Future Evolution of NCEP Operational Prediction Systems

NATIONAL WEATHER SERVICE

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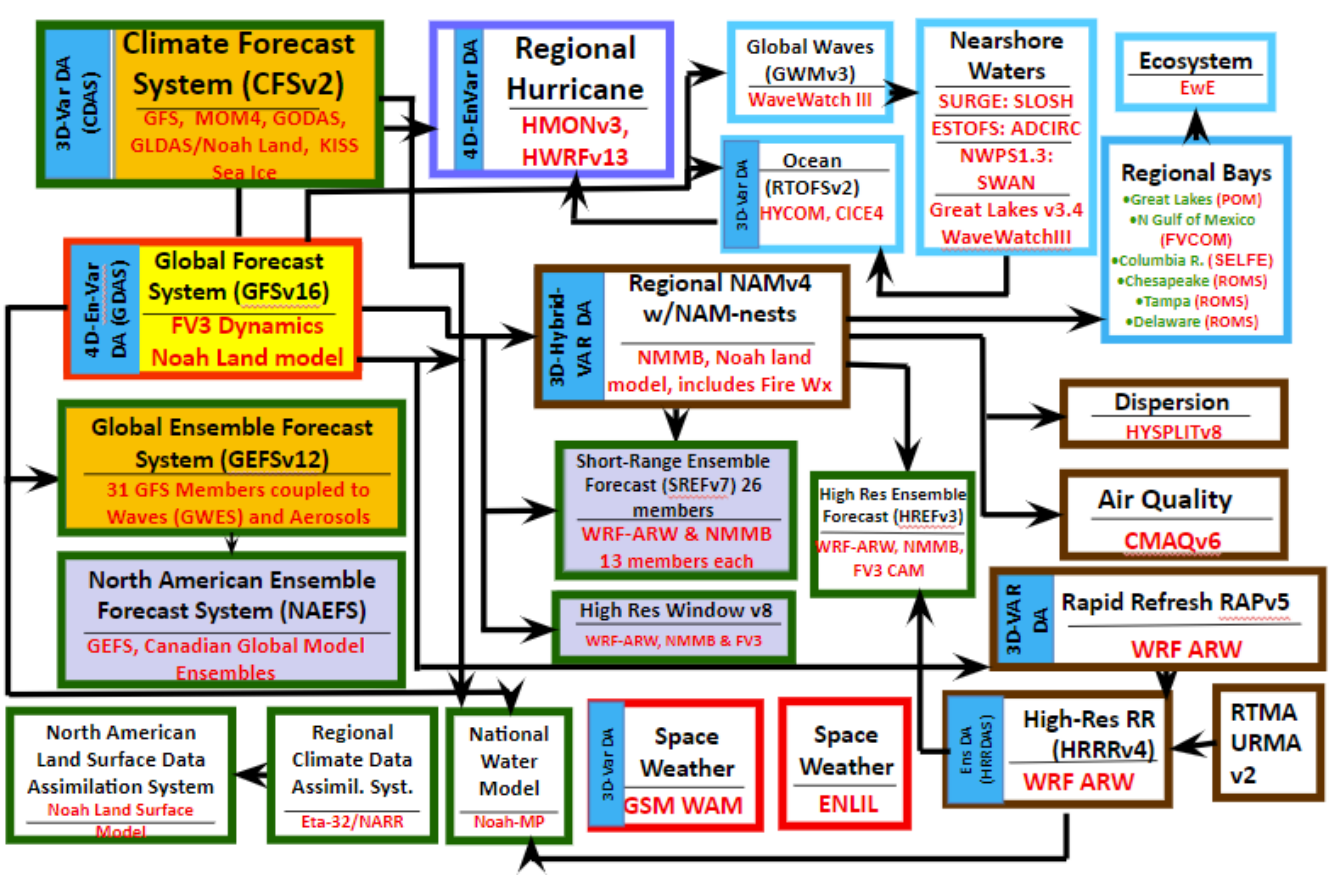
NOAA/NWS/NCEP Environmental Modeling Center

NMME: Meeting Future Needs Workshop, June 21, 2023

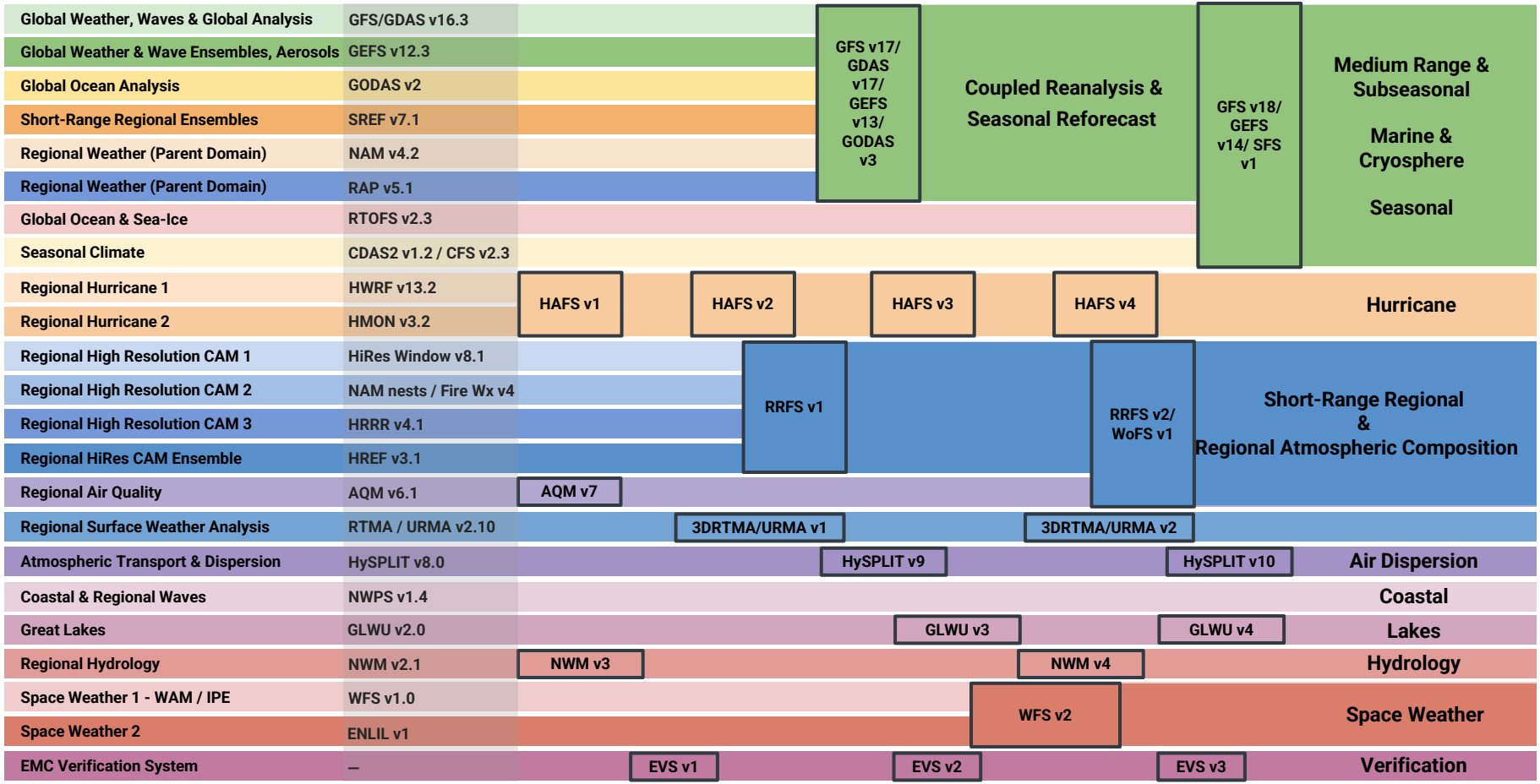
Outline

- Current State-of-the-art of NCEP Production Suite
- NCEP Production Suite Simplification
- UFS Coupled Model for MRW/S2S
- Challenges & Opportunities

Current State of NCEP Production Suite



- NCEP operates more than 38 distinct modeling systems to meet the stakeholder requirements
- Quilt of Models developed to meet the service needs over a long period of time
- Simplification of NCEP Production Suite is critical to reduce redundancy and improve efficiency



Transition to UFS Applications

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE

n plan

Purpose:

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NCEP ENVIRONMENTAL MODELING CENTER (EMC)

5-YEAR IMPLEMENTATION PLAN (FY23-FY27)

TRANSITIONING NCEP PRODUCTION SUITE TO UFS APPLICATIONS

Version 1.0 (December 31, 2022)

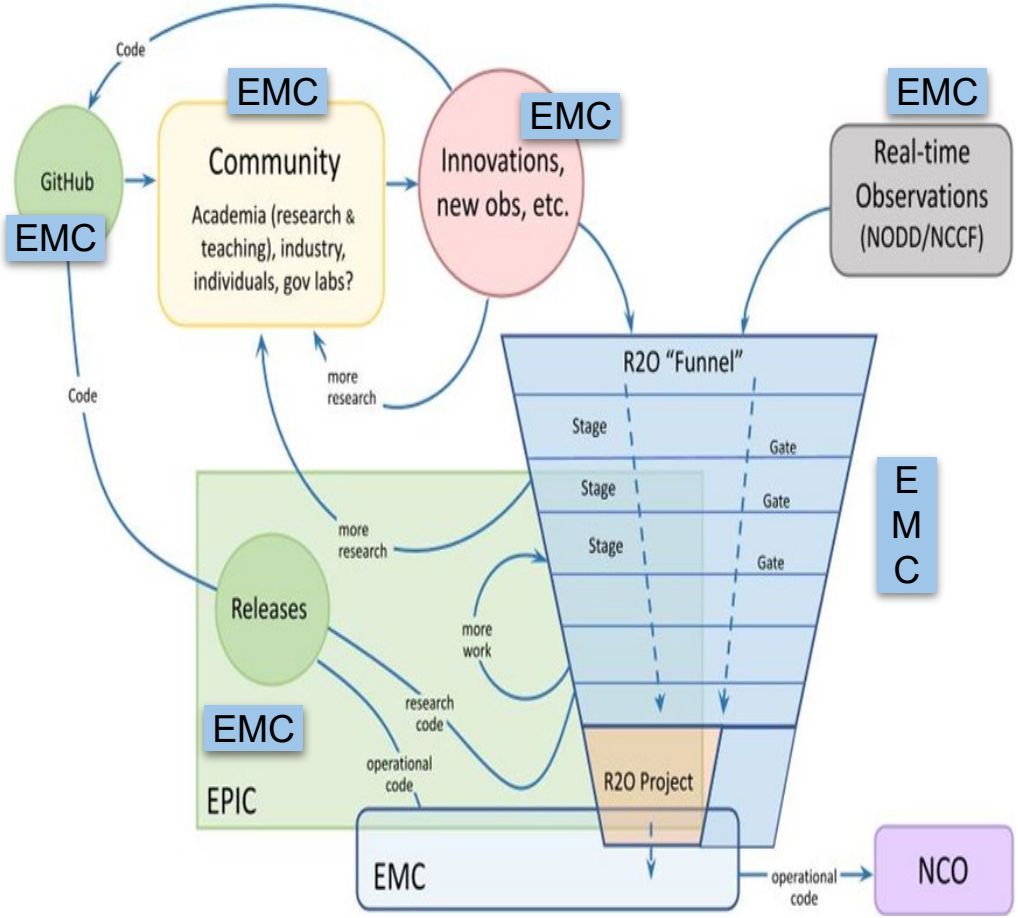
The UFS Community

NOAA Programs that Support UFS

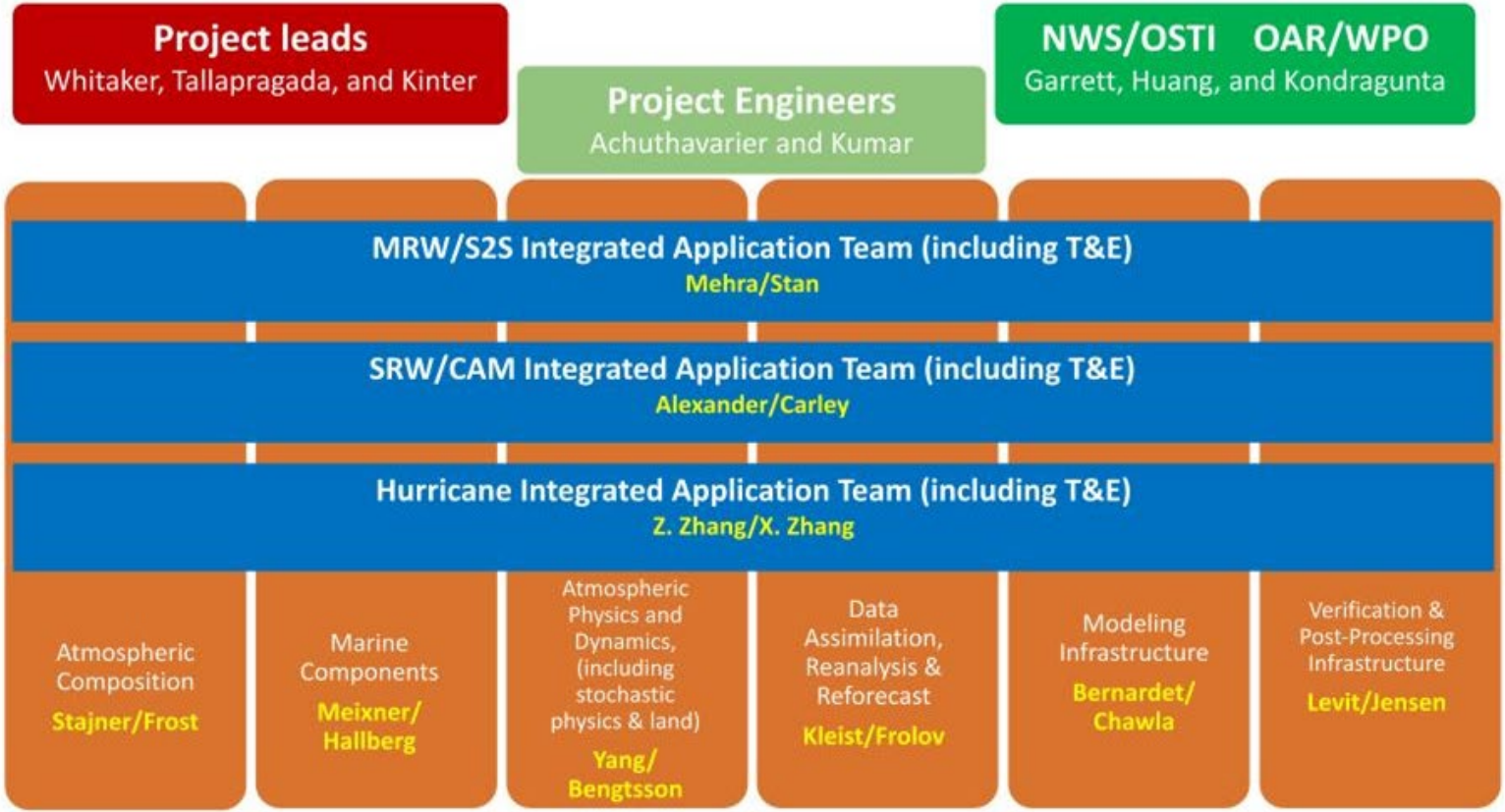
- **NWS/OSTI Modeling Programs:** NGGPS, Weeks 3&4, HFIP
- **OAR/WPO Programs:** EPIC, JTTI, S2S, Atmospheric Composition
- **Disaster Supplementals FY18, FY19, FY22 and Bipartisan Infrastructure Legislation FY22**

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-R2O Project



*Not all UFS Applications are currently supported by the UFS-R2O Project

UFS-based Coupled Model Development

- Each of these is a working coupled application, which is either operational or under active development

FV3GFS – WW3
Impact of waves on atmospheric stress at ocean surface

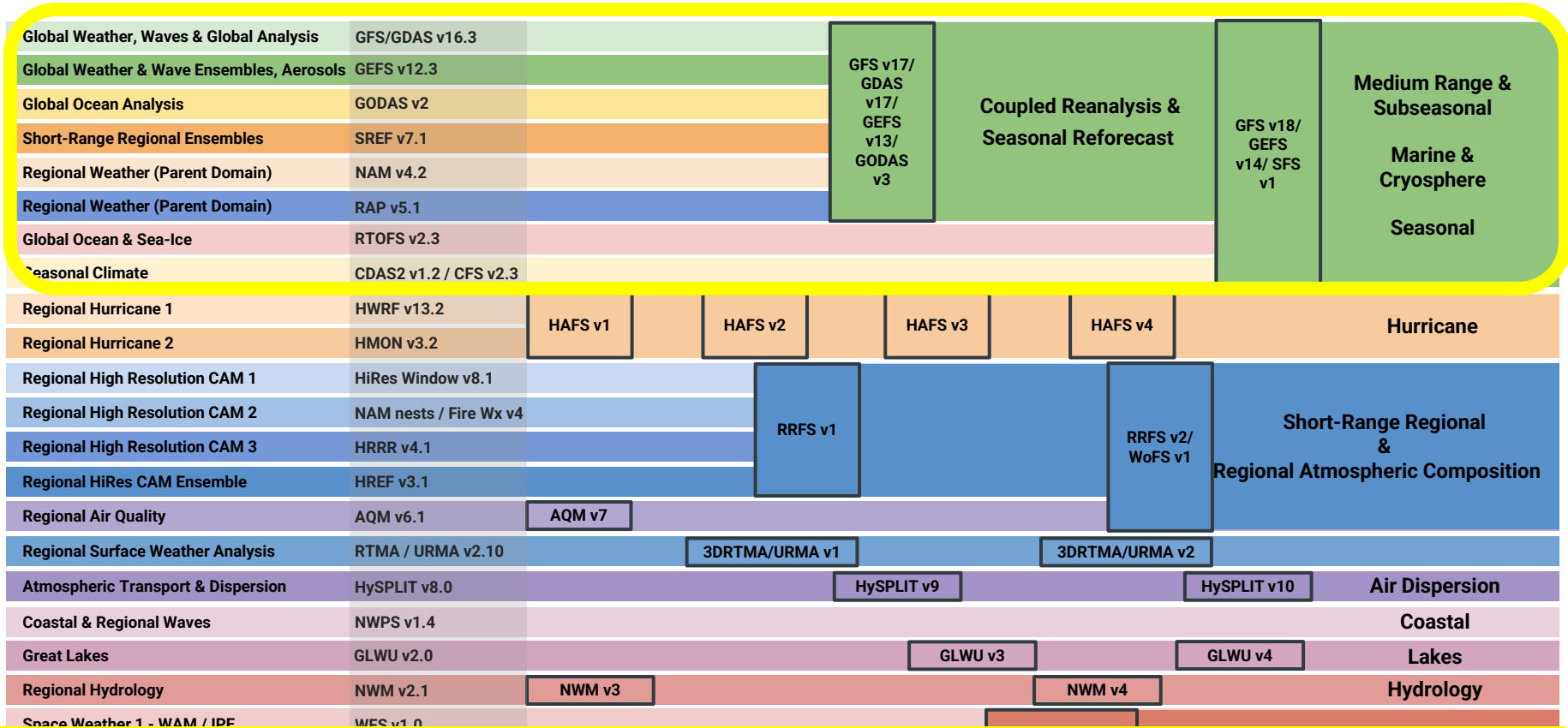
FV3GFS – CHEM
Atmosphere and Aerosols interaction

ADCIRC – WW3 – NWM
Wave, Surge and Inundation coupling

DATM – MOM6 – CICE6
Ocean Ice coupled model with Data Atmosphere for developing Marine DA.

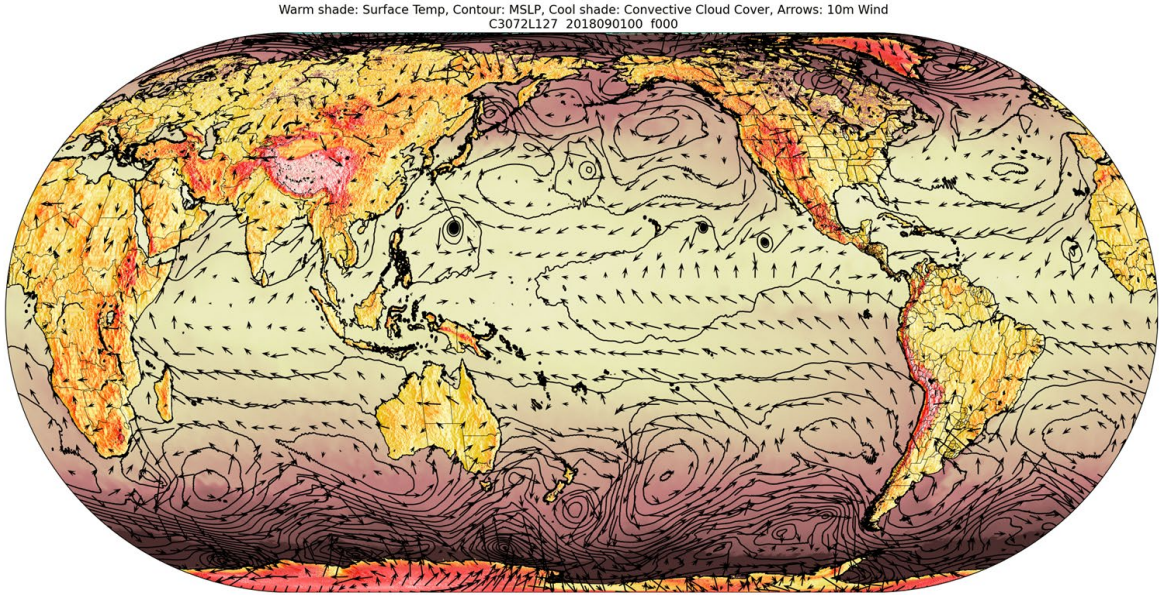
FV3HAFS- HYCOM
Hurricane Analysis and Forecast System

FV3GFS – MOM6 – CICE6 – WW3 – NOAH-MP – GOCART
Global MRW-S2S Applications



MRW/S2S: Unifying Global Systems (GFS, GEFS & SFS)

MRW/S2S: Building a Six-Way Global Coupled Unified Forecast System
For future GFS, GEFS and SFS



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.

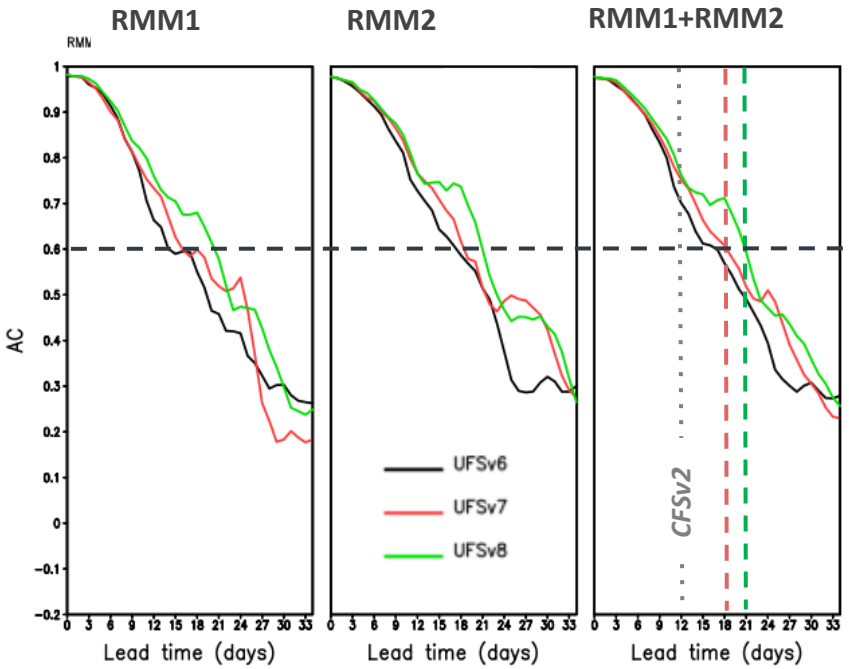
Coupled UFS Prototypes 1–8

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				

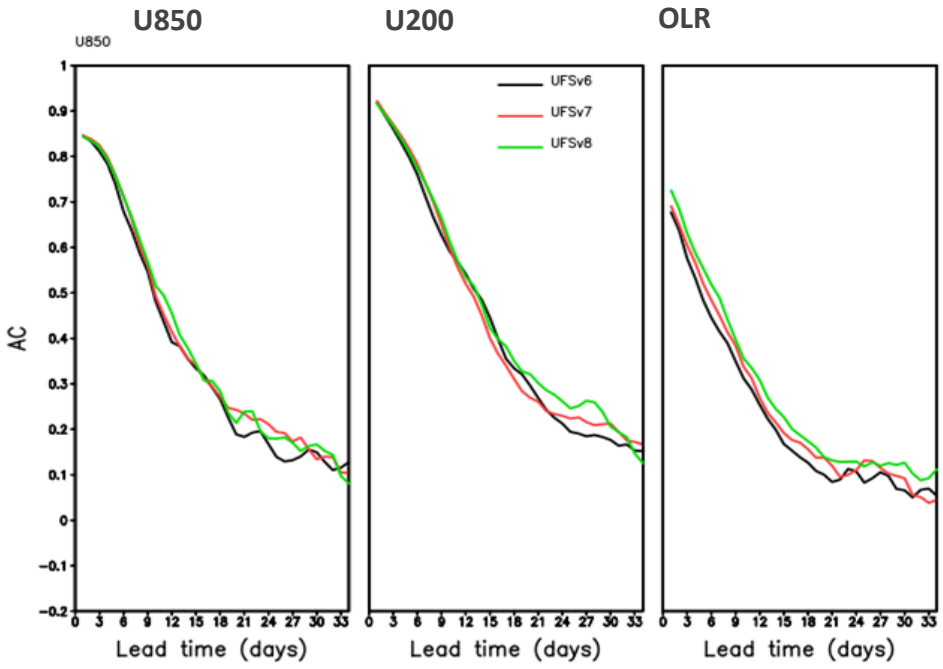
(P8+ includes one-way coupled aerosols)

MJO Skill from various UFS Coupled Model Prototypes

AC for RMM1/RMM2/RMM1&RMM2



AC for Equatorially Filtered U850/U200/OLR

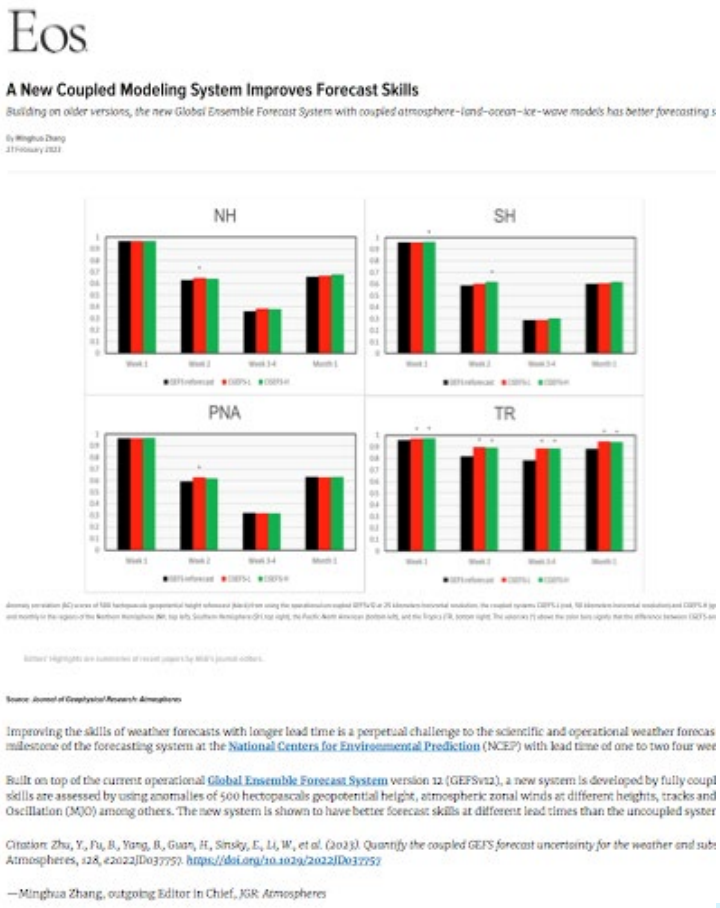


- MJO skill highest of all prototypes
- 21 days to AC=0.6
- Largest improvement from OLR

NCEP Global Ensemble Forecast System (Configuration)

Components		V12 (Oct. 2020)	V13 (Q2FY25)
Atmos	Dynamics	FV3 (Finite-Vol Cubed-Sphere) GFSv15	FV3 (Finite-Vol Cubed-Sphere) GFSv17
	Physics	saSAS, GFDL-MP, K-EDMF, oroGWD	saSAS, **Thompson-MP, sa-TKE-EDMF, uGWD**
	Initial perturbation	EnKF f06 (previous cycle)	**EnKF f00 (early cycle)**
	Model uncertainty	5-scale SPPT and SKEB	5-scale SPPT, SKEB, **SPP, CA**
	Boundary (ocean surface)	NSST + 2-tiered SST	NSST
	Resolutions	C384L64 (25km)	C384**L127** (25km)
Land	Model	NOAH-LSM	**NOAH-MP**
	Initial perturbation	N/A	**Soil moisture**
Ocean	Model	N/A	**MOM6 (0.25^{o}L75)**
	Initial perturbation	N/A	**SOCA-Ens**
	Model uncertainty	N/A	**5-scale oSPPT and ePBL**
Ice	Model	N/A	**CICE6 (0.25^{o})**
	Initial condition	N/A	**SOCA-Ens**
Wave	Model	WW3 (one way)	WW3 (**2-way**) (0.25^{o} lat/lon grid)
Aerosol	Model	GOCART (one way)	GOCART (**2-way**)

GEFSv13 Prototype Experiments - EOS highlights



Eos

A New Coupled Modeling System Improves Forecast Skills

Building on older versions, the new Global Ensemble Forecast System with coupled atmosphere–land–ocean–ice–wave models has better forecasting s

By Minghua Zhang
27 February 2023

Source: *Journal of Geophysical Research: Atmospheres*

Improving the skills of weather forecasts with longer lead time is a perpetual challenge to the scientific and operational weather forecas
milestone of the forecasting system at the National Centers for Environmental Prediction (NCEP) with lead time of one to two four wee

Built on top of the current operational Global Ensemble Forecast System version 12 (GEFSv12), a new system is developed by fully coupl
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Citation: Zhu, Y., Fu, B., Yang, B., Guan, H., Sinsky, E., Li, W., et al. (2023). Quantify the coupled GEFS forecast uncertainty for the weather and sub
Atmospheres, 128, e2022JD037757. https://doi.org/10.1029/2022JD037757

—Minghua Zhang, outgoing Editor in Chief, JGR: Atmospheres

Editor's highlights - JGR Atmosphere (2023)

Source: *Journal of Geophysical Research: Atmospheres*

Improving the skills of weather forecasts with longer lead time is a perpetual challenge to the scientific and operational weather forecast community. In a new study, Zhu et al. [2023] describe one milestone of the forecasting system at the National Centers for Environmental Prediction (NCEP) with lead time of one to two four weeks.

Built on top of the current operational Global Ensemble Forecast System version 12 (GEFSv12), a new system is developed by fully coupling the atmosphere, land, ocean, ice and waves. Forecasting skills are assessed by using anomalies of 500 hectopascals geopotential height, atmospheric zonal winds at different heights, tracks and intensity of tropical cyclones, and the Madden-Julian Oscillation (MJO) among others. The new system is shown to have better forecast skills at different lead times than the uncoupled system.

Citation: Zhu, Y., Fu, B., Yang, B., Guan, H., Sinsky, E., Li, W., et al. (2023). Quantify the coupled GEFS forecast uncertainty for the weather and subseasonal prediction. Journal of Geophysical Research: Atmospheres, *128, e2022JD037757. https://doi.org/10.1029/2022JD037757*

—Minghua Zhang, outgoing Editor in Chief, *JGR: Atmospheres*

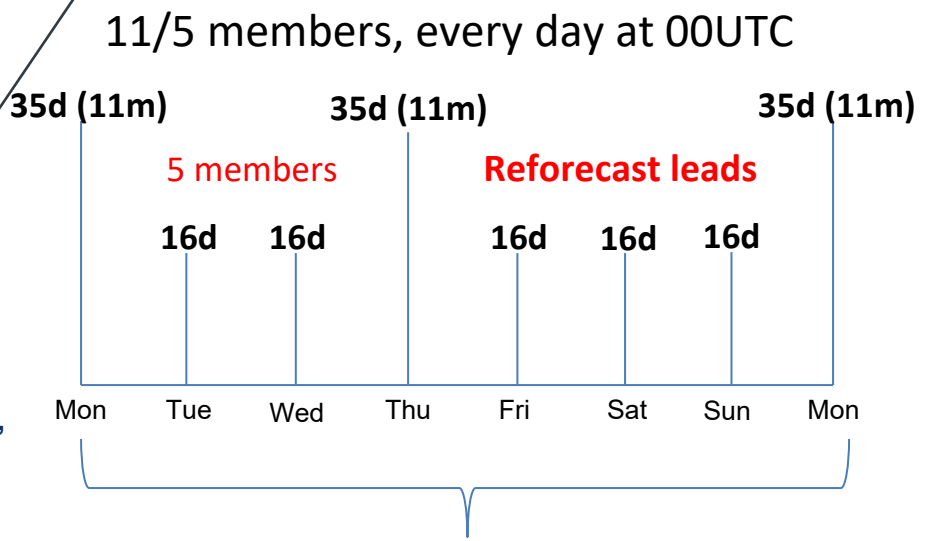
GEFSv13 Reanalysis

- **Replay analysis**
  - 30 years (1994- 2023)
  - HR1 model
    - Atmos-C384L127; Ocn-MOM6 ¼ dL75; Ice-CICE6 ¼ d and et al.
  - ERA5 atmosphere reanalysis
  - ORAS5 ocean analysis
  - Ice and wave - self cycling
  - IAU process
  - 6 streams (6 years for each stream with one-year spinup)
  - On cloud (AWS)

GEFSv13 Reforecasts

- Reforecast
  - 30 years (1994-2023)
  - EMC runs on WCOSS2
- Model configuration
  - Ensemble prototype 4 (HR1 at C384 ¼ d resolution)
- Configuration
  - 5 members, out to 16 days at each 00UTC initial time
  - 11 members, out to 35 days (or 48 days) at Monday and Thursday*
    - *under discussion of optimum way to generate 48 days hindcast
- HPC resources
  - One year: 1400 nodes on WCOSS2 (devmax?)
- Selected variables to save on disk
  - Work on the details
- Replay reforecast demonstration
  - 19 months
  - evaluations from EMC (6 reports); CPC (3 reports), OWP (1 report)

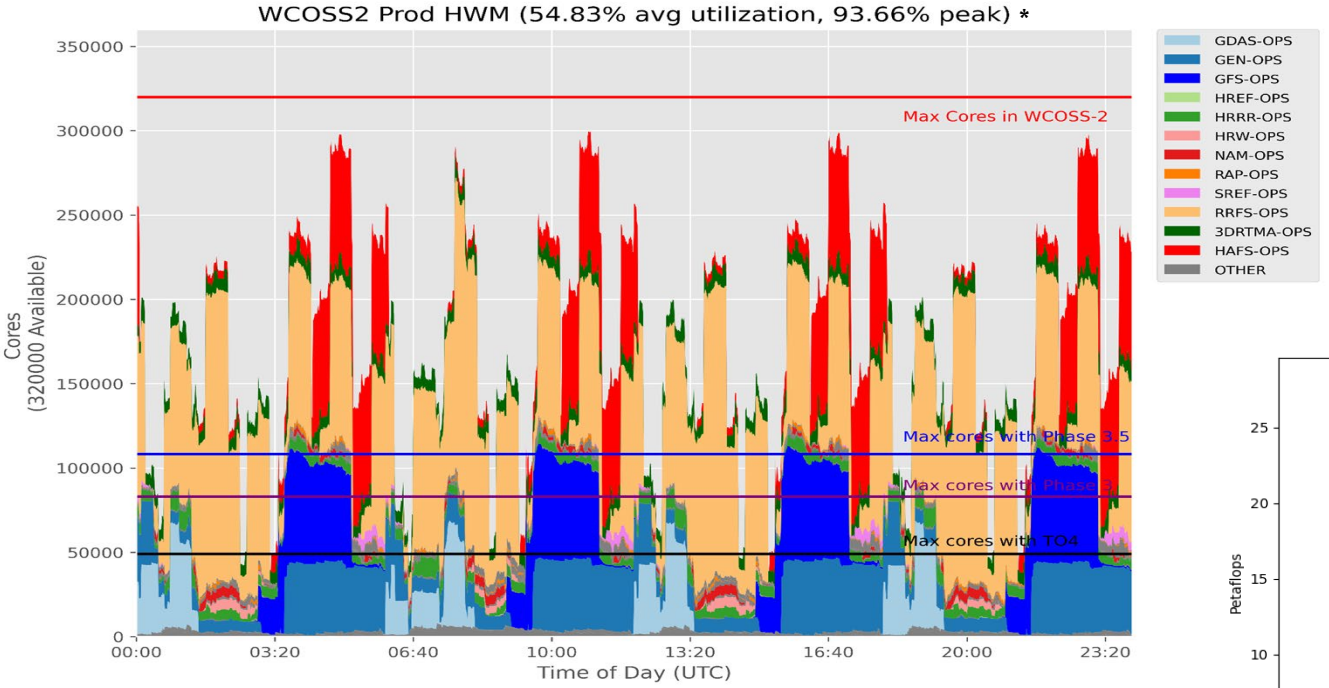
CPC and OWP have approved GEFSv13 configurations through 19 months reforecast demonstration

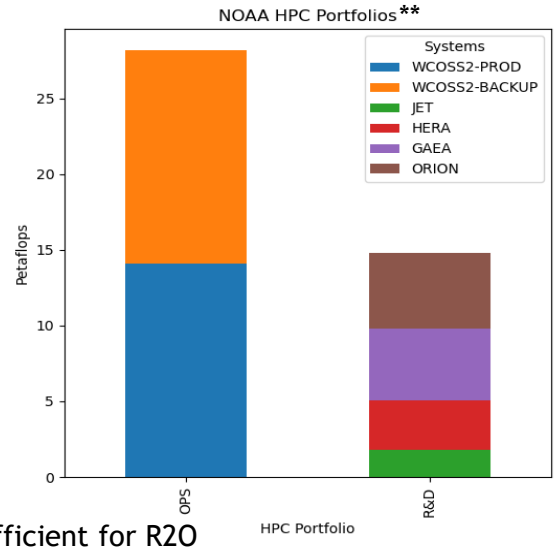


SFSv1 Development Priorities

- Coupled reanalysis should provide balanced ***initializations*** across interfaces between coupled model components that maximize source of long-term predictability, e.g. from ***ocean, sea ice and land***
- Coupled model should minimize systematic drift from initial conditions and minimize false alarms for extreme events, e.g. overconfident in ***El Nino forecast***
- Ensemble forecasts should provide best ***estimation of uncertainties***
- Improvements in physics/dynamics and model components should ***reduce systematic biases*** and improve forecast skill
- ***SFS infrastructure*** should provide critical support to model coupling, testing, evaluation and eventual transition to operations
- SFS developments should be incorporated into **UFS repositories**

Challenges: HPC Resources





* WCOSS2 is expected to increase capacity by about 20% later this year

** Significant increase in R&D HPC is anticipated from DRSA and IIJA, still may be insufficient for R2O

Future evolution of NCEP Production Suite: Key Points

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- Future evolution of NCEP Production Suite is expected to be simplified using UFS Coupled Model Applications
- GEFSv13 and SFSv1 will become flagship NCEP Operational Applications for Ensemble based S2S predictions **
- EMC plays an important role in the UFS Community for O2R and R2O
- Building sustainable partnerships with the research community is critical

Thank you!