UFS-R2O Status and Year 3 Overview

Jim Kinter, Vijay Tallapragada and Jeff Whitaker
(project leads)

6-7 December 2021

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

UFS-R2O Project Inspiration

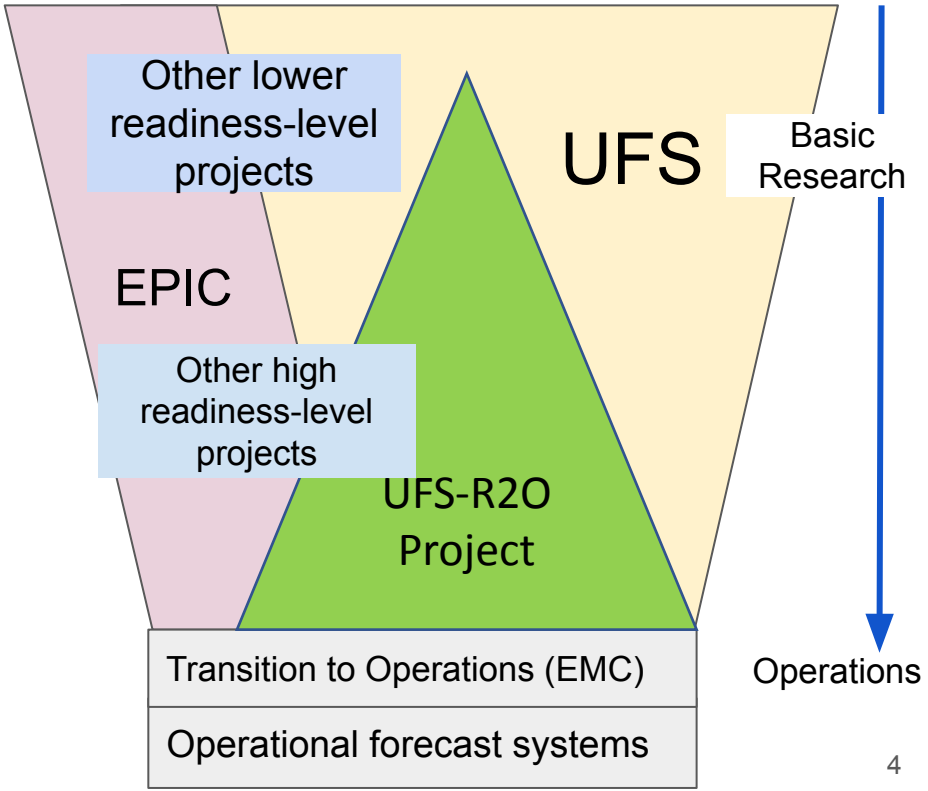
- From UCAR Modeling Advisory Committee (2018 report):
  - **NOAA must be "all-in" in developing and deploying a unified community model, with a unified collaborative strategy**
  - **NOAA Modeling & DA needs to be integrated and collectively managed**
- NGGPS selection of FV3 dynamical atmospheric core
- Establishment of Unified Forecast System (UFS)
- From EPIC Vision and Mission:
  - **Accelerate scientific research and modeling contributions through continuous and sustained community engagement** to produce the most accurate and reliable operational modeling system in the world.

A New Way of Doing Business!

- An experiment to carry out R&D in a **collaborative project within constraints imposed by operational imperatives** and public release timelines
- **Engagement** within NOAA (NWS-OAR-NESDIS-NOS) and wider UFS community, with coordinated funding from **both NWS & OAR**.
- **Interested/engaged/willing participants from inside and outside NOAA under a single management framework**
- Project with a 5-year vision, first 2 years of deliverables defined.

The Wider UFS Context

The UFS-R2O project is a subset of the UFS community that is funded by NOAA and focuses on the transfer of innovations into operations (lower part of the ”funnel”), but is engaged in some lower RL research to ensure the R2O pipeline is continuously fed.



Scientific Priorities

Motivated by forecast priorities collected from stakeholders/testbeds

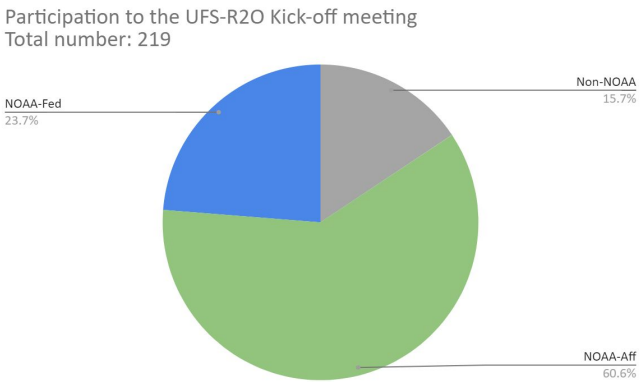
- Reduce coupled model biases
- Improve representation of key modes of variability (including MJO)
- Optimally combine Earth system observations and model forecasts using an advanced data assimilation system to initialize coupled ensembles (land-ocean-sea ice-atmosphere-aerosols).
- Develop a convection-allowing ensemble forecast capability for short-range prediction of severe weather and hurricanes.
- Improve initialization at all scales (convective to global), through improved use of observations and advances in data assimilation algorithms.
- Improve quantification of model uncertainty in ensembles, especially near model component interfaces.

5 Year Vision (highlights)

- Advanced **coupled DA** capabilities
  - Allow observations of one component (e.g. atmosphere) to update all components.
- **JEDI for initialization of all forecast systems**
  - Advanced ensemble, hybrid and 4D-Var algorithms
  - Enhanced use of satellite radiances.
- **Next-gen moist physics** suite for the atmosphere, unified for CAM to global
- CAM-resolution **inline air quality prediction** and direct aerosol feedback
- **Warn on Forecast** system for severe weather outbreaks & flash flooding events
- **Hurricane Analysis & Forecast System** (HAFS) with multiple moving nests
- New applications integrated into UFS:
  - **Coastal inundation, storm surge**
  - **Surface hydrology**
  - **Space-weather prediction**

UFS-R2O Project History

- Summer 2019:
  - EPIC community meeting, need to organize the UFS community in preparation for EPIC
- 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)
  - Program office invited Project Leads (Whitaker/OAR, Tallapragada/NWS, Kinter/Univ)
- Winter 2019-2020:
  - Project structure established
  - Proposal invited: 5-year Project with 2-year deliverables
  - Proposal assembled and downscoped
  - Established external peer-review panel
  - Final proposal submitted (>100 pp)
- March 12-13, 2020: Face-to-face peer-review
- April-May 2020: Descoping and funding decisions
  - $13M/yr: NWS-OSTI $10M and OAR-EPIC & JTTI $3M
- July 2020: Project launch, Kick-off meeting (July 9-10)
  - 200+ attended
- July 2021: 1st annual project meeting



Original Proposed Work: Main Project Outcomes

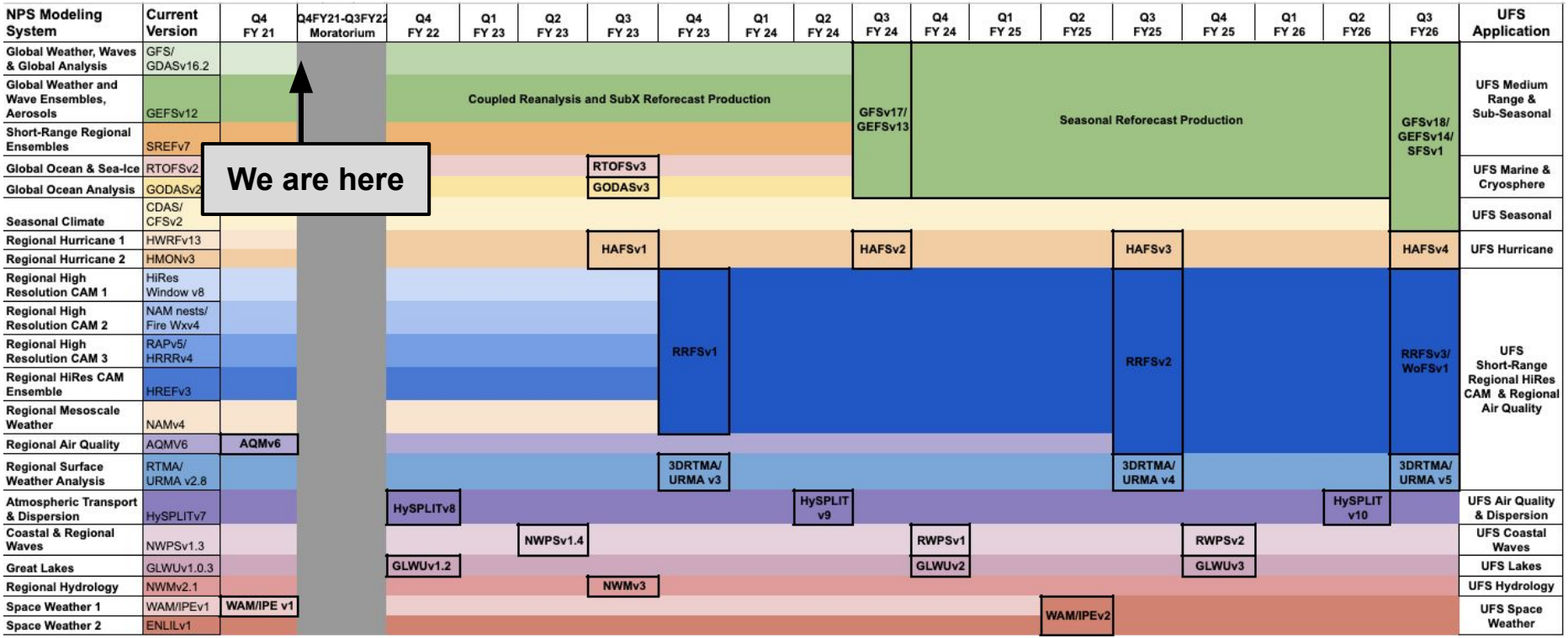
- First 2 major operational systems, global and regional, to be developed jointly between NOAA and the community!
  - Initially targeting GFSv17/GEFSv13/HREFv3/RRFSv1/HAFSv1
- Fully coupled (L-O-SI-A-Ae) global ensemble prediction system, including coupled DA, ready for pre-operational testing and suitable for community research use
  - Addressing science priorities and leading to operational forecast improvements in priority areas
  - Reanalysis/reforecast capability for calibration/bias correction (production in years 3-4)
  - Public releases of coupled Medium-Range weather/S2S application
  - Public releases of JEDI data assimilation framework
- Regional rapid refresh (1-hour cadence) ensemble forecast system for convection-allowing scales ready for pre-operational testing
  - Public release of Short-Range weather application
- Start to sunset existing global and mesoscale prediction systems in collaboration with academic and forecast communities
  - Forecast system unification – simplification of operational product suite

Technical Approach/Guiding principles

- **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)**
- **Continuous evaluation of results.**

Years 2 & 3 - shift from engineering to scientific testing and evaluation

Notional Timelines for Operational Implementation



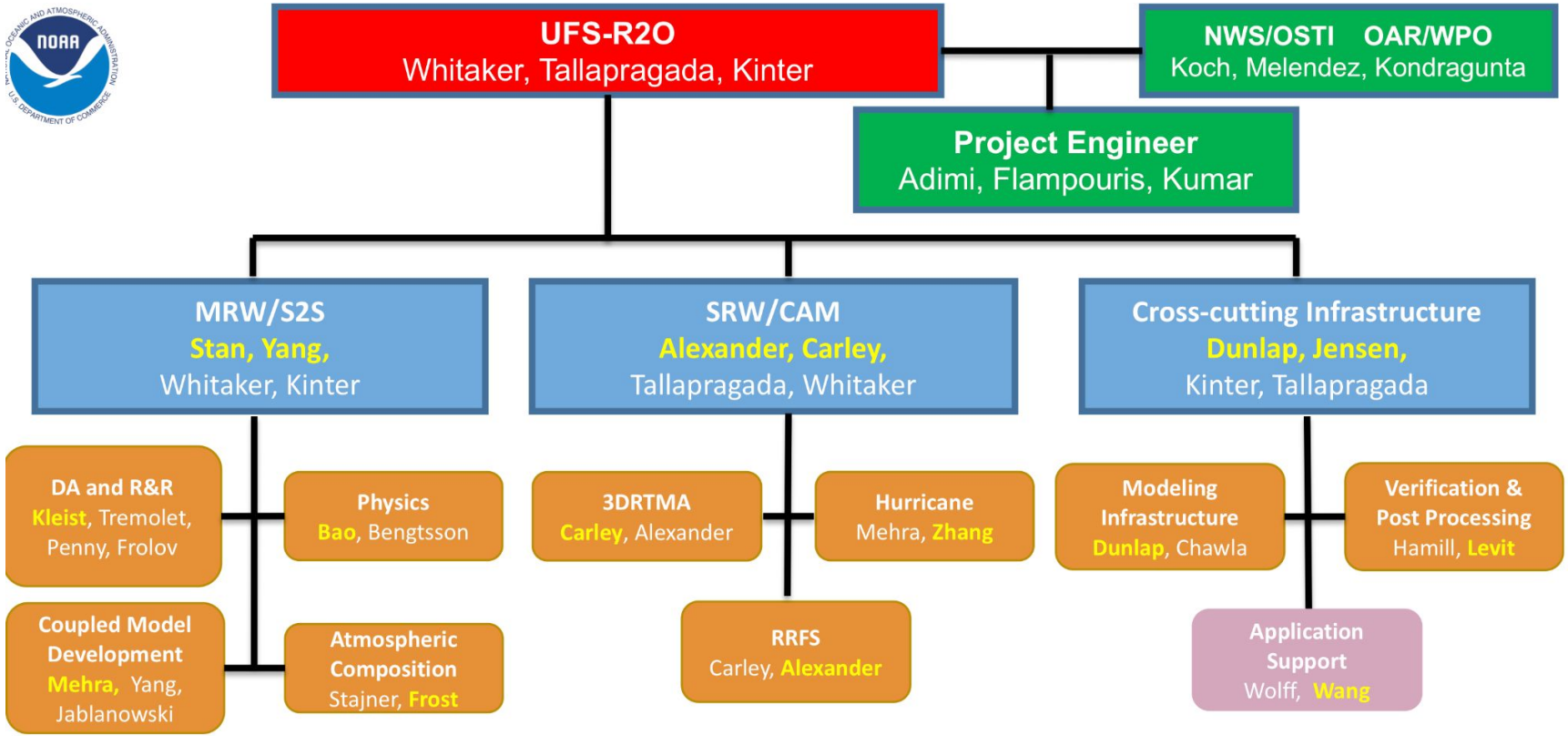
Major Accomplishments in 1st 2rd Years

- **MRW/S2S:**
  - Global coupled system (Atm-Ocean-Ice-Wave) now at prototype version 7 with candidate GFSv17 physics (including NOAH-MP).
    - Final prototype-8 coming in Q1FY22, will contain finalized physics suite.
    - Evaluation of prototypes shows skill at target lead-times comparable to or superior to existing operational levels
  - 40-year 1 deg marine re-analysis using marine JEDI (SOCA) completed.
  - Prototype weakly-coupled ATM/OCN/ICE data assimilation system running on NOAA RDHPCS and in the cloud.
  - Developed UFS-Aerosols (coupled atmosphere-aerosol application), CCPP coupling of predicted aerosols to physics.
- **CAM/SRW and HAFS**:
  - FV3-LAM implemented in operations on 5/11/21 (replaces NMMB member in HREFv3).
  - First SRW app release, prototype RRFS system running in the cloud.
  - Implementation of telescoping nest(s) for hurricanes in HAFS.
- **Modeling Infrastructure**:
  - Community Mediator (CMEPS)
    - NOAA-NCAR collaboration - unifies coupling in UFS and CESM, allows for ‘data models’ to replace active components for testing)

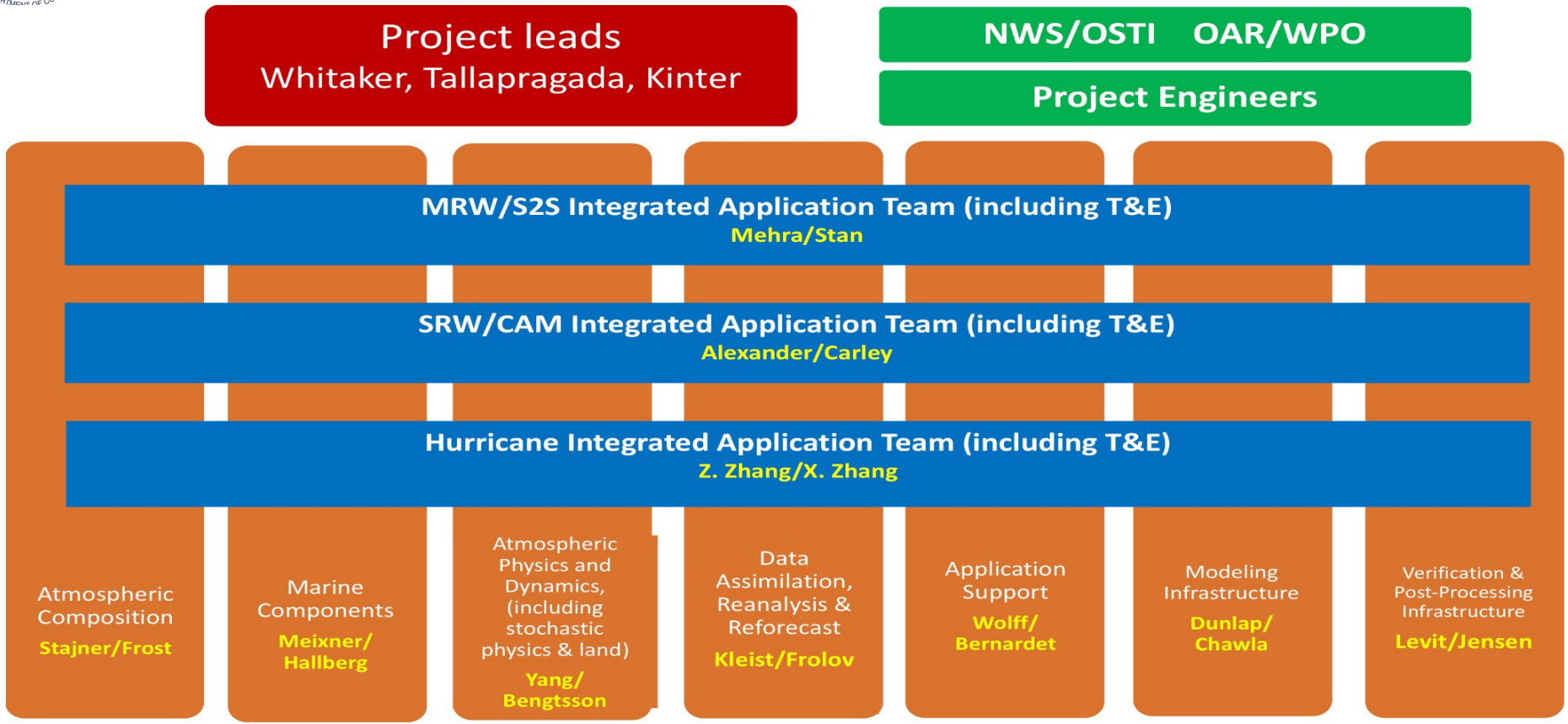
Emerging Challenges

- JEDI transition behind schedule for atmospheric and land applications.
  - Ocean/sea-ice (SOCA) on track for operational implementation
- Coupled reanalysis delayed due to HPC resource limitations, JEDI delays
  - Alternate strategy needed for initializing GEFSv13 reforecasts.
- Issues with simulation of marginally resolved convection (RRFS 3km)
  - Likely related to numerical diffusion in dycore and/or physics/dynamics coupling.
- Issues with HAFS development
  - Telescopic and moving nest development still ongoing, DA configurations not finalized
- Development of a unified, portable, extensible workflow system, including verification and validation.
  - Have not yet identified resources to accomplish this - began coordinating with EPIC.

Old Project Structure



New Project Structure



Application Teams Year-3 Priorities

- **MRW/S2S**
  - Advanced Testing & Evaluation of final configuration for GFS v17
  - Testing & Evaluation of ensemble prototypes for defining final configuration for GEFS v13
  - Experiments targeting possible configuration for SFS v1
- **SRW/CAM**
  - Fully tested 3DRTMA/URMA prototype for NA domain; Improved background for 15, 20, and 45 min past the top of the hour and grids of significant wave height and analysis uncertainty, Develop Guam RTMA/URMA
  - Support advancing RRFSv1 toward implementation, resulting in a prototype; Include development efforts for RRFSv2+ [JEDI, blending and overlapping windows]; Continuation of ML calibration for GEFS to facilitate SREF retirement
  - Start transitioning WoFS to FV3 LAM
- **HAFS**
  - Two HAFS configurations for Initial Operational Capability (IOC) for the 2023 hurricane season, replacing NOAA's current operational hurricane forecast systems, HWRF and HMON
  - Advanced data assimilation system, Physics schemes in CCPP framework for TC forecast systems, and Coupled system using CMEPS

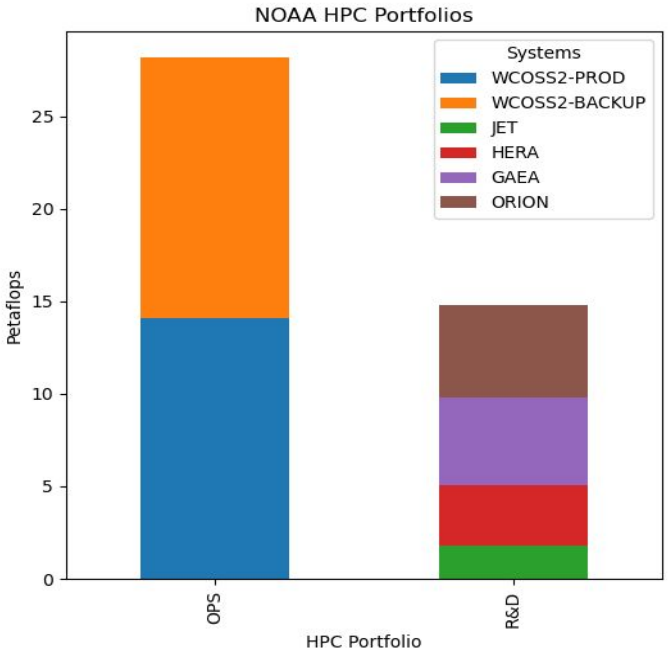
Cross-Cutting Year-3 Development Priorities

- **Atmospheric Composition**
  - Aerosol coupling with radiation microphysics (all applications)
  - Improved emissions (MRW/S2S, CAM/SRW)
- **Marine Components**
  - Improved wave model physics, two-way coupling to ATM and OCN (MRW/S2S, HAFS)
  - High-resolution regional and global MOM6 development. (MRW/S2S, HAFS)
  - Incorporate new CICE physics, new C-grid dycore. (MRW/S2S)
- **Atmospheric Physics and Dynamics**
  - NOAH-MP land model improvements. (all applications)
  - Final configuration of GFSv17, RRFSv1 and HAFSv1 physics (deterministic and stochastic), tuning to improve performance. (all applications)
  - Continue development of scale-aware microphysics, convection, PBL, gravity wave schemes for next versions of all applications, working toward unification. (all applications)
  - Improve simulation of marginally resolved convection, through improvements in dynamics-physics coupling and numerics/diffusion. (RRFS, HAFS)

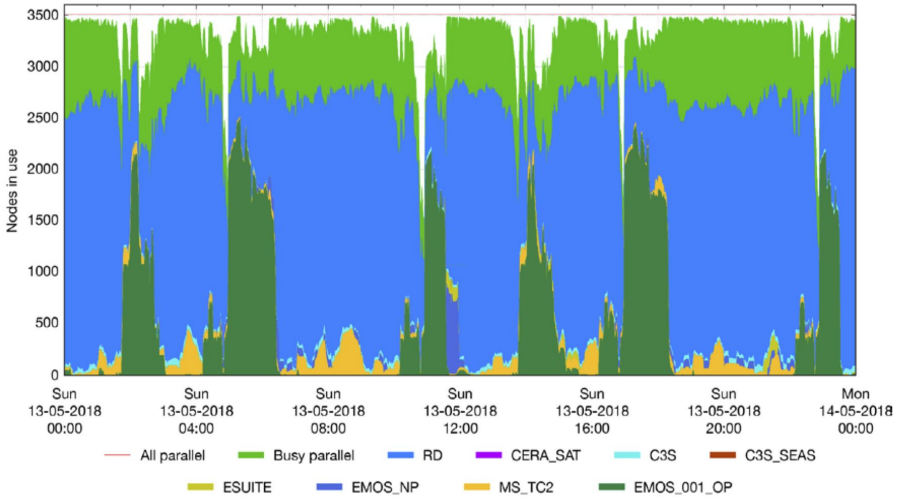
Cross-Cutting Year-3 Development Priorities

- **Data Assimilation/Reanalyses & Reforecasts**
  - Continue development of ensemble-based weakly coupled DA system for GFSv17/GEFSv13. (MRW/S2S, HAFS)
  - CAM-scale ensemble DA development (RRFS, WoFS)
  - Generation of initial conditions for GEFSv13 reforecasts (MRW/S2S)
  - Accelerate transition to JEDI (all applications)
- **Application Support**
  - App releases, user training, support, documentation, and workshops (all applications, with EPIC)
- **Modelling Infrastructure**
  - ESMF, CCPP and workflow development, releases, optimization (all applications)
- **Verification and Post-Processing Infrastructure**
  - METplus development, focusing streamlined verification/validation capability for UFS-R2O application T&E.
  - NWS evaluation of UFS applications (HAFSv1, RRFSv1, 3DRTMAv1) for operational implementation in FY23.

HPC Resource Challenges



NOAA HPC portfolio in FY23. The aggregate capacity of R&D computing is roughly equivalent to the half operational capacity, but is split among several machines



ECMWF compute capacity in 2018. The blue area (RD) is research, the green areas are operational (real-time and pre-implementation parallel) and the yellow areas are member state applications. Note that research occupies roughly 75% of the system.