms, scalability, and feedback schemes
- Coupled Ocean-Wave-Atmosphere (two-way) interactions



Intensity forecast guidance from HAFS-A are improved over the operational HWRF after day-2 but still lag behind at the first 48hr forecasts (need for Vortex initialization and Data Assimilation)

Path Forward

- **Integrate with EPIC**
  - Proposal included sections anticipating EPIC engagement
- **Community support (enhanced by EPIC)**
  - Support multiple compute-platforms and community collaborators
- **Organization**
  - Coordinate across multiple institutions using contemporary communication tools and project engineers; integrate other funded NOAA projects
- **Make model output available to the community**
  - NOAA Data Lake & NOAA Big Data Program

Engaging with the UFS-R2O Teams

UFS-R2O Web Site

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

EMC, PSL, GSL, CSL, NSSL, ARL, GFDL, AOML, NESDIS

Engagement Opportunities

UFS R2O

UFS-R2O data on AWS cloud:
https://vlab.noaa.gov/web/ufs-r2o/dataproducts

- 40-year 1 deg marine reanalysis using marine JEDI (SOCA)
- MRW/S2S prototype data (*P5, P6, P7, P8 to come soon*)
- RRFS ensemble prototype data

UFS code releases: https://ufscommunity.org/

- MRW/S2S application
- SRW/CAM application
- Components: METplus, ESMF, CCPP, ...

How to Engage with the UFS-R2O Teams

- **For specific interests contact Application Team and Development Cross Cutting Team Leads (Slide 12)**
- **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 user supported and tested system, the publicly released MRW/S2S v1.1 system is best (https://ufscommunity.org/news/medrangeweatherapp_v1p1/)**

UFS Meetings & Reports

- AMS Jan 2022
  - Special Session on the UFS R2O Project (**1B, J2B, 3B, Jan 24**)
  - UFS Community Modeling Forum (**Weds, Jan 26**)
  - EPIC Symposium (**J9, J10, J11, J12, Jan 24-26**)
  - UFS R2O Project Town Hall (**Thurs, Jan 27**)
- UFS Webinar Series *Monthly, Every Second Thursday 1pmMT/3pmET*
- Weeks 3-4/S2S Webinar *Monthly, Every First Monday 4pmMT/2pmET*
- Developmental Testbed Center (DTC) UFS Evaluation Metrics Workshop Report (Final Metrics Lists) METplus Training Series **(**Nov 29 2021 - May 1 2022)
- Forecasters Workshops Report
- Land Modeling Workshop Report (to release soon)

NOFO Opportunities to Collaborate with UFS

NWS/OSTI NOFO Projects (NGGPS, Weeks 3-4/S2S, HFIP):

FY22 Applications due on Feb 7, 2022

https://www.weather.gov/sti/stimodeling

OAR/WPO NOFO Projects (JTTI, CTB, S2S):

FY22 Applications Closed on Nov 17, 2021

https://wpo.noaa.gov/NOFO

FY22 NWS/OSTI NOFO

(NOAA-NWS-NWSPO-2022-2007072 on grants.gov)

UFS R2O

Eligible Applicants: US institutions of higher education , industry, non-profit, state, local, Indian government

Three Competitions: 1) NGGPS; 2) Weeks 3-4/S2S; and 3) HFIP

Total Amounts: Approximately $3,000,000 for the first year of multi-year (2 or 3 year) projects; Maximum $300K per project

Point of Contact (POC) & Readiness Level (RL):
POC from NCEP centers or UFS R2O teams
RL from 4 to 7 with target operational systems

Timeline:
Application due: Feb 7, 2022
Project start date: Sep 1, 2022

NGGPS: Advance the UFS Medium-Range Weather Application, coupling among atmosphere, ocean, wave, ice, land and atmospheric composition, data assimilation and ensemble techniques, post-processing forecast tools

Weeks 3-4/S2S: Advance the UFS Subseasonal (GEFS) and Seasonal (SFS) Applications, coupled data assimilation, reanalysis, process-level diagnostic tools and validation/verification metrics

HFIP: Advance the UFS Hurricane Application, improve operational hurricane forecasts to meet societal requirements to save lives and mitigate loss of economic disruption

Contact: nws.sti.modeling.team@noaa.gov

Season Forecast System (SFS v1)

- SFSv1 will replace the Climate Forecast System version 2 (CFSv2) to provide guidance for seasonal outlooks in FY26
- Improve representation of slowly varying processes in the land, ocean, sea ice and aerosols and their interactions with atmosphere
- Improve representation of atmosphere-ocean-ice coupling, atmosphere-land coupling, stratosphere-troposphere coupling, and simulation of climate modes such as ENSO, MJO and QBO
- Improve ensemble design to best estimate uncertainties, and conduct multi-decade, coupled reanalysis and reforecasts to calibrate real-time forecasts

Questions?

For more information:

- **UFS-R2O Project**: **https://vlab.noaa.gov/web/ufs-r2o**
  - Jamese Sims (NWS OSTI) jamese.sims@noaa.gov
  - Vijay Tallapragada (NWS EMC) vijay.tallapragada@noaa.gov
- **UFS**: **https://ufscommunity.org/**
  - Hendrik Tolman (NWS OSTI) hendrik.tolman@noaa.gov
  - Ricky Rood (U-Michigan) rbrood@umich.edu
- **EPIC**:
  - Maoyi Huang (OAR WPO) maoyi.huang@noaa.gov
- **JTTI**:
  - Chandra Kondragunta (OAR WPO) chandra.kondragunta@noaa.gov