EMC 5 Year Implementation Plan - Transition to UFS Applications

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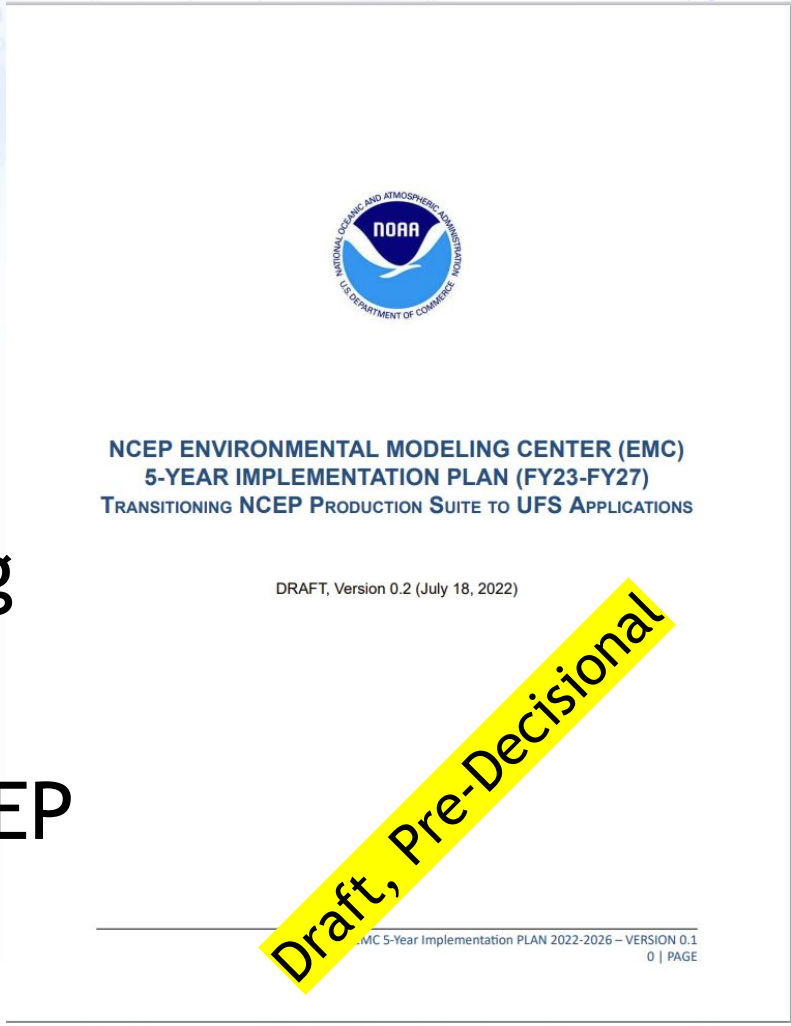
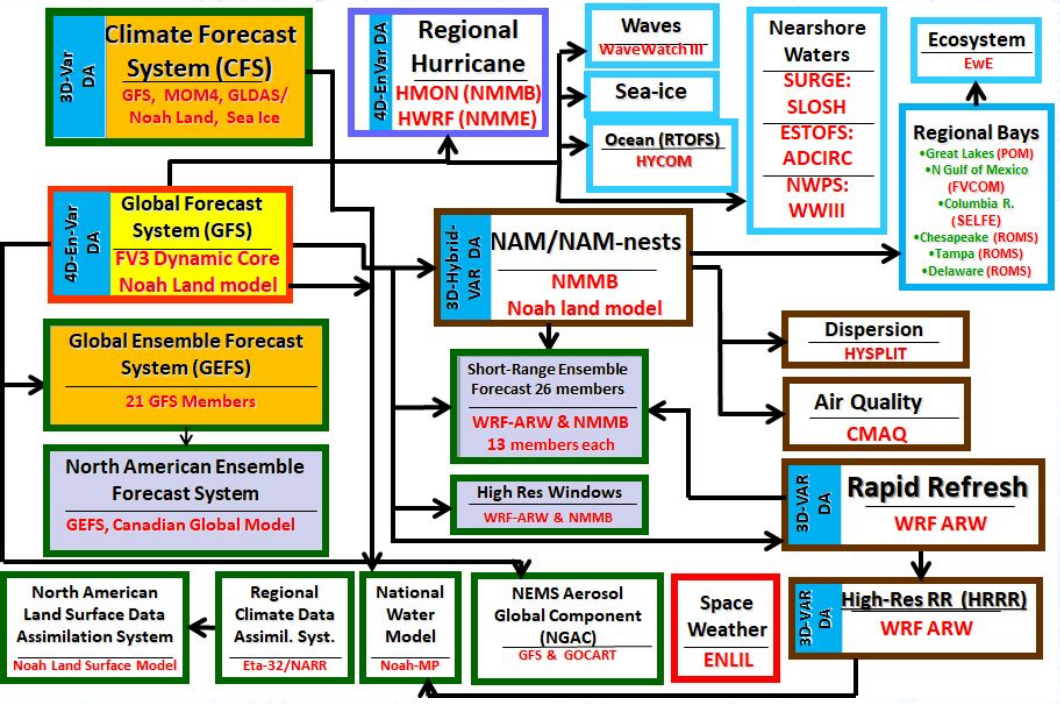
UIFCW, July 21, 2022



Outline

- Current State-of-the-art of NCEP Production Suite
- Development of a 5-year (rolling) implementation plan
- Themes for NCEP Production Suite Simplification
- Notional Schedule for future model upgrades
- Project Plans and Charters and Project Management
- Where we would like to be in 5-10 year time frame
- Challenges

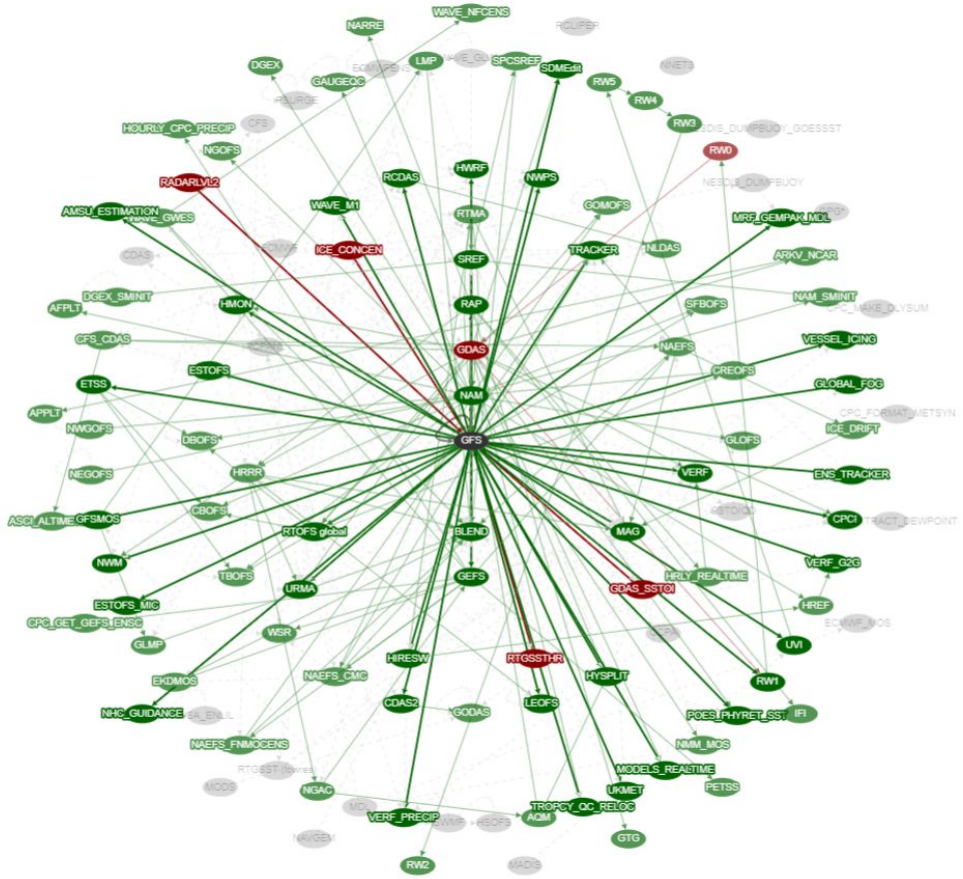
Current State of NCEP Production Suite



Distinct Modeling Systems of NPS:

- AQM: CMAQ North American Air Quality Model (84 hrs)
- CFS: Spectral model coupled to ocean and ice & weakly coupled DA for seasonal forecasts (9 months)
- GDAS/GFS: FV3 based atmospheric model coupled to wave model, with GSI based DA (16 days, medium range)
- GEFS: FV3 based atmospheric model coupled to wave and aerosol models (35 days, sub-seasonal)
- HiRes Window: Regional NMMB (72 hrs)
- HREF: Ensembles of WRF ARW and FV3 (72 hrs)
- HRRR/RAP: Regional WRF ARW with ensemble DA (36 hrs)
- HWRF: Regional WRF NMM-E hurricane model coupled to ocean and waves (126 hrs)
- HMON: Regional NMMB hurricane model coupled to ocean (126 hrs)
- HySPLIT: Regional on-demand dust/smoke/volcanic ash prediction
- NAM: NMMB North American Mesoscale Model (84 hrs)

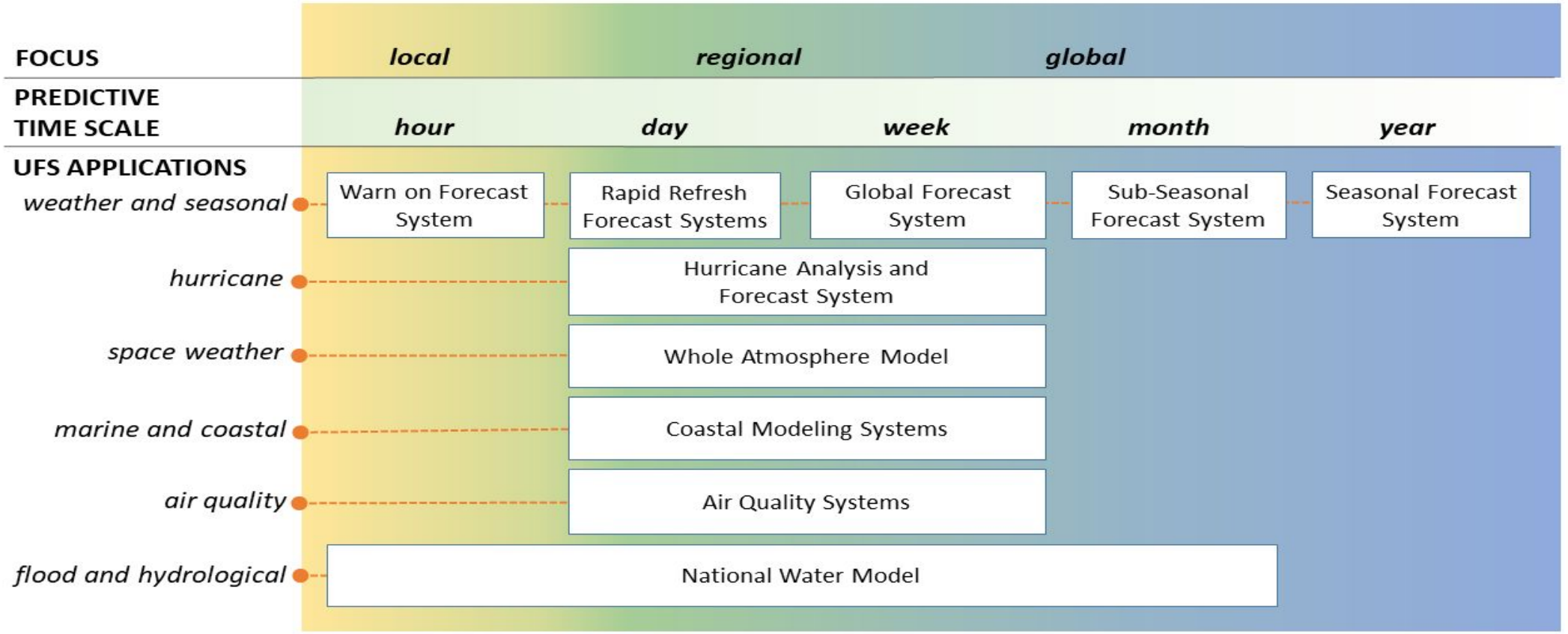
Current State of NCEP Production Suite



Distinct Modeling Systems of NPS:

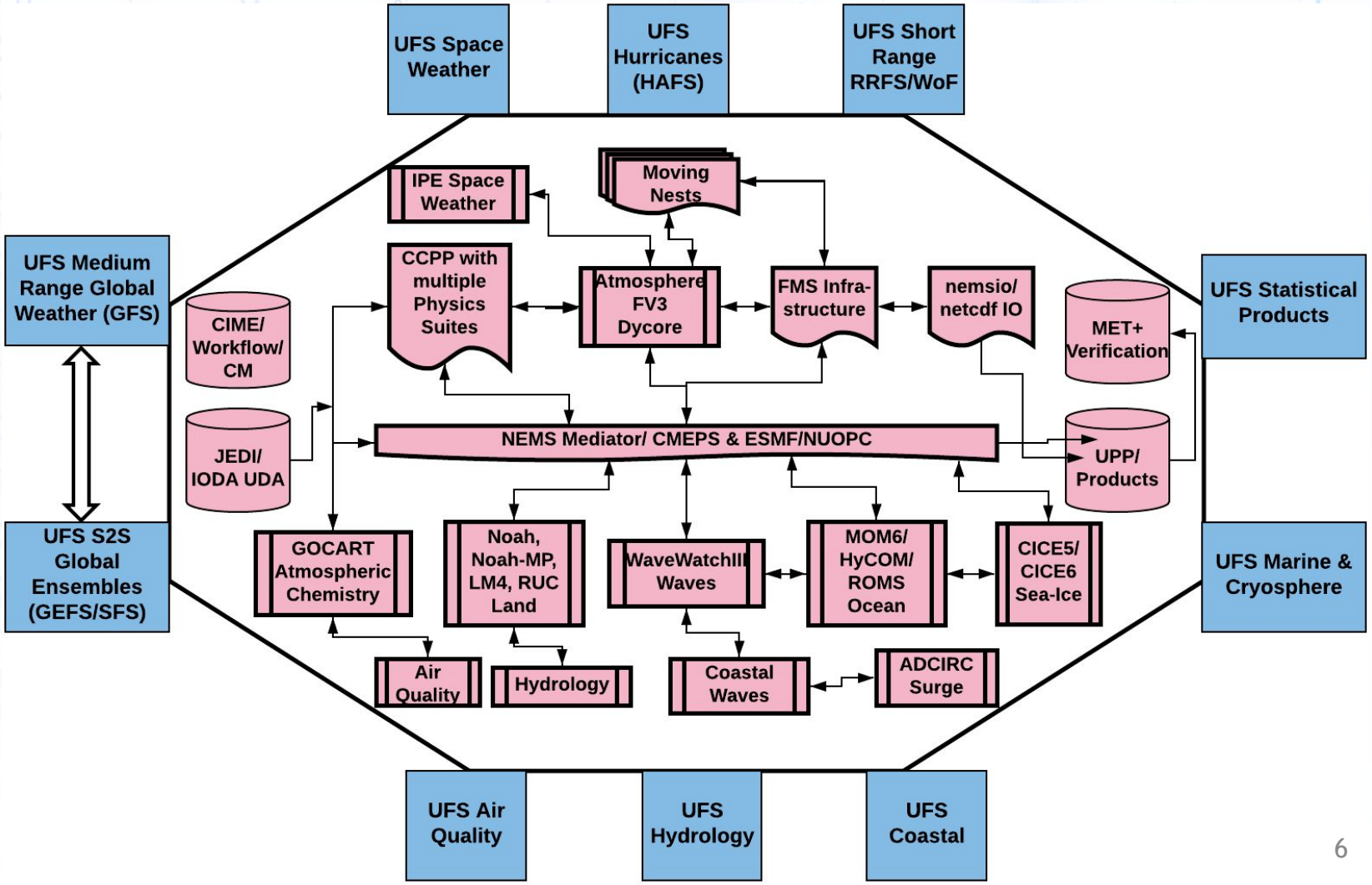
- NAM Nests: High-Resolution NMMB Nests (84 hrs)
- NWPS: SWAN Nearshore Wave Prediction System
- NLDAS: Regional Land Data Assimilation System
- NAEFS: North American Ensemble Forecast System (GEFS+Canadian Ensembles)
- NWM: WRF Hydro for Water Prediction (5 days)
- RTMA/URMA: Regional Mesoscale Analysis
- RTOFS: HyCOM Global Ocean Model (5 days)
- SREF: Short Range Ensemble with WRF ARW, NMMB (84 hrs)
- Great Lakes: WaveWatch III for great lakes (10 days)
- Space Weather: Global Spectral Whole Atmosphere Model
- Space Weather: WSA EnLil Solar Wind Prediction Model

The Goal: Transition to UFS Applications



Conceptual UFS Applications

Components of UFS are configured to develop distinct applications while maintaining the dependencies between the applications and products



Guiding Principles for NPS Unification: Implications and Concerns

Two distinct Approaches:

- **Change the underlying modeling systems of current NPS with UFS based applications**

Pros:

- All (or most of the) NPS applications will be upgraded to use UFS based solutions
- Model development will be streamlined with unified infrastructure
- No change to products, cadence and delivery timelines

Cons:

- We will still have “many” modeling systems running in operations
- Can’t avoid redundancy
- Stove-piped development will continue
- Code management becomes complicated
- Implementation schedules compete considering SPA resources
- Ineffective use of WCOSS resources (HWMs continue peaking at certain times of the day)

Guiding Principles for NPS Unification: Implications and Concerns

Two Distinct Approaches:

- **Unify groups of NPS applications with UFS based applications (recommended path)**

Pros:

- All (or most of the) NPS applications will be grouped into fewer applications using UFS based solutions
- Number of modeling systems will be dramatically reduced
- Model development will be streamlined with unified infrastructure
- Implementation schedules easier to manage
- Better utilization of WCOSS and SPA resources

Cons:

- Existing products and delivery timelines will change (some products will be substituted and some will retire)
- Downstream dependencies (non-WCOSS applications) need to adopt to the new products/timelines
- Individual implementations become big and complex
- Difficult to implement upgrades (non-linear impacts for coupled components)

New WCOSS to enable significant advancements

Cray Shasta system: 12.1 PetaFlops

Multi-tiered storage

- 2 flash filesystems each with...
  - 614 TB usable storage
  - 300 GB/s bandwidth
- 2 HDD filesystems each with...
  - 12.5 PB usable storage
  - 200 GB/s bandwidth

Total aggregate storage - 26.2PB at 1TB/s

Lustre parallel filesystem

Compute nodes

- 2,560 nodes (60 spare)
- **327,680 cores**
- **128 cores/node**

1.3 PB of memory

- 512 GB/node
- 200Gb/s Slingshot interconnect

Dogwood and Cactus, Became Operational on June 28, 2022

Development of a 5-year (rolling) implementation plan

Purpose:

- Describe major development and operational implementation projects planned for the next five years
- How those fit within the broader NOAA Strategic Vision and Roadmap and Unified Forecast System (UFS) Strategic Plan,
- How EMC projects link with other model-related projects internally within NOAA and with the broader U.S. modeling community.

Facilitates planning for:

- **Budget**: estimated costs for the execution of various projects planned for implementation (proactive planning to secure funding)
- **Personnel (feds + contract support):** level of effort and areas of expertise for both federal employee and contract support
- **High Performance Computing (HPC)**: Aligns planned development with HPC needs for R&D, pre-implementation testing and evaluation, reanalyses and reforecasts, and operations
- **Linkages with community partners:** collaborate with internal NOAA and external community partners by capturing linkages and dependencies with their related work (broader community projects for unified modeling, including the UFS-R2O Project and others supported by NWS/OSTI, OAR/WPO, OAR/CPO, and EPIC)

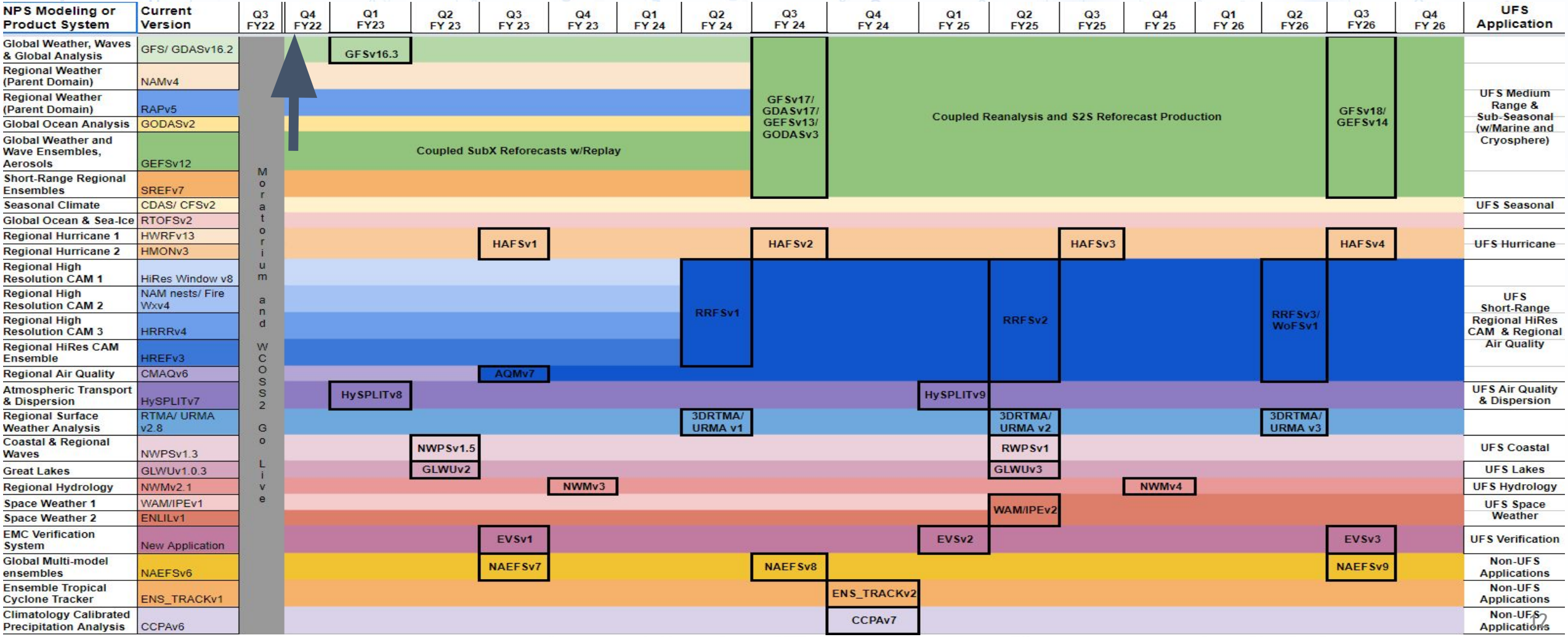
Scientific and technical priorities

- Basic science challenges to meet forecaster priorities and stakeholder interests
- Improvements needed in the associated technologies (e.g., infrastructure) in order to achieve the science goals
- Provide value added products while maintaining continuity of operations
- Improve efficiency in model implementations and operational maintenance

- Improved science and forecast skill
- Meet Stakeholder requirements
- Achieve Simplification of NCEP Production Suite
- Enhanced Community collaborations

Notional Schedule for future model upgrades

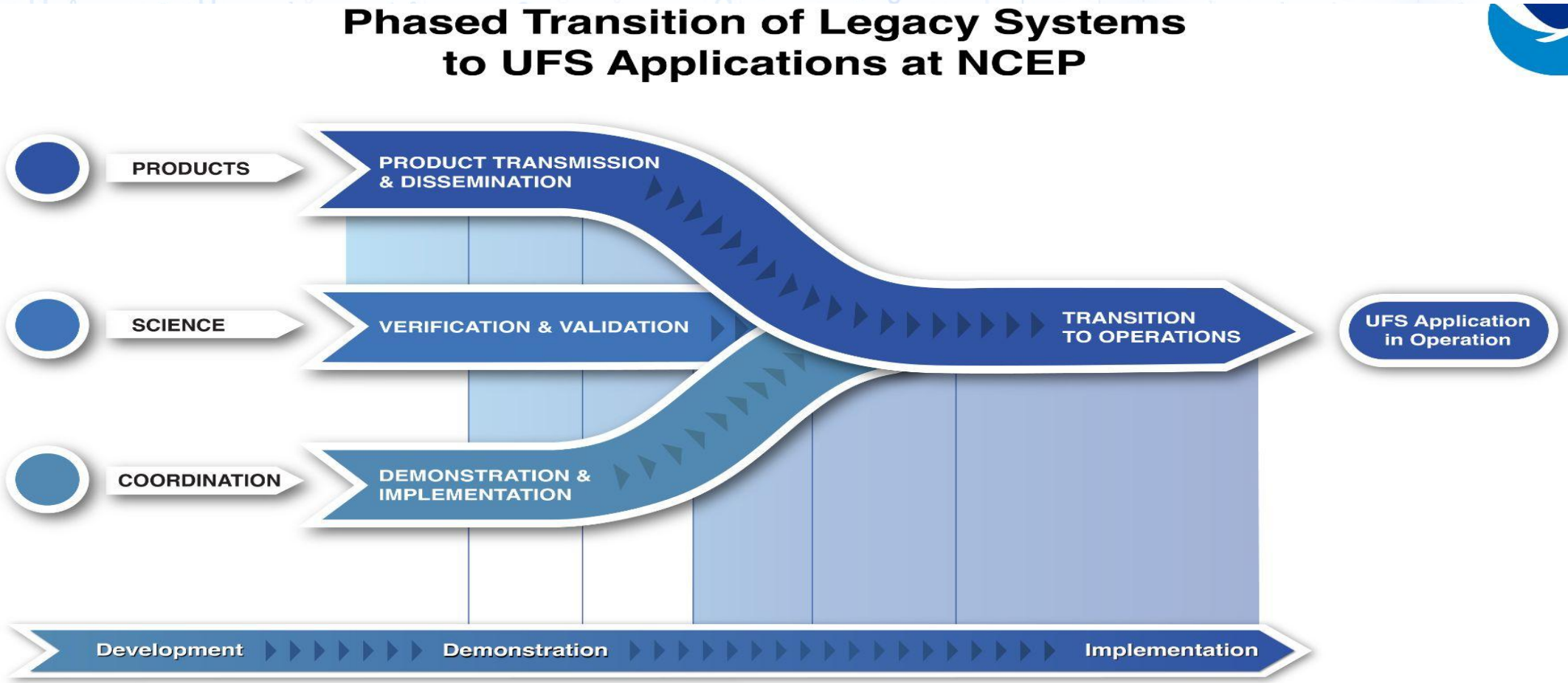
(a.k.a. "Rainbow Diagram", updated as on 7/1/22)



Strategic migration to UFS Applications

UFS Application Teams	Current Operational Applications	Projected UFS Application *(*possible replacements)*
Medium-Range Weather (MRW)	GFS, GDAS, RTOFS, GODAS, GEFS	GFS, GDAS, ***GODAS**,* GEFS
Subseasonal-to-Seasonal (S2S)	GEFS, CFS	GEFS, ***SFS****
Hurricane	HWRF, HMON	***HAFS****
Short-Range Weather/Convection Allowing Model (SRW/CAM)	NAM, NAM Nests, Fire Weather Nests, HiResWindow, RAP, HRRR, HREF, SREF, RTMA/URMA	***RRFS*, 3DRTMA/URMA****
Air Quality & Dispersion	GEFS-Aerosol, CMAQ, HySPLIT	GEFS-Aerosol, ***RRFS-CMAQ**,* HySPLIT
Coastal/Lakes	NWPS, GLW	***RWPS**,* GLW
Hydrology	NWM	NWM
Space Weather	WAM/IPE, WSA/EnLil	WAM/IPE, WSA/EnLil

Three-pronged strategy for migration to UFS Applications



Themes of Unification: DA & Physics

JEDI-based Unified Data Assimilation System for Reanalysis and operational applications

- Complete the transition to JEDI for all applications.
- A 10-year NWS DA Strategy for operational applications is being developed
- Specific details on transitioning from GSI to JEDI are being worked out for various UFS applications

CCPP-based Unified Physics for atmospheric components of operational applications

- Common Community Physics Package (CCPP) to facilitate the development and implementation of physics parameterizations in atmospheric models
- Speed up the transition of physics innovations to operation and to reduce maintenance cost of future operational systems
- Not all current physics parameterizations are applicable for applications across different temporal and spatial scales. The decision for the unification of each individual scheme needs to be made based on both scientific merit and impact on operational forecast skills.

Themes of Unification: Infrastructure and Products

UFS Common infrastructure and Code Management for shared components

- Community Mediator for Earth Prediction Systems (CMEPS)
- Common Community Physics Package (CCPP) framework
- Earth System Modeling Framework (ESMF)
- Interfaces, utilities and libraries required for constructing a modeling system
- Workflows for T&E and operations

Unified Post-Processing and Product Generation Tools for operational applications

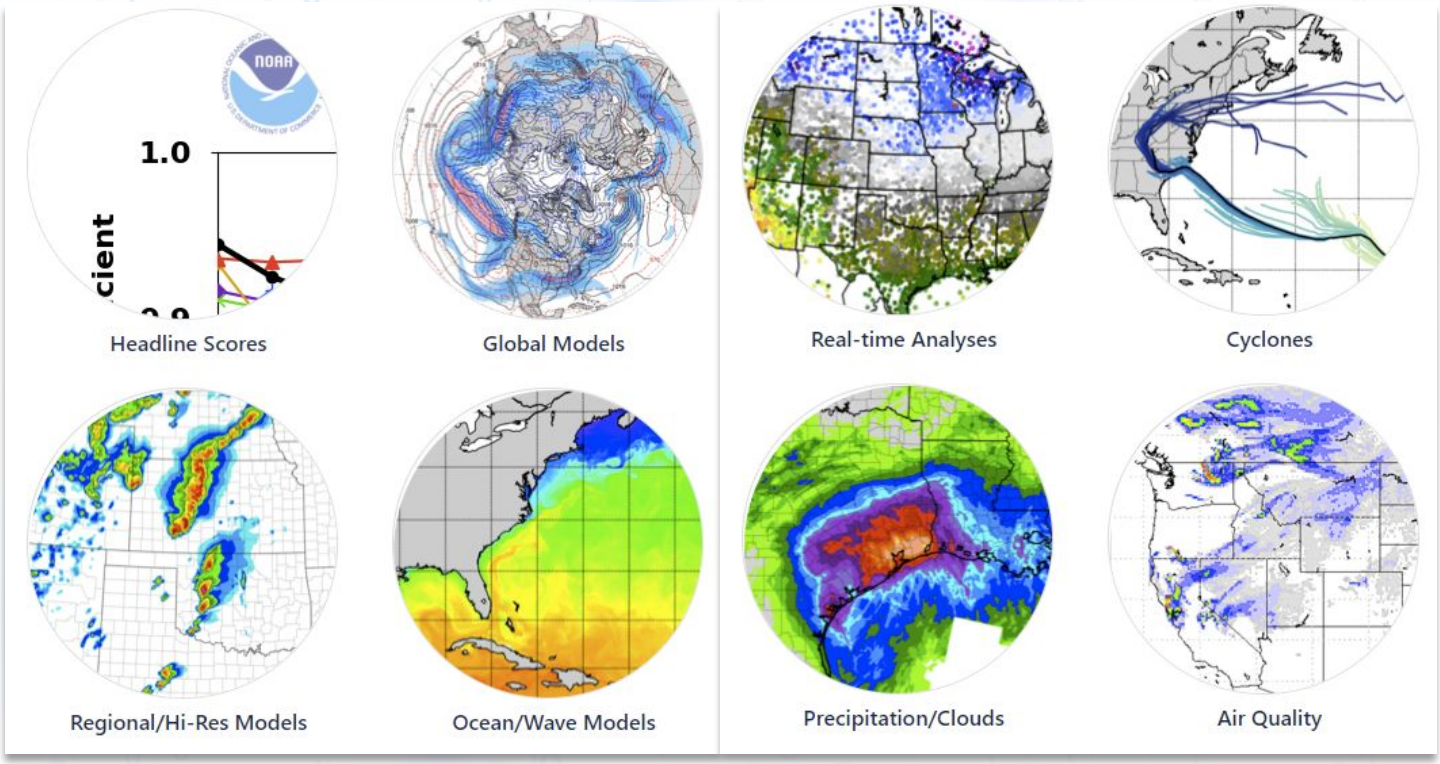
- Unified Post Processor (UPP) for generating products from raw model output
- Derived products such as tropical and extratropical cyclone trackers, ensemble post-processing products, and products tailored to various stakeholder requirements
- Coordination with dissemination portfolio to distribute various products through various channels

Themes of Unification: Verification

Unified Verification System for operational applications

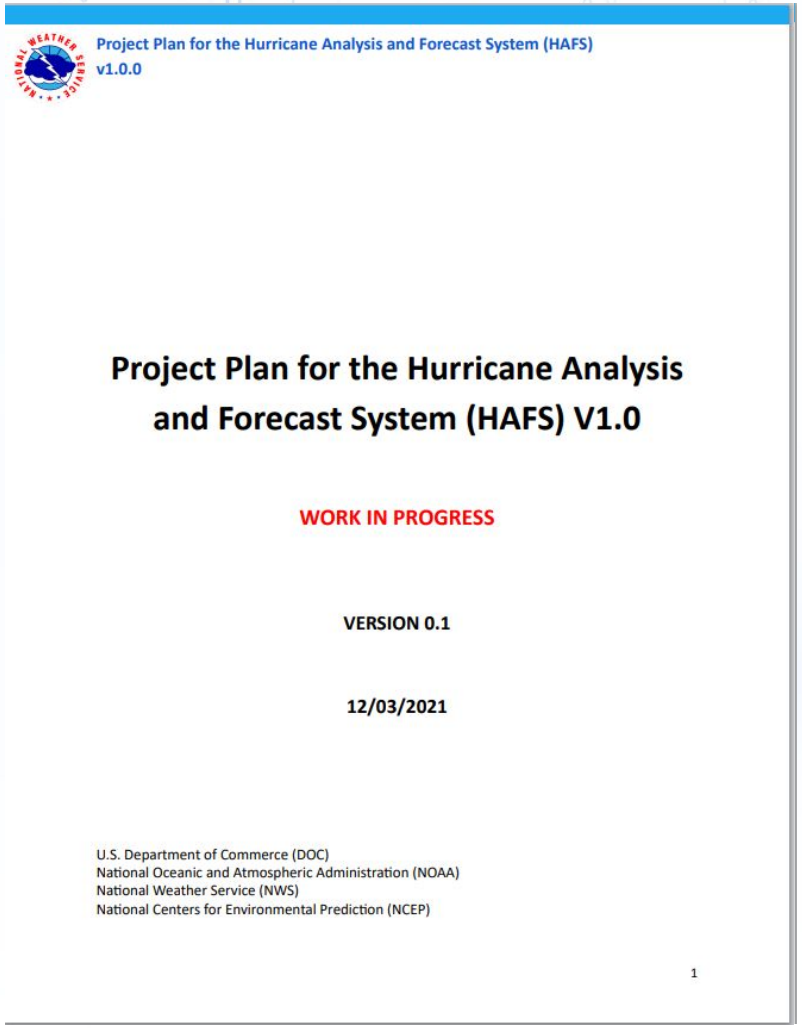
- EMC Verification System (EVS), new, unified verification software system based on METplus
- Will measure performance of all EMC real-time model systems and products
- Produces statistical data and graphics for the EMC Verification Website
- Inputs from DTC Community Workshop on V&V & Metrics

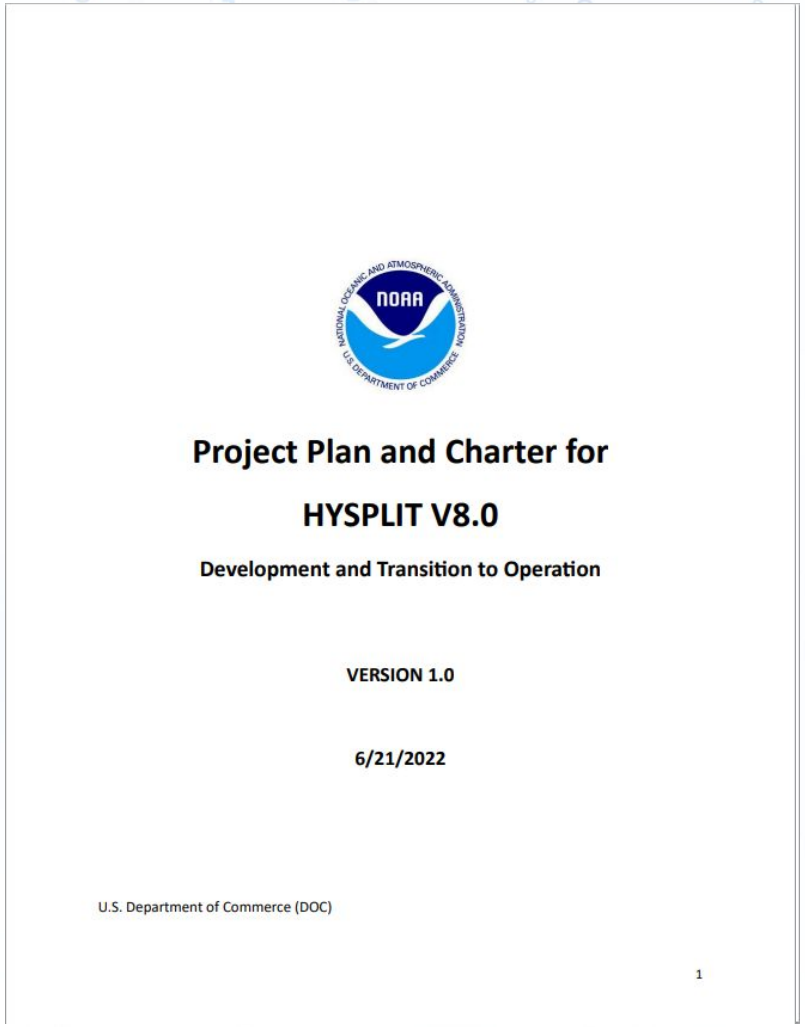
New EMC Verification Websites

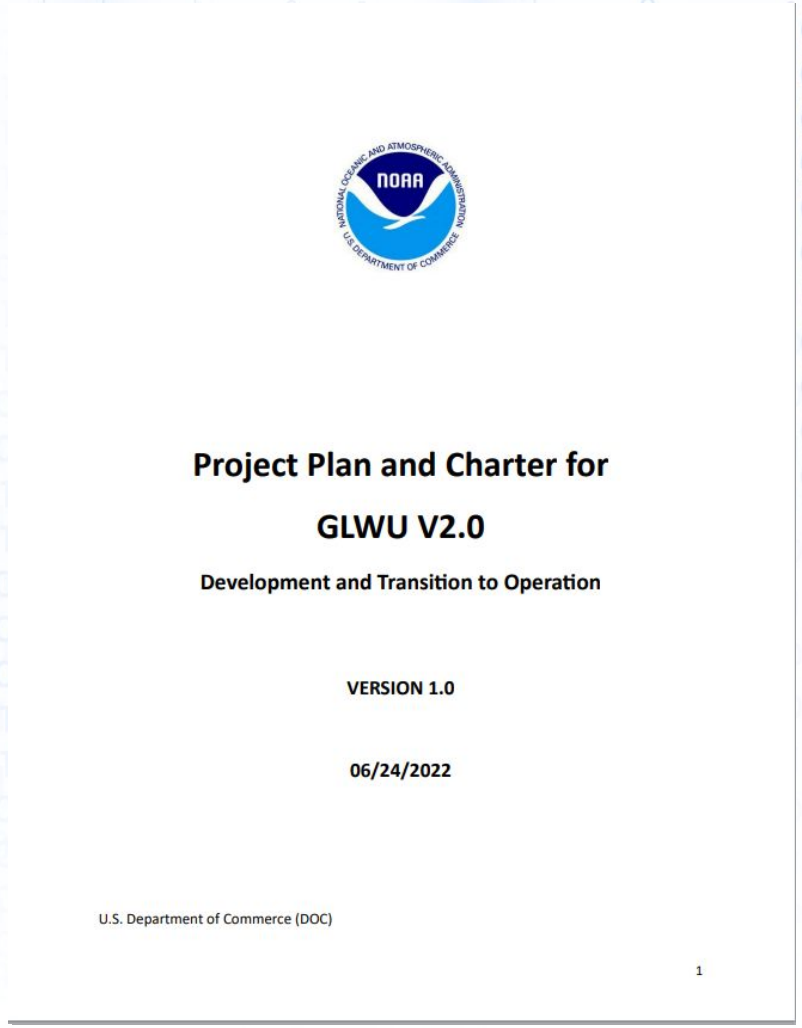


https://www.emc.ncep.noaa.gov/users/verification/

Project Plans and Charters for Major EMC Implementations







Project Plans and Charters for Major EMC Implementations

Project Plan and Charter for AQM V7.0

Development and Transition to Operation

VERSION 1.0

07/01/2022

U.S. Department of Commerce (DOC)
National Oceanic and Atmospheric Administration (NOAA)
National Weather Service (NWS)
National Centers for Environmental Prediction (NCEP)
Environmental Modeling Center (EMC) &
NCEP Central Operations (NCO)

1

NCEP Project Plan and Charter

Implementation of Global Forecast System Upgrades (GFSv16), Q2FY2021

Effective Date: Date of last signature **GFS V16.0.0 Plan v1.0**
Responsible Organizations: NWS/NCEP/EMC & NCO

SIGNATURE PAGE

Concurred by:

Vijay Tallapragada — 8/27/19
Vijay Tallapragada; EMC Modeling and Data Assimilation Branch Chief — Date

CHAWLA.ARUN.1392723290 — 8/27/19
Arun Chawla; EMC Engineering and Implementation Branch Chief — Date

LEVIT.JASON.JOHN.1365857810 — 8/27/19
Jason Levit; EMC Verification, Post-Processing & Product Generation Branch Chief — Date

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Carissa Klemmer, NCO Implementation & Data Services Branch Chief — Date

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Brian Gross; EMC Director — Date

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Prepared by:

Vijay Tallapragada; EMC Modeling and Data Assimilation Branch Chief

Farida Adimi; EMC Project Management Support

GFSv16.0.0 Project Plan & Charter 3

HYSPLIT Version 8 for Q4FY22

July 07, 2022

Project Information & Highlights

FOM: Fanglin Yang **Backup:** Vijay Tallapragada
Leads: Jeff McQueen (EMC), Mark Cohen (ARL), Alice Crawford (ARL), Steven Earle (NCO)
Scope: Latest HYSPLIT code; ensemble based volcanic ash from GEFS with AWIPS2 compatible files; HREF to WOC for WFO dispersion applications; RSMC Time of Arrival product (TOA); retire/replace HYSPLIT smoke runs. **Expected benefits:** Address IAEA requests for RSMC, ICAO requests for VAAC. Better code coordination with ARL
Dependencies: ARL code delivery; SDM/SAB acceptance; IDP and WOC team support; Operational WOC server updates to host ensemble meteorological files

Issues/Risks/Concerns

Risk: None

Schedule

Milestones & Deliverables	Date	Status
Code delivery from ARL to EMC; Freeze system code	1/5/22	Complete
Complete Project Plan; NCO EE Meeting	3/14/22	Complete
Start/Complete full retrospective runs. Start preliminary real time runs	4/30-5/29/22	Complete
Start/Complete real-time EE2 evaluation	5/30-6/24	Complete
Conduct CCB brief	6/27/22	Complete
Conduct OD brief	7/14/22	On track
Submit final Code and SCN to NCO	7/19/22	On track
Start NCO 30-day IT stability test	8/29/22	Planned
Operational Implementation	Q4FY22	Planned

EMC NCO Blue text indicates change from previous quarter

Total Resources

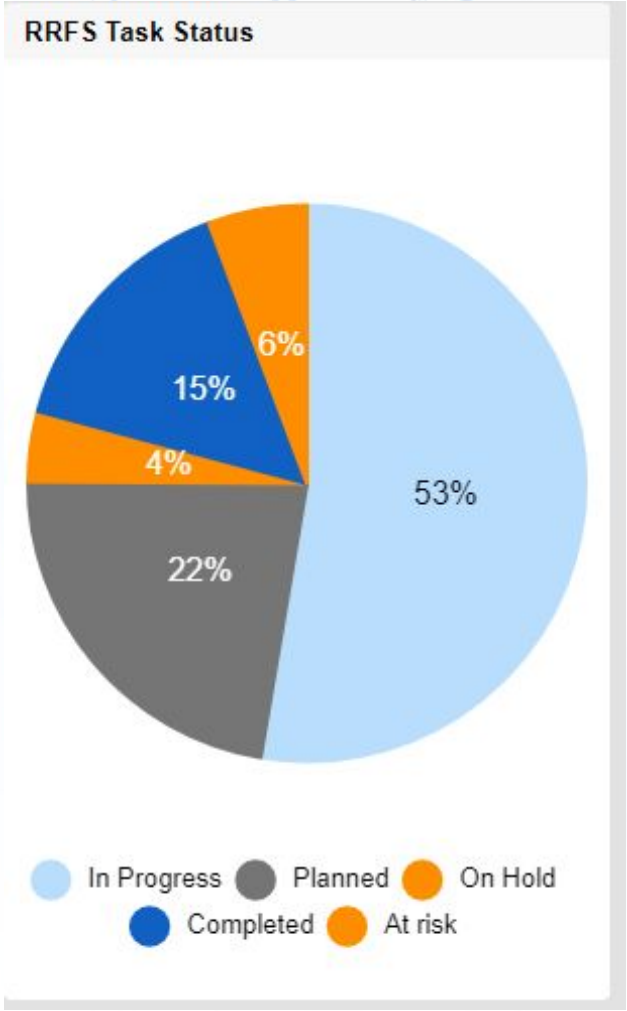
Staff: 0.1 Fed + 1.1 contract, incl. dev; + 0.9 ARL Fed FTEs
Funding Source: STI NAQFC; OAR
Compute: Retro: 40 for 3 months; **real time:** 40 for 4 months; **Ops:** up to 41 nodes for on demand ensemble ash for VAAC
Archive: Ops: 400 GB/day

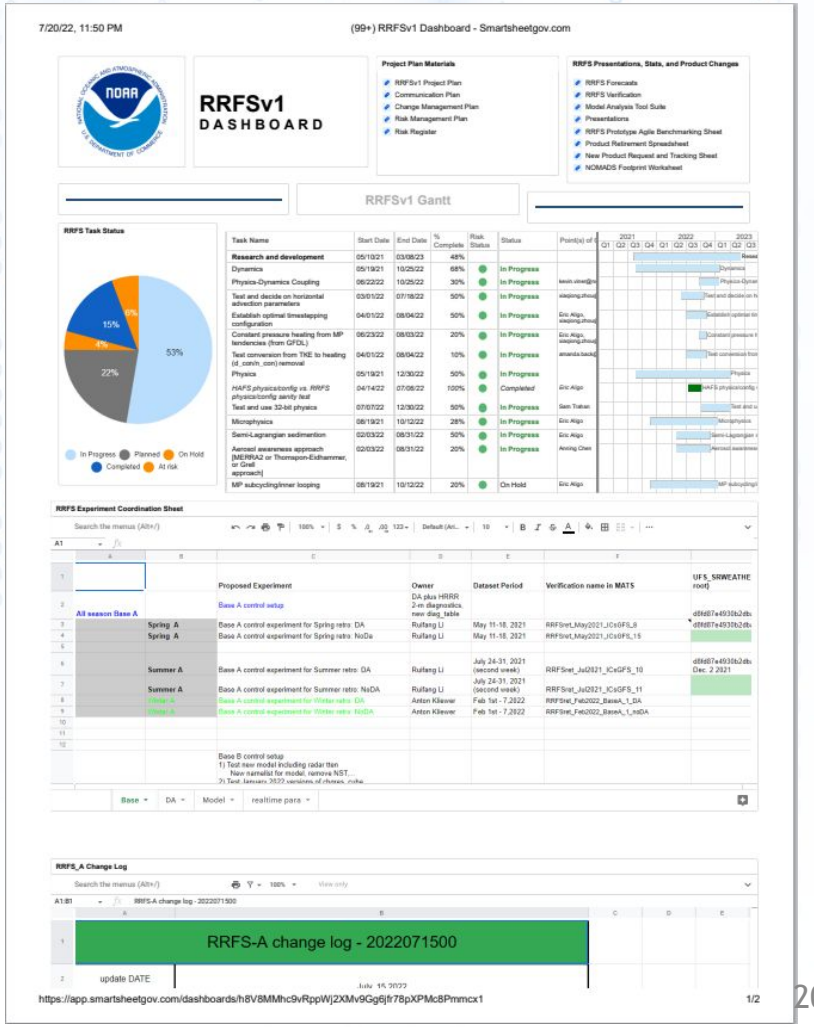
R Management Attention Required | Y Potential Management Attention Needed | G On Target

Project Management

Smartsheet Based Project Management

- Gantt Charts
- Issue Tracking
- Risk Register
- Communication Plan
- Change Management Plan
- Integrated Master Schedule
- Decision Trees
- Reports, snapshots, task coordination etc.





Risk Registers

HAFS Risk Register

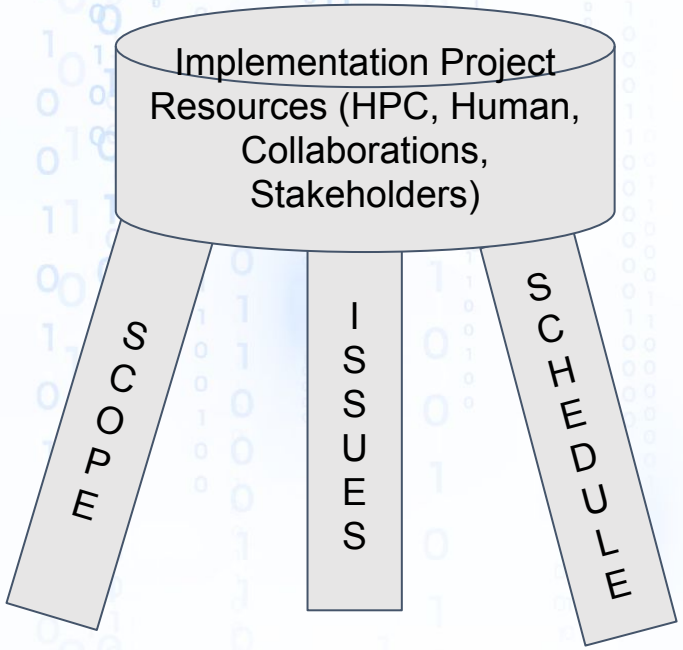
RISK DESCRIPTION	IMPACT DESCRIPTION	IMPACT LEVEL	PROB LEVEL	RISK LEVEL	ACTION STRATEGY	Mitigation DETAILS	Mitigation IMPACT
The runtime for the forecast job is too long (SST downscaling for moving nest does not scale by increasing resources), won't fit in the HAFS operational window (< 96 min) on WCOSS2	Will not be able to implement HAFS IOC on WCOSS2	5	3	15	Mitigate	Actively work on the scalability issue	Speed up the forecast code to meet the runtime requirement on WCOSS2
No enough disk space on WCOSS2 to stage necessary GFS input files	Will not be able to demonstrate HAFS IOC using WCOSS2 resources	5	4	20	Mitigate	Have submitted request form to HPFRAC for more disk allocation on WCOSS2, waiting for decision	Use WCOSS2 to run retrospectives and provide real-time results of HAFSv1 IOC to NHC

Risk Registers

The Turbulence algorithm in UPP needs to be updated to GTG4 and tuned to RRFS deterministic member	The airspace may be shutdown in the worse case scenario as the CONUS trubulence products will be unusable when RRFS is implemented without updating and tuning GTG algorithm in UPP. FAA mandates require arilines to fly around turbulences	5	5	**25**	Mitigate Add Resources
Skill of RRFSv1 does not match that of HREFv3	If the skill of the RRFSv1 does not meet or exceed that of HREFv3, then operational convective outlooks and other products could be negatively impacted by degraded guidance.	5	5	**25**	Mitigate Extend Timeline
Operational Current Icing Product (CIP) product on WCOSS can only run on RAP	In situ icing (CIP) product will go away if adjustments aren't made to enable it to run on RRFS input	5	5	**25**	Mitigate Reduce Scope
Insufficient RRFSv1 retrospective data for tuning/training of GTG4	3 months of summer and 3 months of winter RRFS retrospectives are needed for training of the GTG4 algorithm. Without 6 months total of retrospectives, risk significant degredation of GTG performance	5	5	**25**	Mitigate Extend Timeline
Insufficient retrospective data to redevelop LAMP and Gridded LAMP (if necessary)	If sufficent retrospective data is not provided for redevelopment (if necessary), LAMP and Gridded LAMP will be significantly degraded.	5	5	**25**	Mitigate Extend Timeline

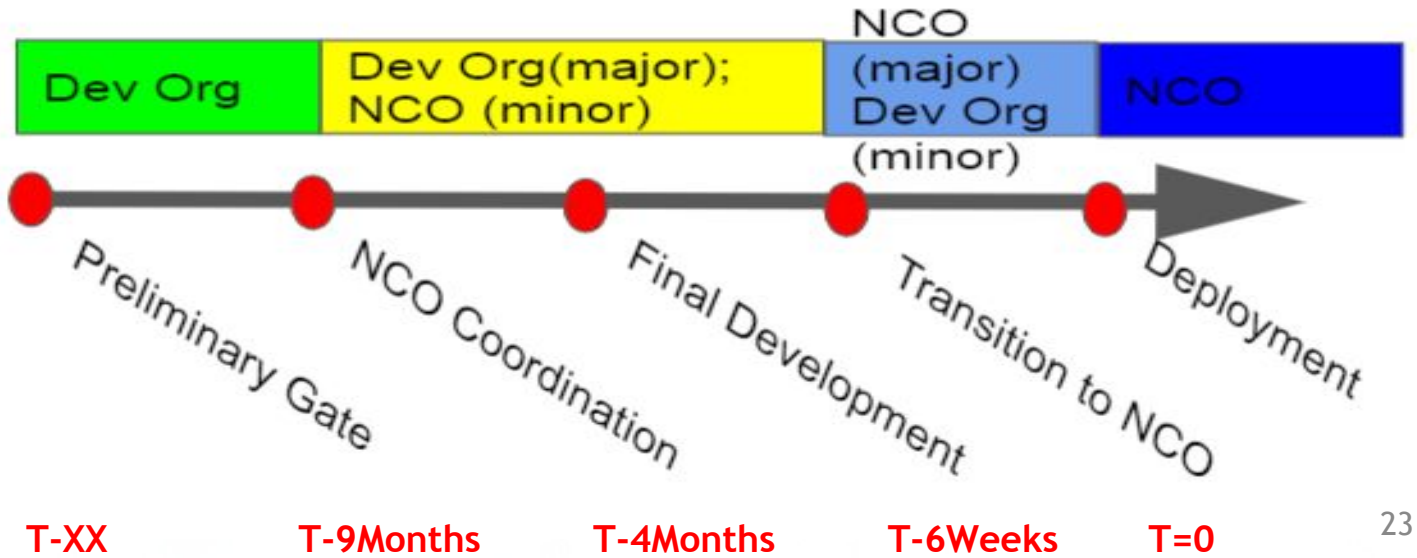
RRFS Risk Register

Challenges: Schedule, Scope, Resources & Issues

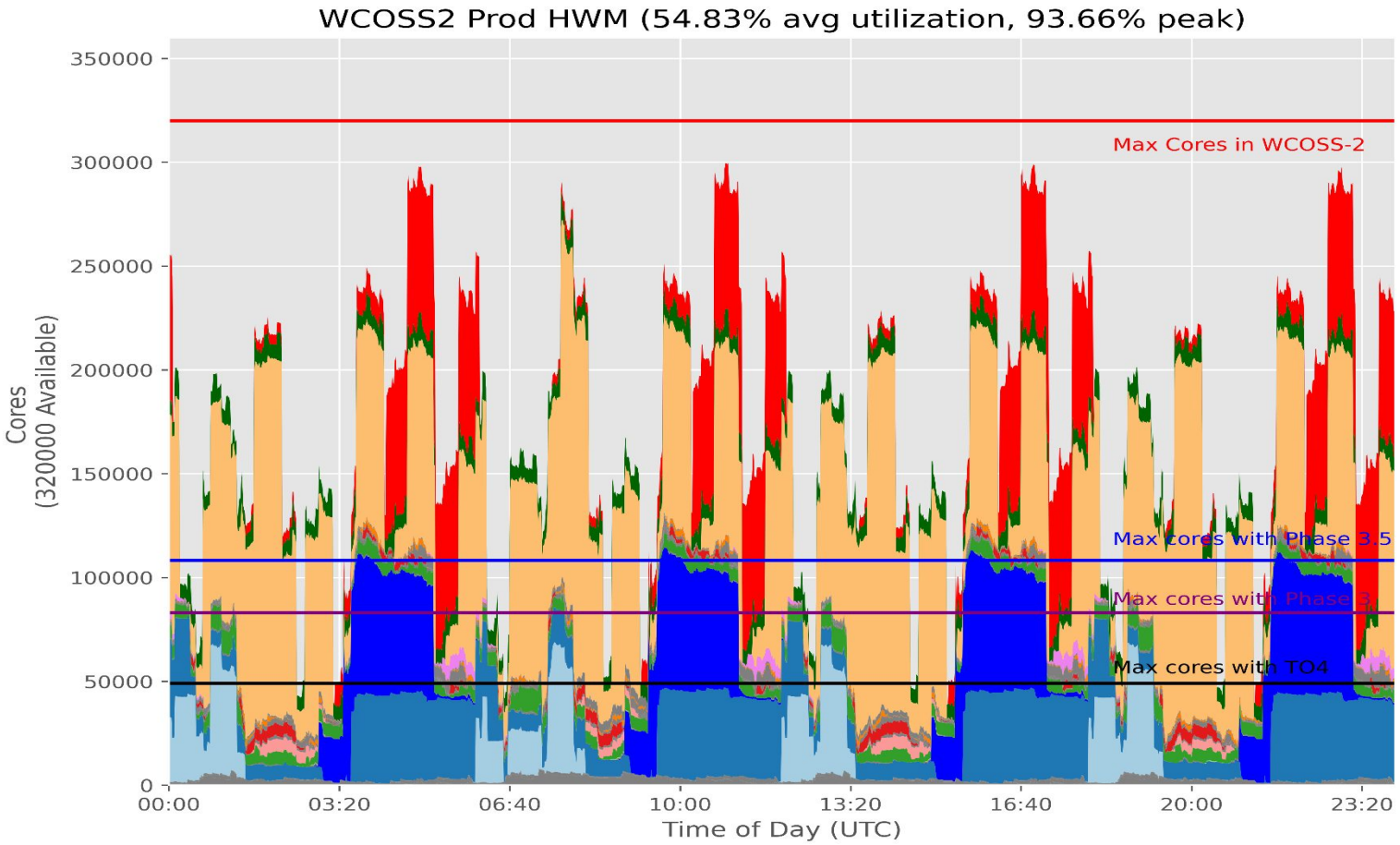


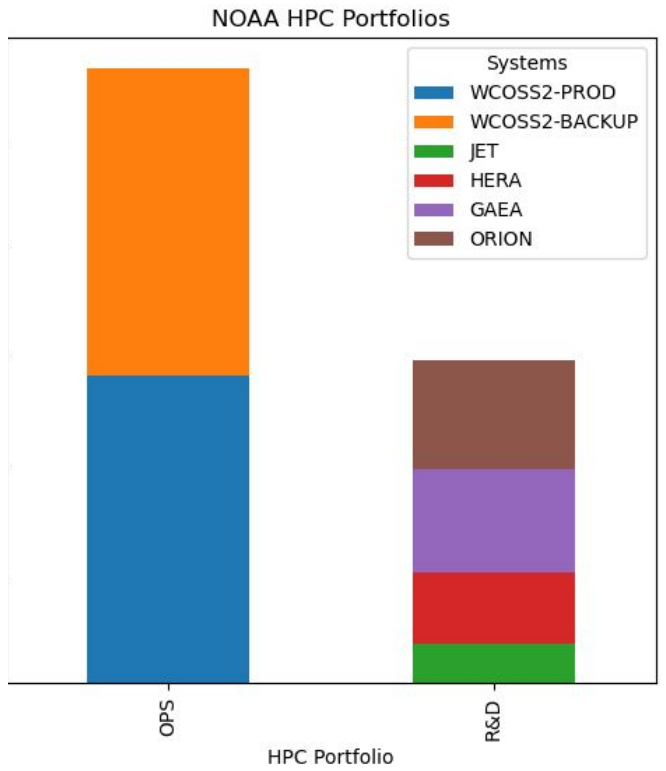
Delicate balance between Scope, Schedule and Resources

- Prioritization of Scope vs Schedule
- How much slack should be built into the project?
- Accountability?
- Decision Making Process?



Challenges: HPC Resources





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

Challenges: HPC Resources

UFS-R2O Application	Oper. WCOSS2 compute *(EMC estimate)	to enable R&D/T2O (x6) (Immediate Need)
GEFSv13/GFSv17	*110K cores / 4.1 PFlops	660K cores / 24.6 PFlops
HAFS	*72K cores / 2.7 PFlops	432K cores / 16.2 PFlops
RRFS/3D-RTMA	*167K cores / 6.2 PFlops	1M cores / 37.2 PFlops
SFS	31K cores / 1.1 PFlops	186K cores / 6.6 PFlops
Total	~ 380K cores / 14.1 PFlops	~ 2.28M cores / 85 PFlops

Challenges: Product Deliveries

Current product generation and delivery strategy is unsustainable

- Fewer models means more complex systems
- We can go with higher resolution and more ensembles - can we realize the benefits in the product space?
- Reaching the scalability limits for many applications (waves, aerosols, I/O, bandwidth etc.) - need support from software engineering
- Significant re-thinking required for product dissemination
- Engage the stakeholders way ahead
- Can we avoid “Jet-Blue” syndrome?

Performance Requirements

- 99.9% Operational Use Time
- 99.0% On-time Product Generation
- 99.0% Development Use Time
- 99.0% System Availability

- System/technical requirements not commensurate with scientific requirements
- 99% Development use time is not guaranteed in the past
- Risk averseness is good - but should not be an impediment to innovation

Where do we see ourselves in 5+ years? Advancing UFS Global Coupled Models to Convective Allowing Scales

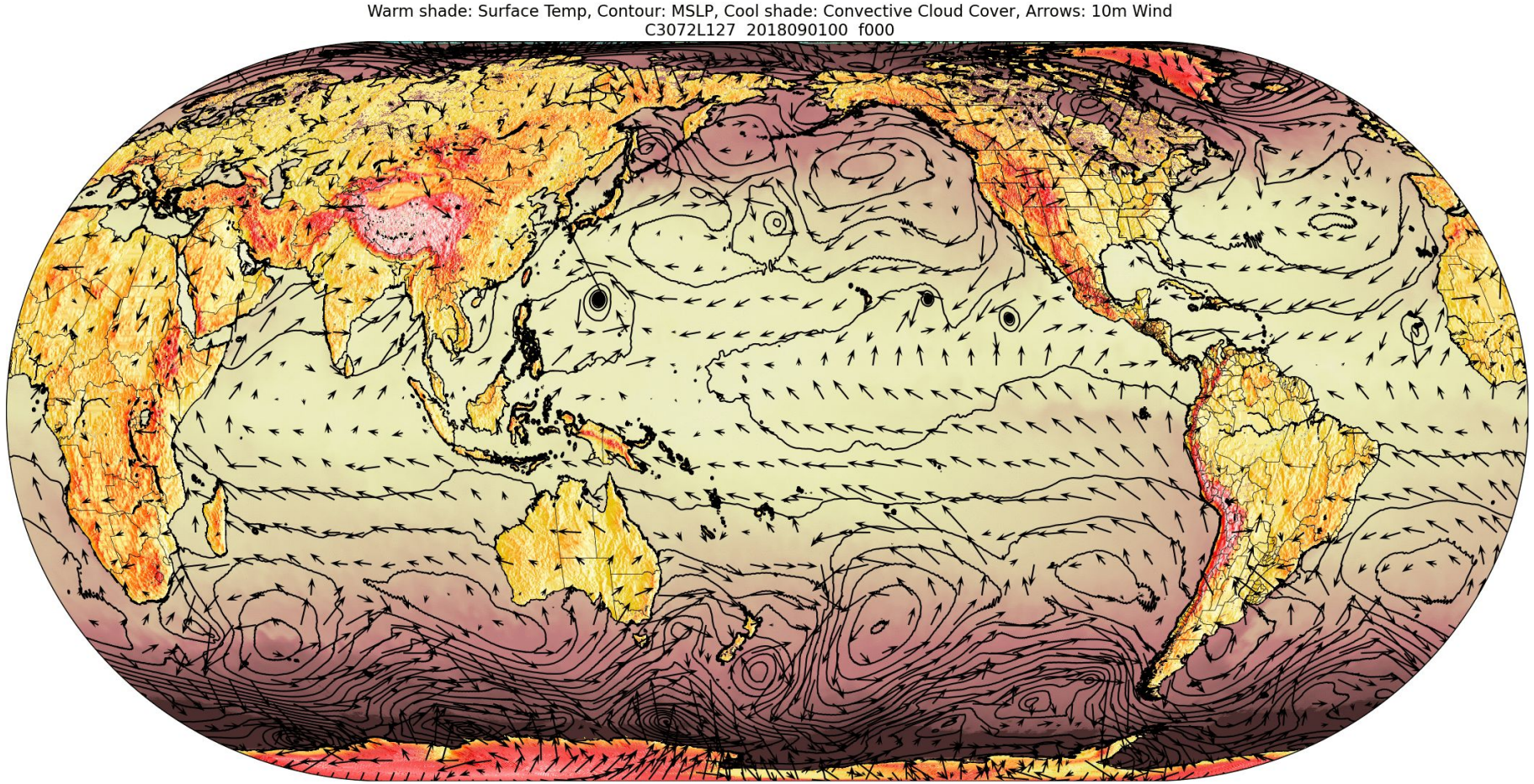
We can implement a fully coupled UFS Global Model at convective allowing resolutions TODAY.

UFS Components	Current Operational Configuration	Potential Operational Configuration	Resource use (ops)	Resource use (High-Res)
Atmosphere (includes land)	C768L127 (~13km)	C3072L127 (~3km)	112 nodes, 6.5 min/day wall time	614 nodes, 78 min/day wall time ~5000* nodes will bring the run time to ~8 minutes (with 32-bit dynamics, mixed mode)
Ocean/Ice	-	0.25deg MOM6/CICE6		
Waves	0.25deg	0.25deg		
Aerosols	-	0.25deg		

Courtesy: S. Moorthi, EMC

*WCOSS2 ops+dev has 5120 nodes

Where do we see ourselves in 5+ years? Advancing UFS Global Coupled Models to Convective Allowing Scales



C3072L127 2018/09/01
120 hour forecast
Warm shade: Surface Temp, Contour: MSLP, Cool shade: Convective Cloud Cover, Arrows: 10m Wind

Can potentially unify GFS, RTOFS, RRFS and HAFS into a single system

Courtesy: S. Moorthi and Keqin Wu, EMC

Concluding Remarks

- EMC is striving to adopt to the “community-based” model development for all operational applications
- Transition to UFS Applications by any means is not straightforward or simple
- Maintaining legacy applications while building new applications is resource intensive
- Sustained and stable funding/support for EMC and for our collaborators is required to accomplish the NPS Unification/Simplification
- EMC 5-Year (rolling) Implementation Plan (EIP) is designed to keep the R2O2R Process Transparent and help our collaborators and stakeholders to be on the same page with us during the whole process of model implementations (R2T2O)
- Target Release Date for EIP is Q1FY23

Thanks for your attention!

Questions?