Model Development Priorities at EMC

NATIONAL WEATHER SERVICE

The Team
AI4NWP Workshop
November 28, 2023

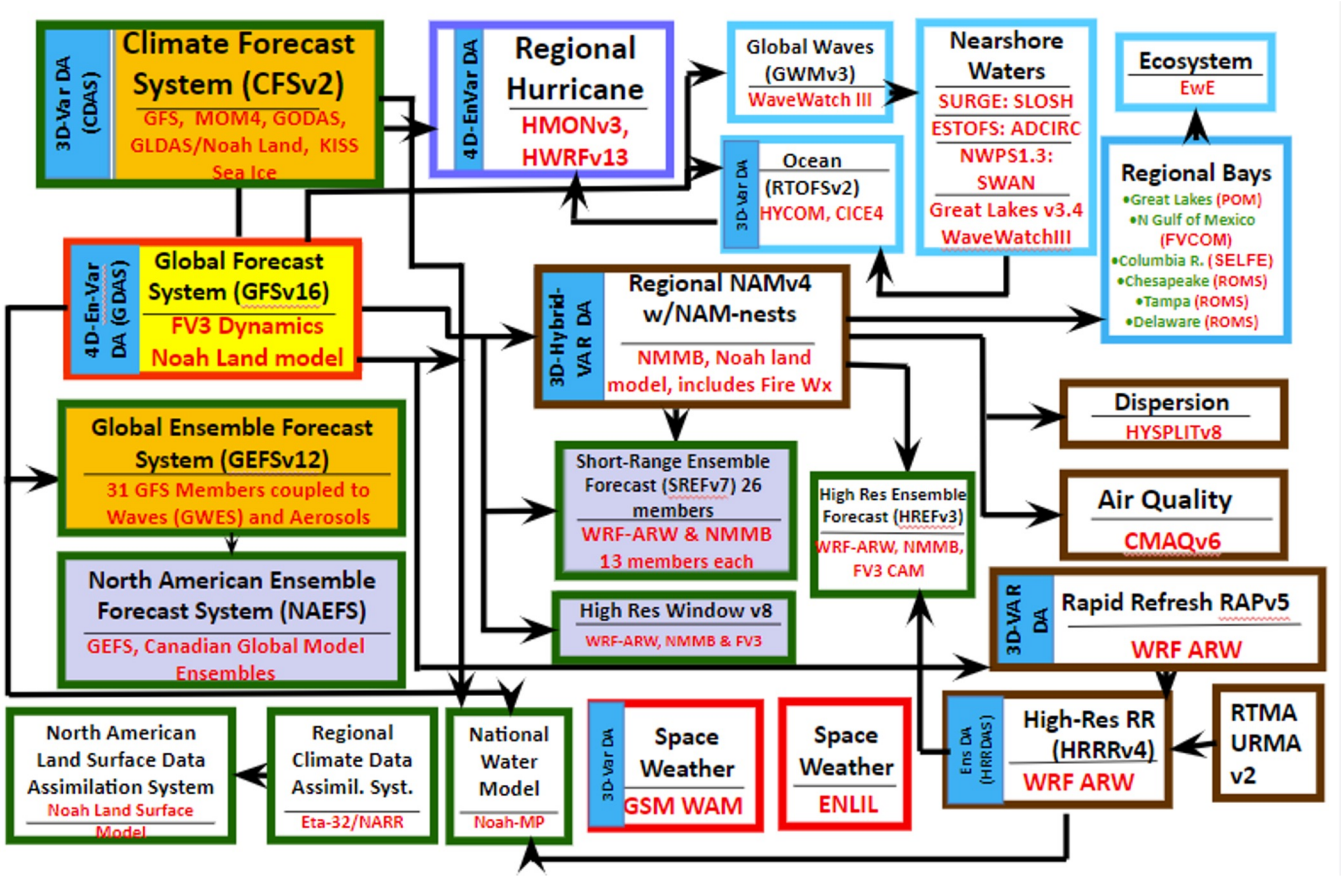
The NCEP Production Suite of the Future

NATIONAL WEATHER SERVICE

The Team
AI4NWP Workshop
November 28, 2023

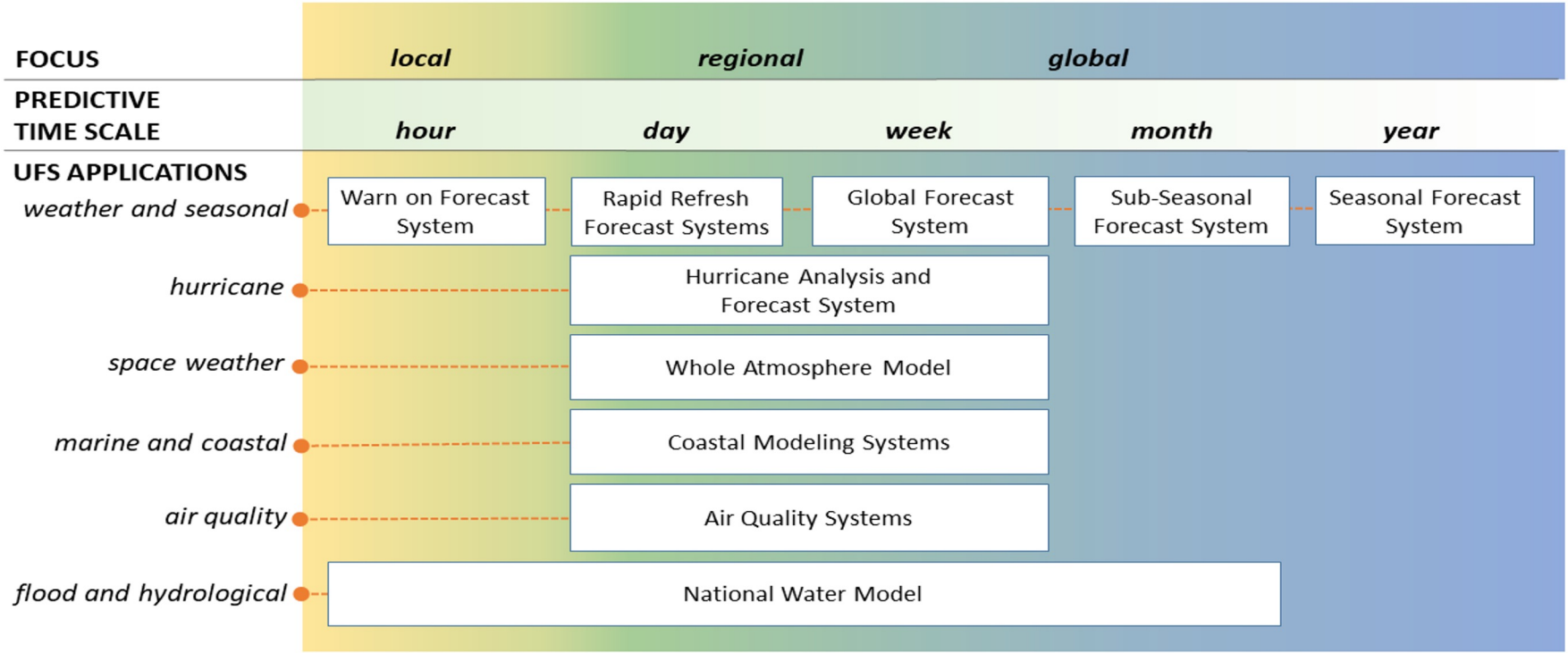
- **Acknowledgements**
  - All of the outstanding scientists and engineers at the Environmental Modeling Center, and Collaborators within NOAA, at other Federal agencies, Academia, and the Private Sector
- **Reference**
  - EMC 5-Year Implementation Plan

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

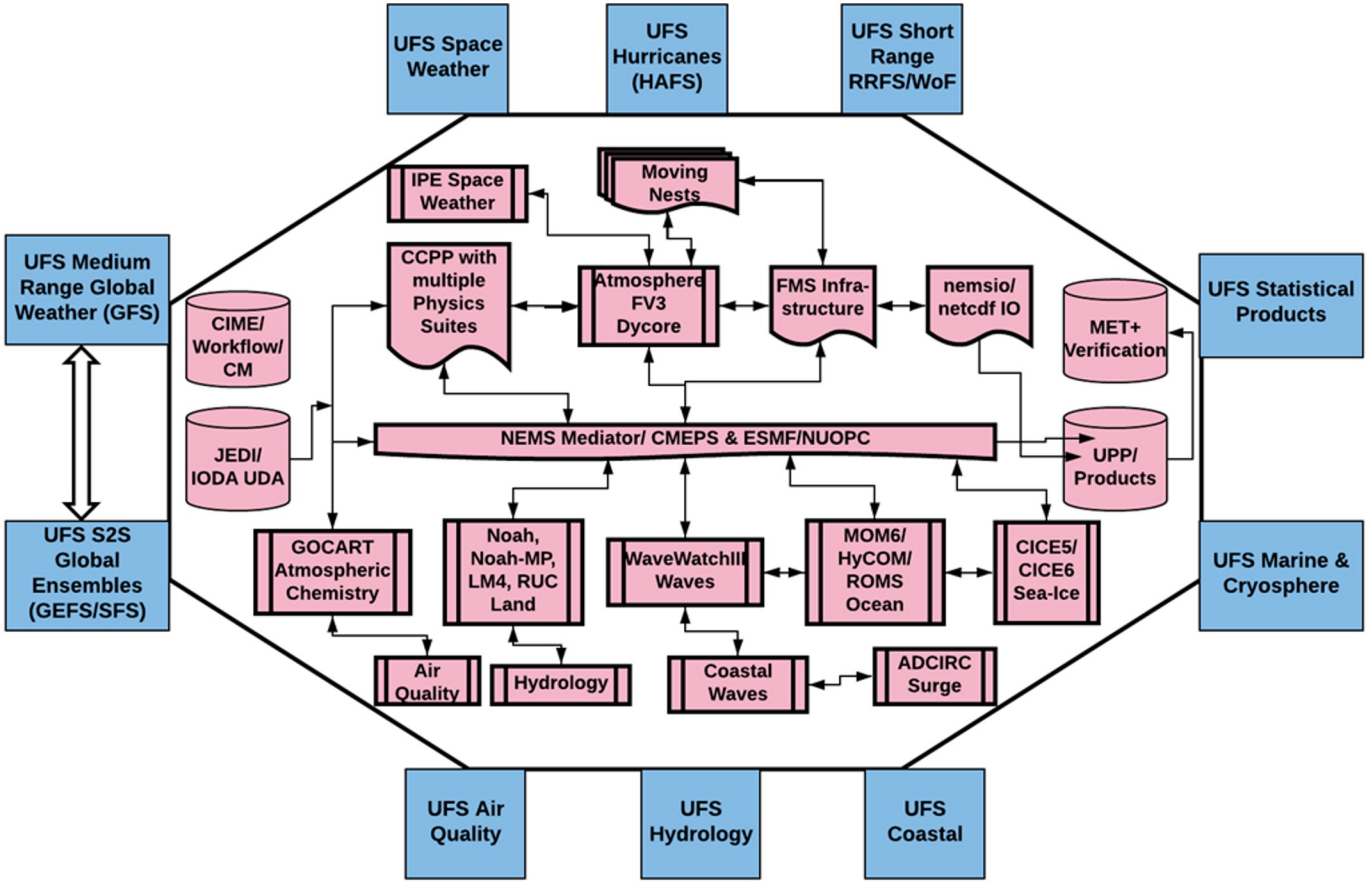
The Goal: Transition to UFS Applications and Simplify NCEP Production Suite



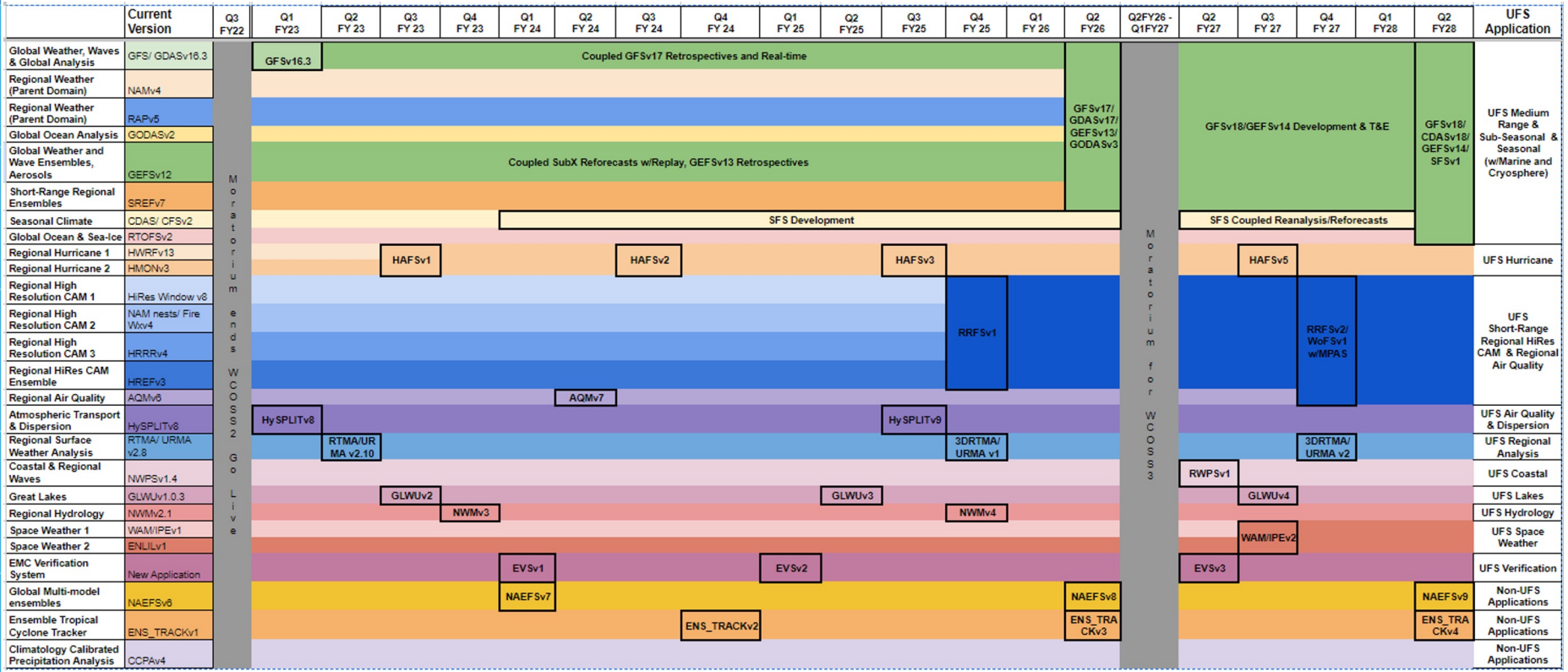
NPS Transitioning to UFS Applications

"UFS is configurable into multiple applications that span local to global domains and predictive time scales from less than an hour to more than a year."

Conceptual UFS applications in production covering all NPS applications, maintaining the dependencies between the applications and products.

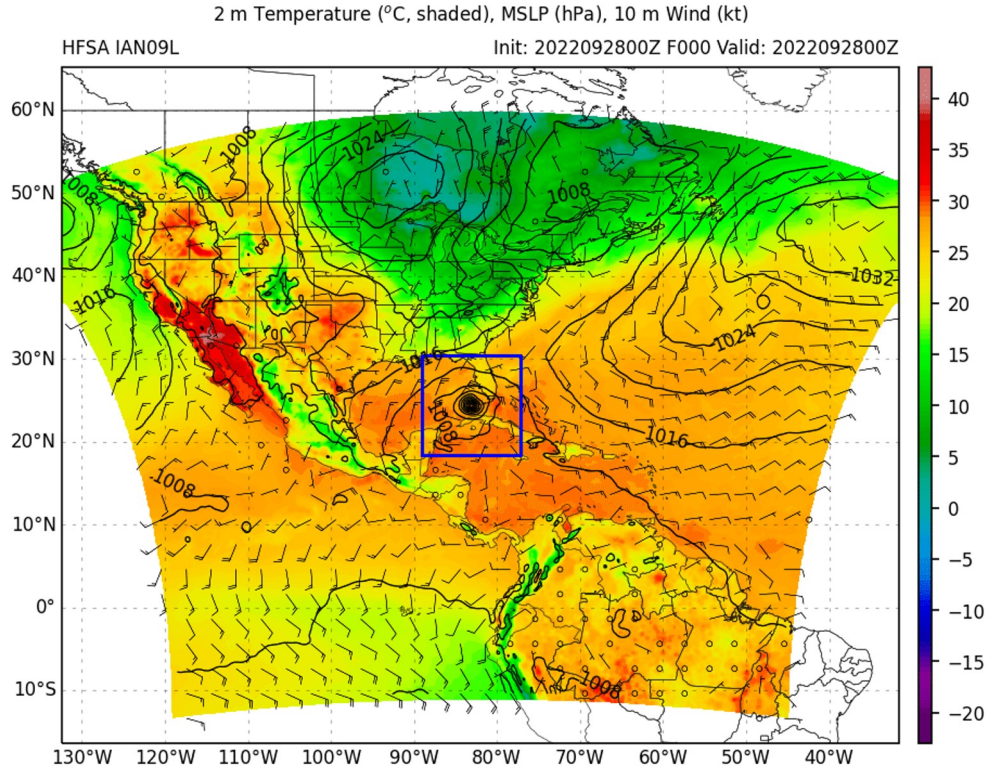


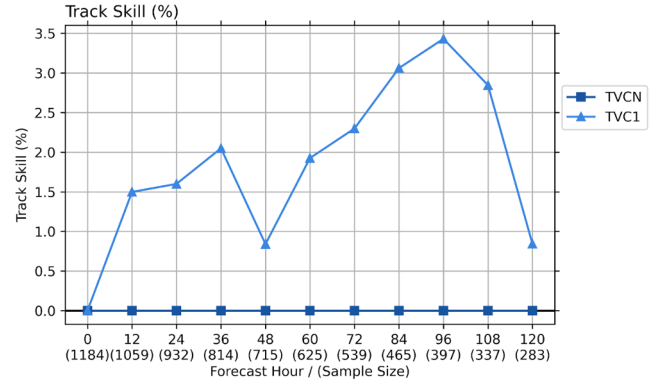
Notional Schedule for Transition to UFS Applications

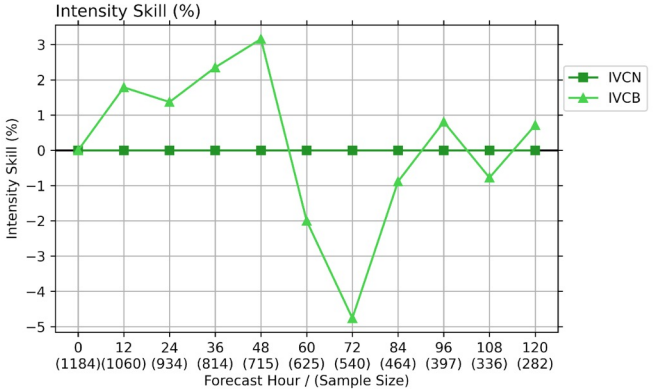


Hurricane Analysis and Prediction System

HAFSv1 Approved for Operational Implementation for 2023 Hurricane Season

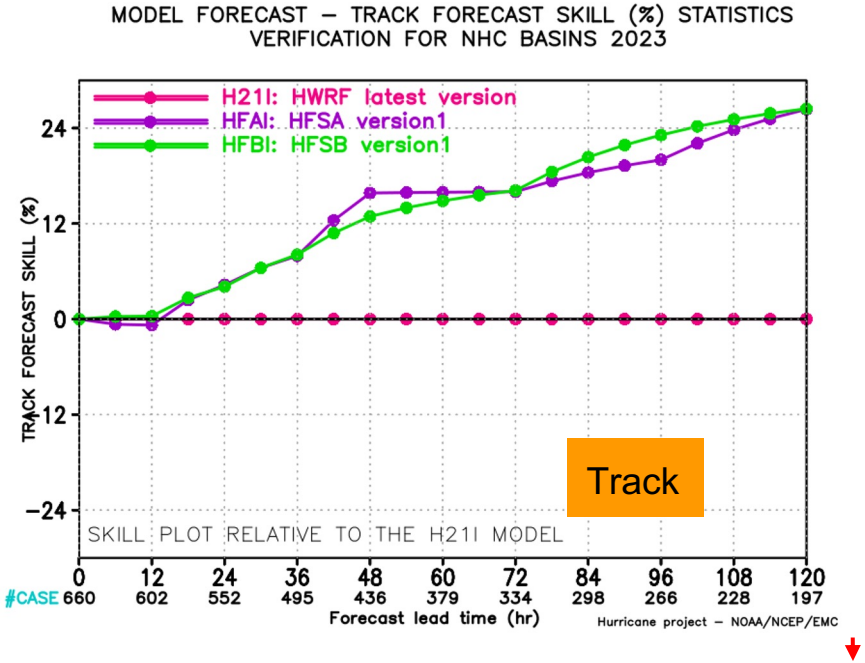


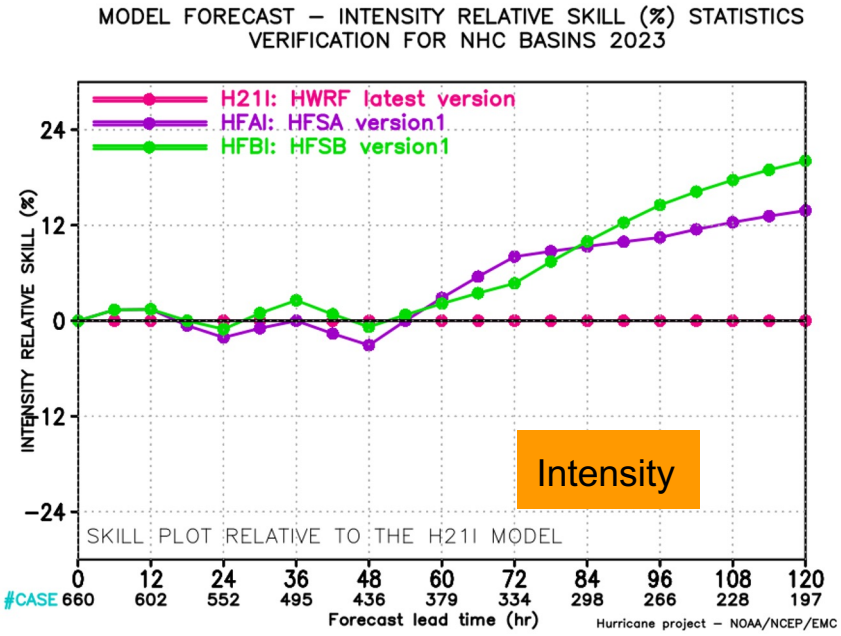




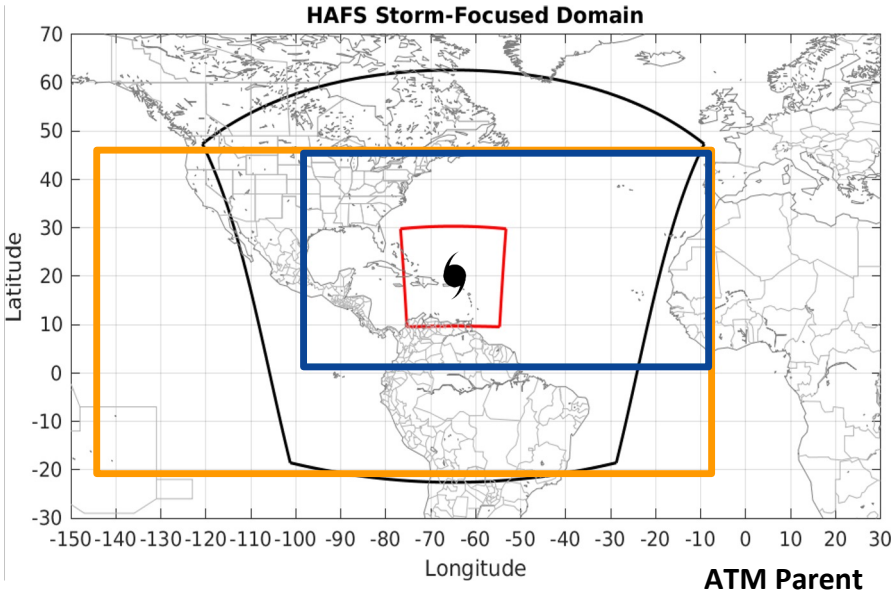
NOAA's New Generation Hurricane Model HAFS Forecast Skills Relative to Legacy HWRF

All 2023 Storms in NHC Basins

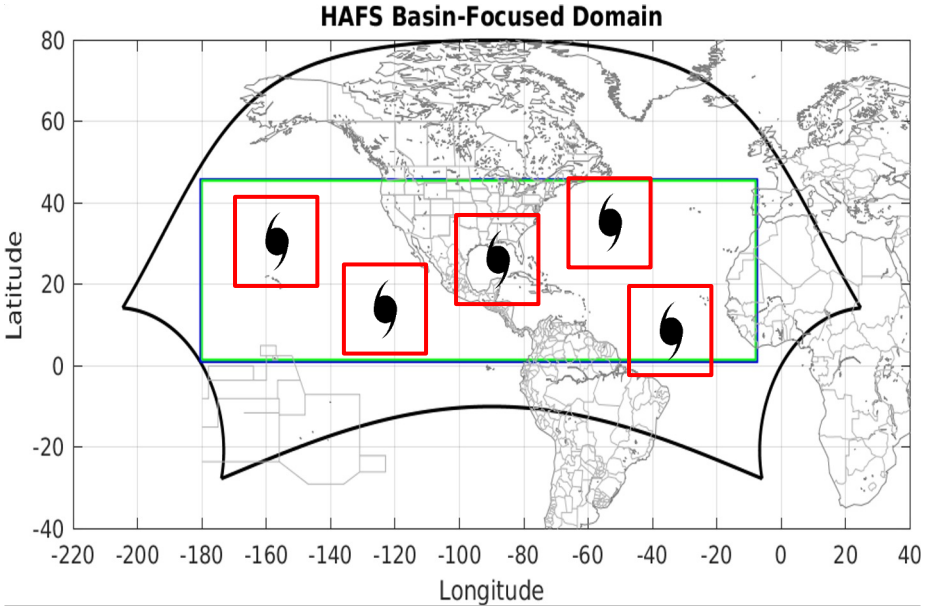




HAFS Development Priorities: future innovations

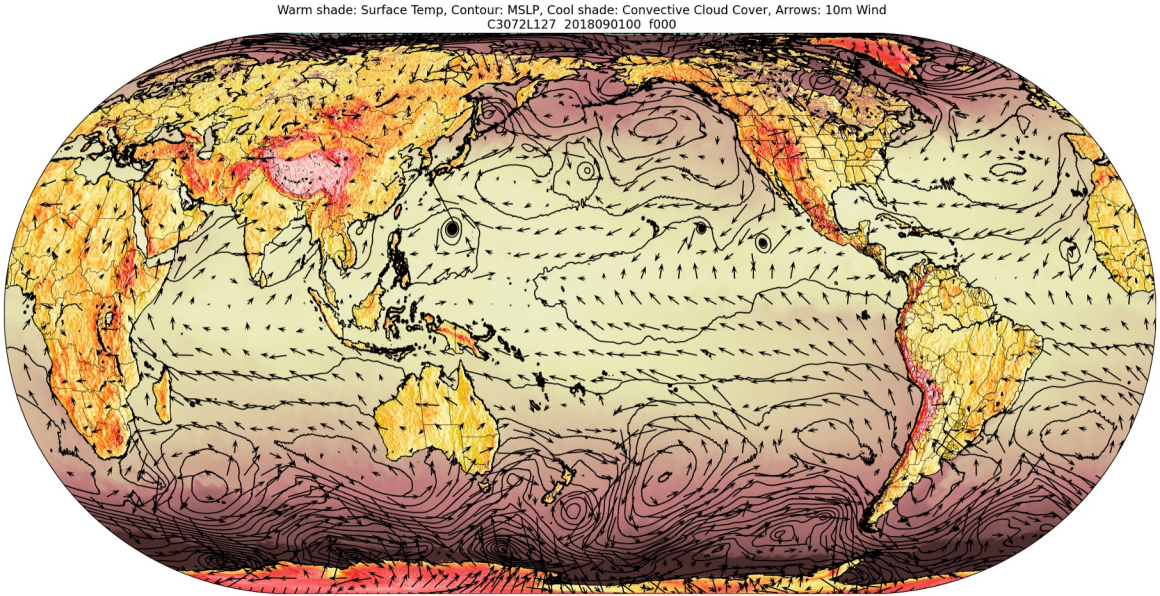


ATM Parent
ATM Nest
HYCOM Ocean
WWIII Wave



Global Coupled Prediction Systems

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)

GFSv17 Development Priorities

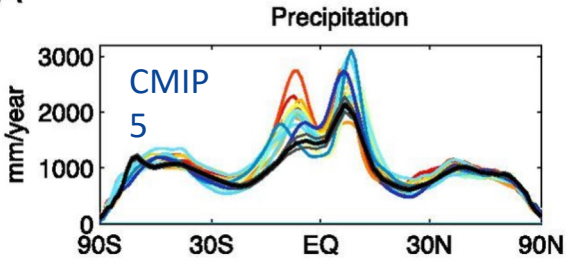
- Coupled forecast model (atm, land, ocn, ice, wav)
- Improved DA with marine JEDI (more later)
- Physics improvements including Noah-MP land model and Thompson Microphysics
- Unstructured Wave grids w/2-way coupling
- Higher resolution (9-km target)
- Improve on known issues in GFSv16
- Consolidation of NCEP production suite
  - GODAS combined in Coupled GDAS
  - Retirement of NAM and RAP

GEFSv13 Development Priorities

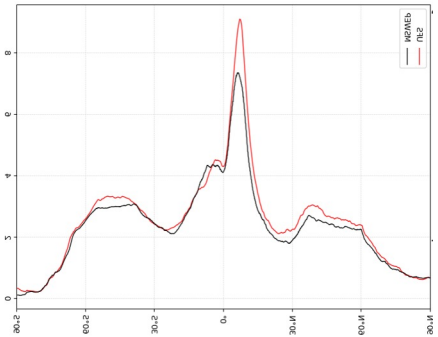
- Have the same model configuration as of GFSv17 (Latest UFS coupled forecast model)
- Include interactive aerosols in all ensemble members
- Early cycle EnKF analysis for ensemble initial perturbations
- Advanced model stochastics for all component models
- Reanalysis/reforecast
- 30 years reforecast to support forecast calibration (and training)
- Extend forecast length to 48 days
- Improve on known issues in GEFSv12
- Consolidation of NCEP production suite
  - Retirement of SREF

No Double ITCZ in UFS P8 climate run

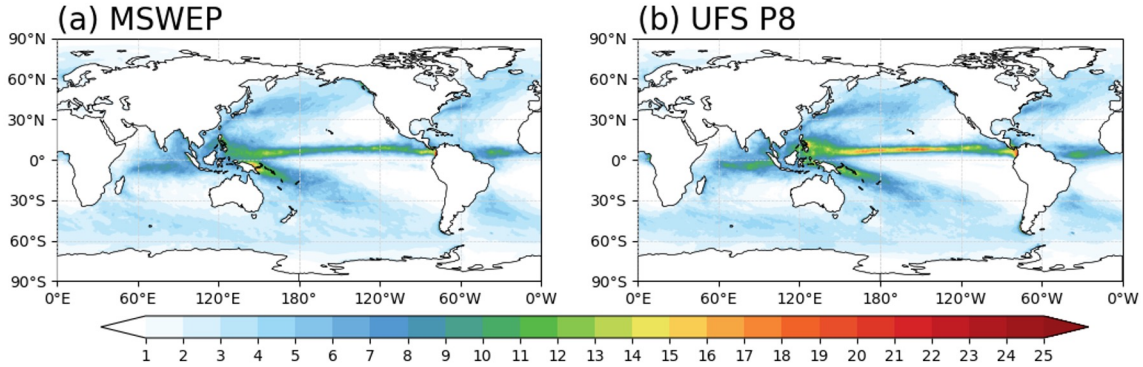
A



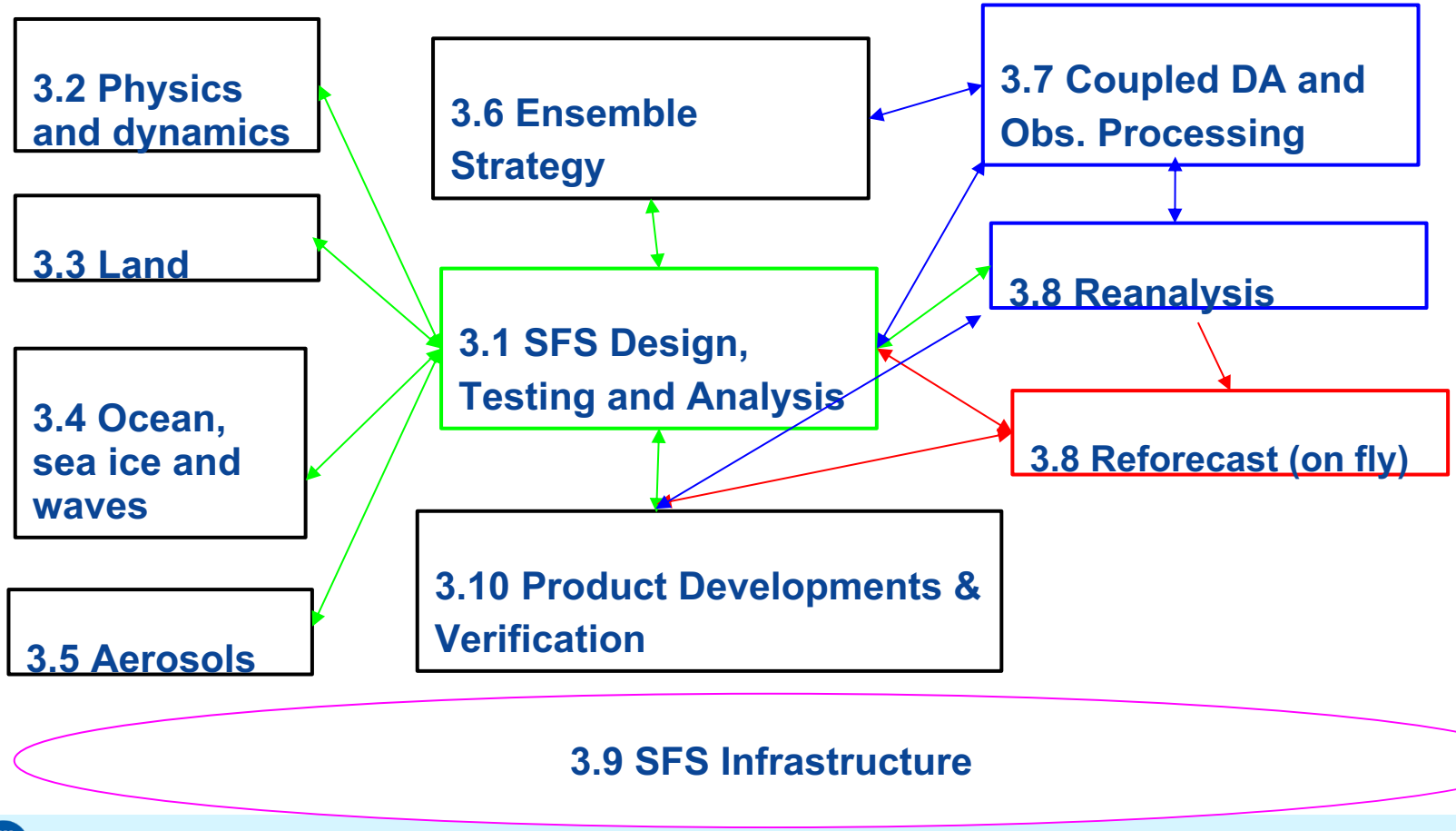
[Hwang and Frierson, 2013, PNAS]



UFS P8 overestimates ITCZ, but doesn't show double ITCZ



SFSv1 Planning: Ten Focus Areas

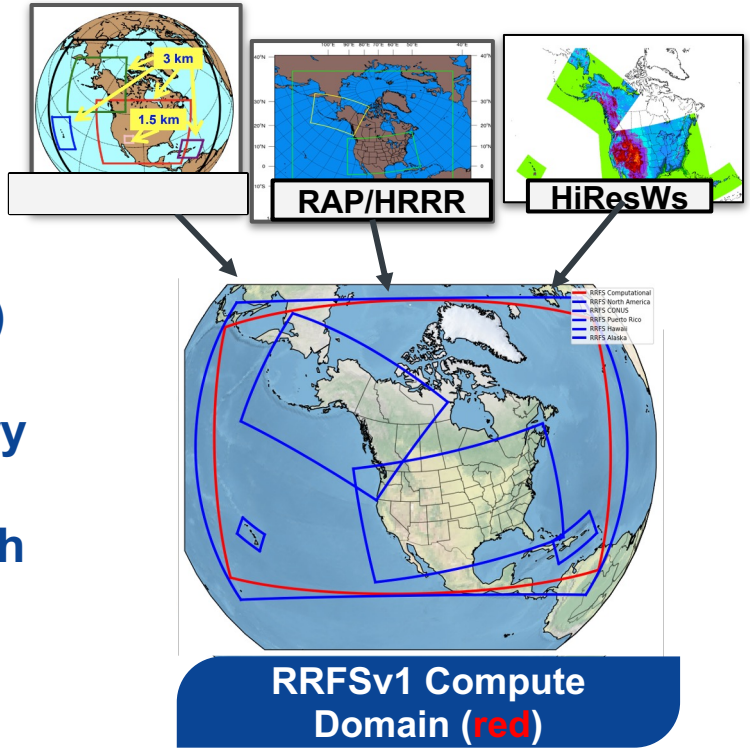


Regional Prediction System

Rapid Refresh Forecast System (RRFS)

A UFS Application

- FV3 dynamical core Limited Area Model
- Hourly updated
- 3 km grid spacing over North America
- 65 vertical layers
- Hybrid 3DEnVar assimilation (30 members)
- Includes Smoke & Dust
- Deterministic forecasts to *at least* 18h every hour
- Deterministic & Ensemble forecasts to 48+h every 6 hours

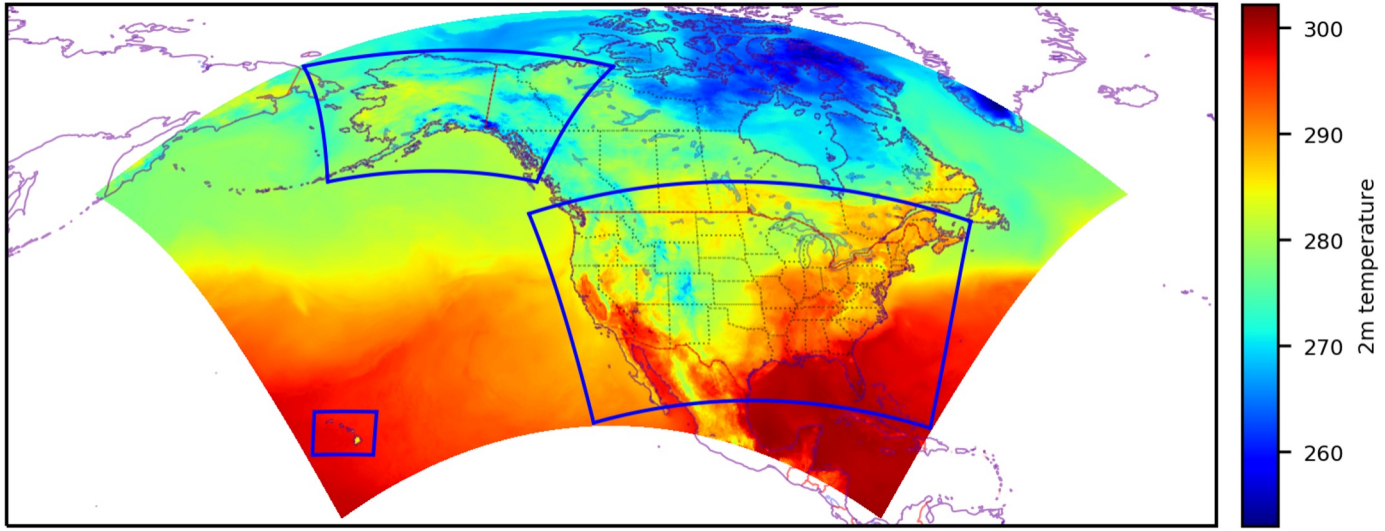


RRFSv2

- Possible transition from FV3 dynamical core to MPAS
  - Motivated by long standing performance issues with convective-storms
- Adding American Samoa and Micronesia Support
- Expanding ensemble forecast membership/cycles
  - Moving to single physics if not accomplished in v1
- Transition from GSI to JEDI data assimilation software/infrastructure
- Inclusion of more blending/overlapping-windows/multi-scale information for analysis
- Addition of new observations: DPQC radial velocities, GREMLIN, PBL height, all-sky radiances, etc…
- Transition to Noah-MP LSM, RRTMGP?, Air Quality/Chemistry?

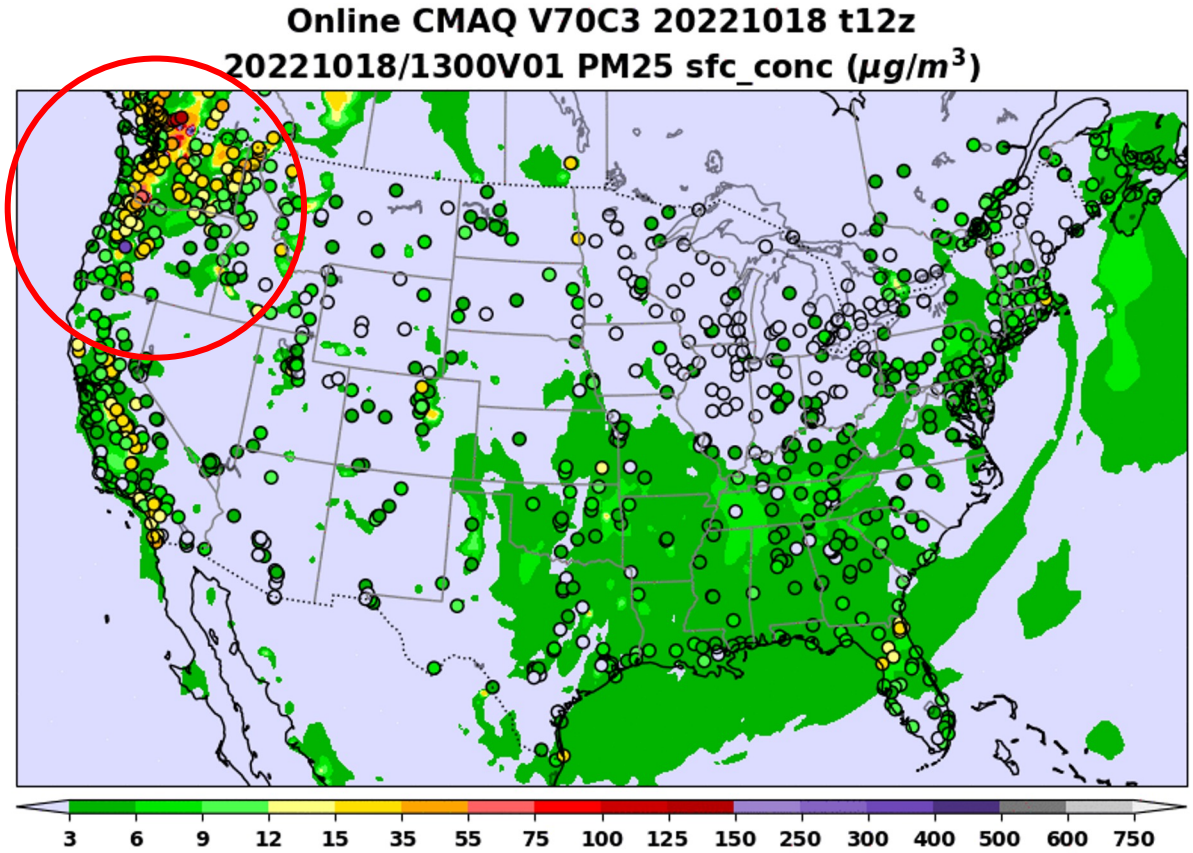
Air Quality Prediction System

UFS based AQM: a single large North American domain



- **<u>Near-real-time</u> online-CMAQ is running since July 8, 2022 over the North American large domain at 13 km resolution that covers all 3 current operational product domains: CONUS, AK and HI.**
- **Updates were integrated into this near-real-time run. Planned for implementation in early 2024**
  - Fengsha dust module
  - Bias correction
  - Post-processing for 8h ozone maximum and daily average PM2.5
  - Updated LBC and wet deposition
  - Inclusion of RAVE wildfire emissions over North American domain
  - Refined treatment of anthropogenic and biogenic emissions

Fine particulate matter (PM2.5) predictions



Online-CMAQ system was tested retrospectively and in **near-real-time** with **R**egional hourly **A**dvanced Baseline Imager (ABI) and **V**isible infrared Imaging Radiometer Suite (VIIRS) **E**missions (**RAVE**) **hourly** wildfire emission inputs.

Evolution of predicted concentrations of fine particulate matter (PM2.5) is shown for 72-hour predictions initialized on October 18, 2022 together with independent AirNow observations of PM2.5 (in filled circles). High values of PM2.5 due to wildfires are visible in the Pacific Northwest.

Data Assimilation Advancements: Transition to JEDI

Joint Effort for Data assimilation Integration

Infrastructure for Unified Data Assimilation

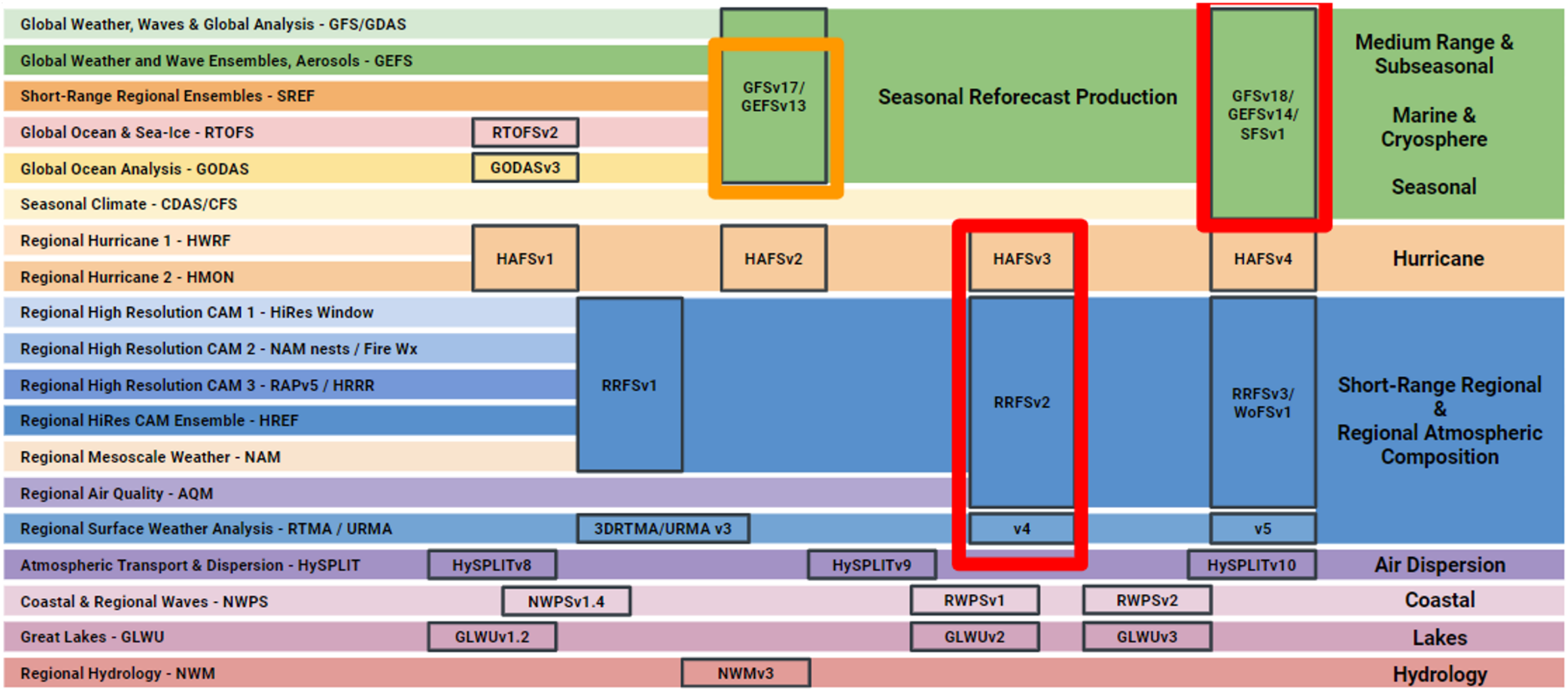
GSI in operations since 2007, but portions of the code are 30+ years old

JEDI is a project within the Joint Center for Satellite Data Assimilation (JCSDA)

JEDI provides a software infrastructure for DA that:

- is model agnostic (but requires an interface to models!)
- is generic and portable
- does not impose specific methodologies or algorithms
- allows to share efforts (new observation types, etc.) across different orgs.

JEDI will allow us to have one shared codebase for all DA,
from global to regional, and for all Earth-system components



Notional JEDI Transition Schedule

Full Transition
Non-Atm Components

Review/Current Status & 10 Year Strategy

Completing Final Review

History & Current Status

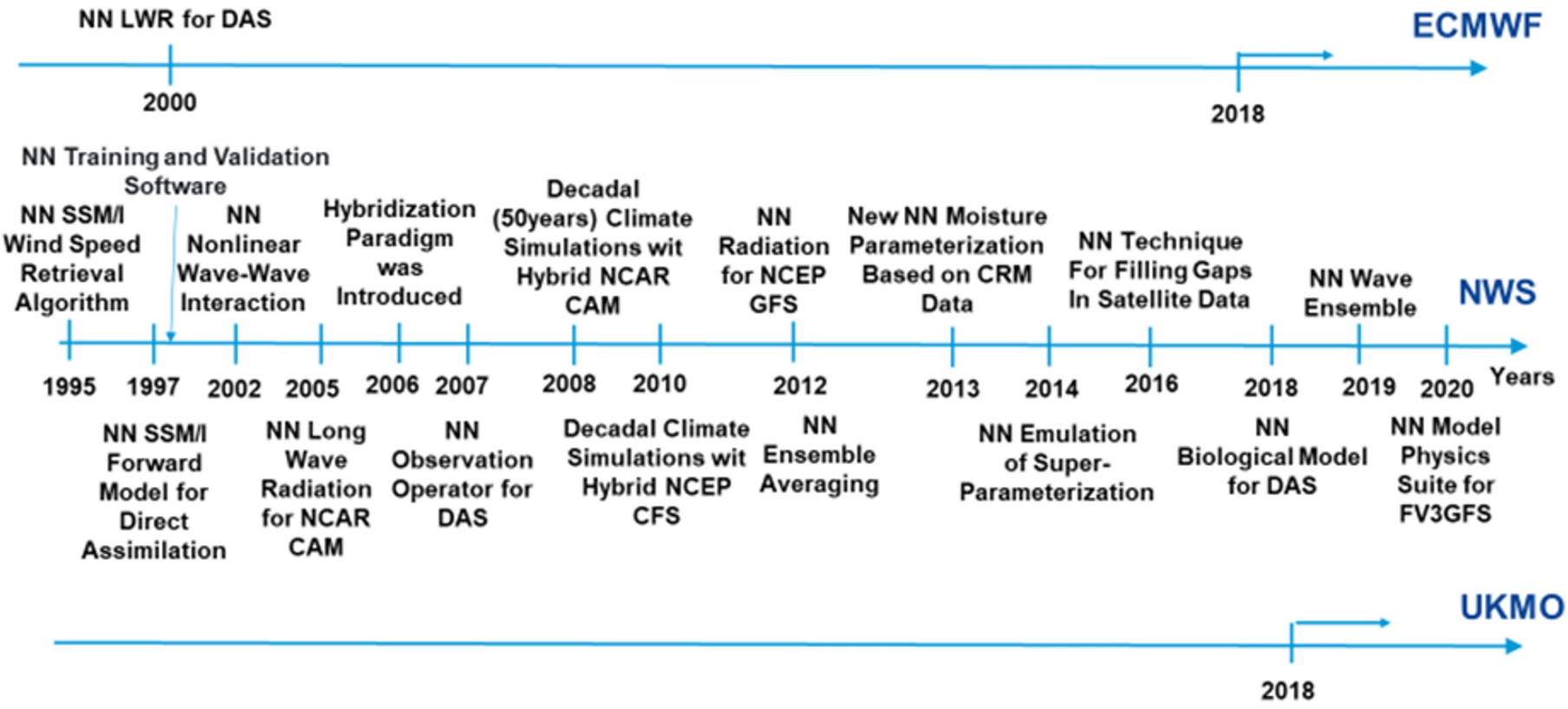
- Introduction
- Atmospheric Systems
- Marine, Land, Composition, and Coupled Assimilation
- Current Use of Observations
- Monitoring & Observation Impacts
- Current Implementation Procedure

10 Year Strategy

- Introduction
- Advanced Infrastructure/JEDI
- Research and Development
- Data Assimilation Vision - Holistic Approach

Application of AI/ML for Operational NWP

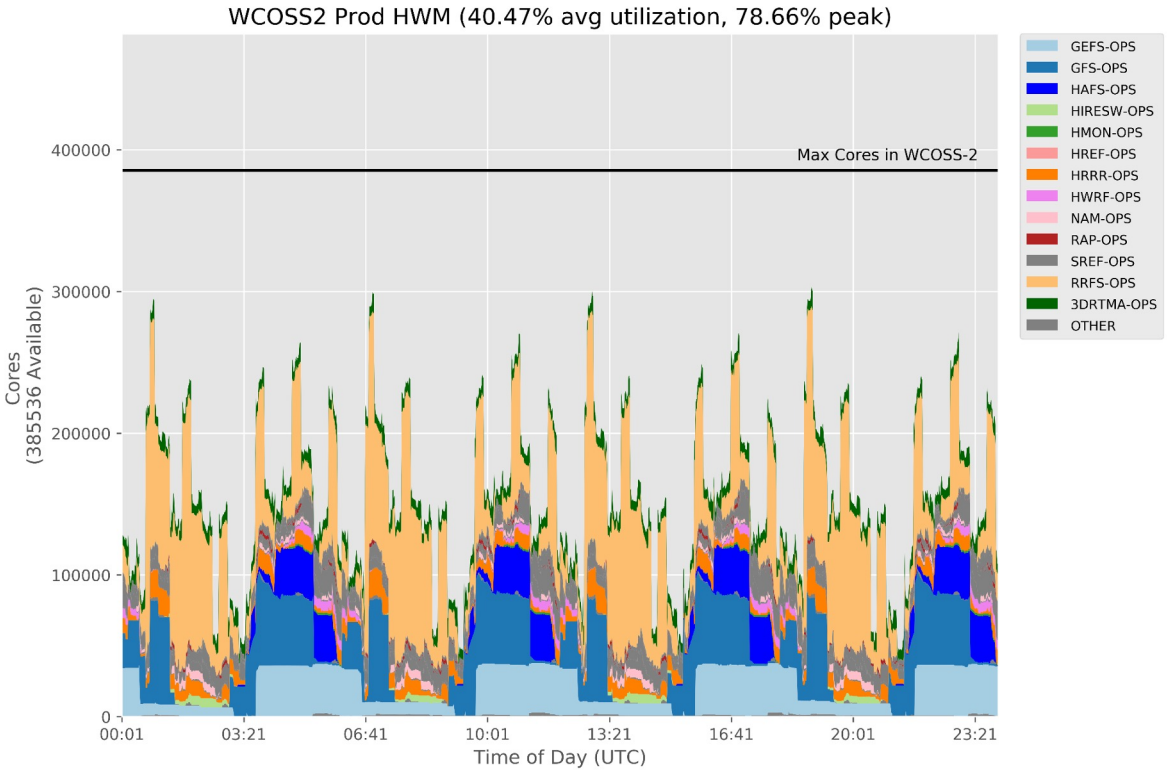
EMC Developments in ML for NWP & Climate

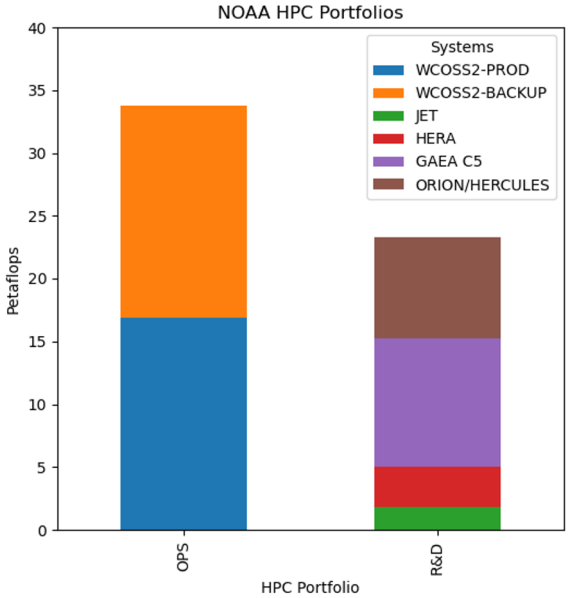


Current/Planned AI/ML Activities at NCEP/EMC

Observations	Data Assimilation	Forecast	Post/Product
Radiosonde processing	Physics emulation	AC Accelerated Transport	Wave Systems
Satellite Thinning	Improved Background	Atmospheric Chemistry Emulator	Air Quality Bias Correction
AMV super-observations and error estimation	Background Error Covariances	Physics Suite Emulation	Sub-Seasonal/ Seasonal forecast products
Conventional / Aircraft quality control	CRTM emissivity modeling	Radiation Parameterizations	
Observation Anomaly Detection	High-resolution background downscaling and emulation	Ensemble Forecasting / Forecast Model Emulation	
	Radiance bias correction	Fire emissions for sub-seasonal to seasonal predictions	

Challenges: HPC Resources





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

Imagine a World ….

- Operational Production Suite backbone of continuously assimilating comprehensive coupled Earth System Model
  - “Digital Twin” - constant update of global state and innovation of training data
- Regular prediction systems (e.g., 2/day global, hourly CAM) and ad hoc (hurricane, fire, dispersion, etc)
- Variety of approaches - deterministic, ensemble-based, surrogate systems trained on reanalysis and backbone
- Cloud-based systems to accommodate HPC requirements as-needed

Thank you!