NOAA's Next Generation Global Prediction System (NGGPS)

Building a Community Unified Forecast System (UFS)

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

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Outline

I. NOAA Planning for Modeling
   - From a weather & climate perspective
   - Towards a Unified Forecast System (UFS)

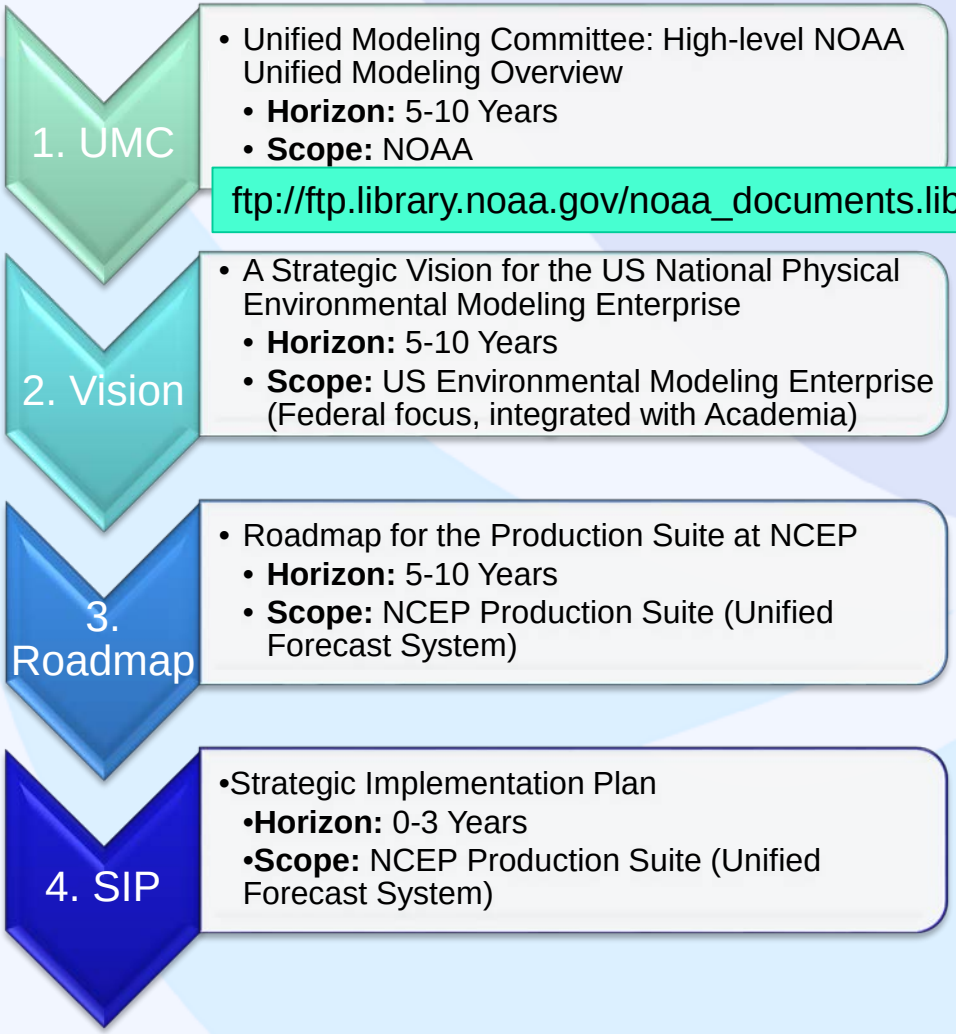
II. Strategic Implementation Plan for NGGPS
   - Community and Governance

III. NGGPS Progress (EMC)
   - Timelines and Results

IV. Getting involved
   - ‘Git’ing the Code’

I. Planning Overview

A Hierarchy of Plans



(1) A broad "strategy document" from the NOAA Unified Modeling Committee (UMC; under the auspices of the NOAA Research Council); spans the entirety of the NOAA modeling enterprise, inclusive of bio-geo-chemical, social and physical.

(2) The NWS and OAR are developing a ing out 10 years and bridging US Physical Environmental Modeling Enterprise with the higher level NOAA UMC effort.

(3) Also emanating from an NWS-OAR partnership, is a Roadmap document that lays out how we can move the NCEP Production Suite towards the vision described in the Vision Document.

(4) At a practical level, the Strategic Implementation Plan (SIP), describes NOAA's concrete steps over the next 3 years to build the Next Generation Global Prediction System based on the Unified Forecast System, beginning with numerical weather prediction across scales and in partnership with with the community (all stakeholders).

Strategic Vision

Physical modeling at NOAA, 5-10 year vision

AA level approval

Effort pre-dates UMC

Finalized, awaiting signatures

Strategic Vision: Key Elements

Focus on products supporting mission requirements

Unified modeling and data assimilation

- Coupled, ensemble based, reforecast and reanalysis
- Including pre- and postprocessing, calibration, verification validation

Focus on community modeling

- Operations ***and*** research

Evidence-driven decisions

- Same standards for all who contribute

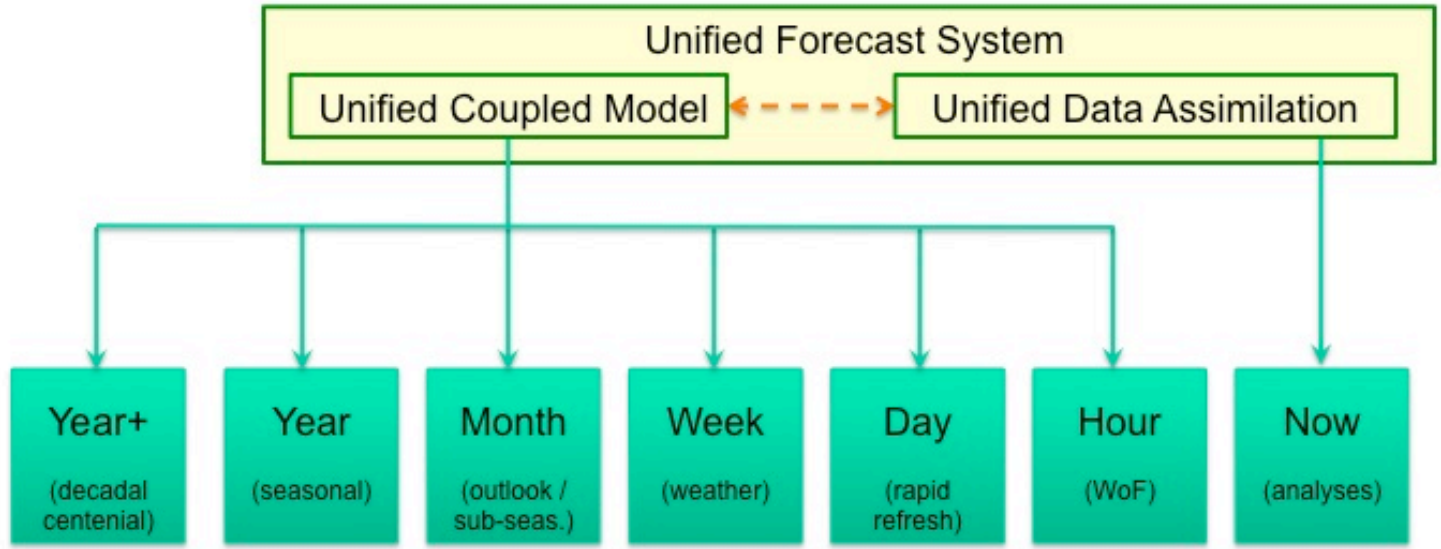
Transparent and robust governance

- Service requirements
- Technical requirements / solutions
- Prioritization

See SIP for community governance

Strategic Vision Fig. 1

Strategic Vision: Temporal Domains



Global	Global	Global	Global			Global
		Regional refinement	Regional refinement			
Down-scaling	Down-scaling			Regional	Regional	Regional

Unified Forecast System = Coupled Ensemble + Reanalysis + Reforecast

Strategic Vision Fig. 2

Roadmap

Production Suite, 5-10 years

AA level approval

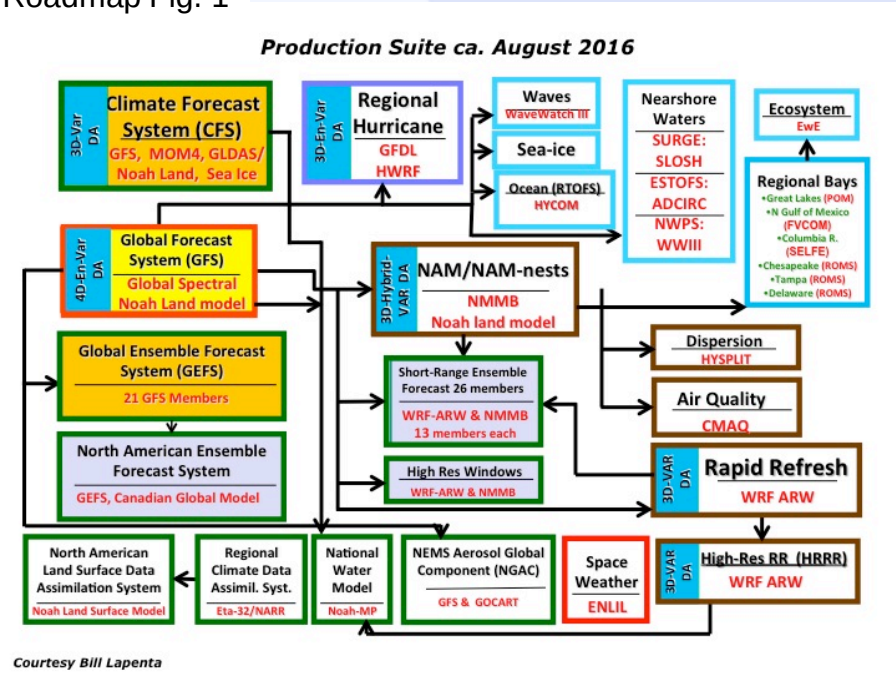
Effort pre-dates UMC

Finalized, awaiting signatures

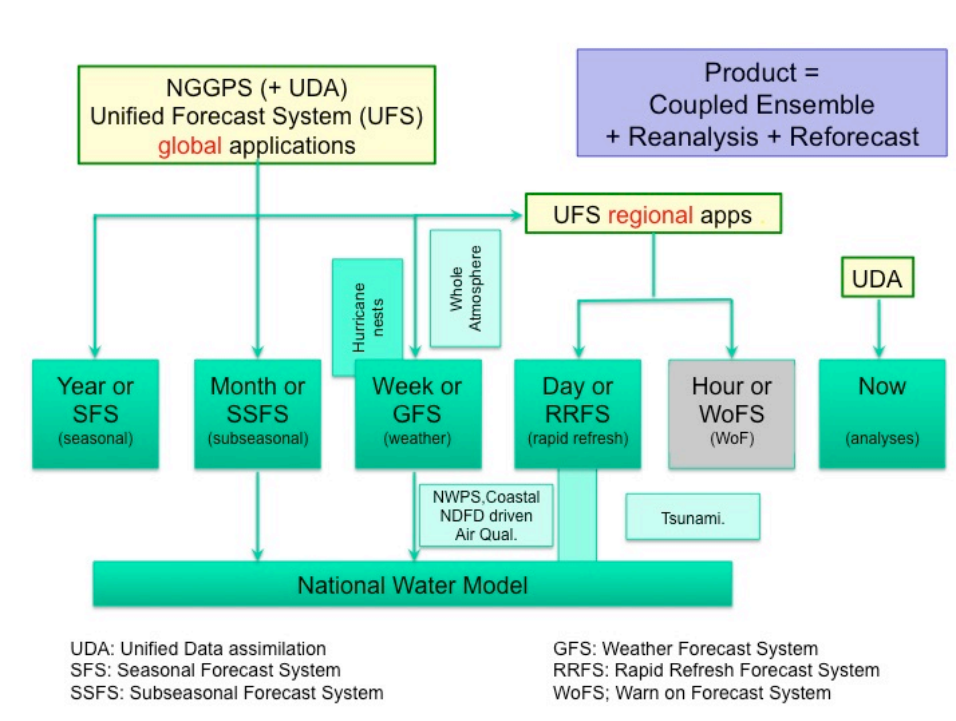
Roadmap: Big Picture

Moving from atmosphere focus to holistic environmental approach

Roadmap Fig. 1



… we will move to a product based system that covers all present elements of the productions suite in a more systematic and efficient way



Starting from the quilt of models and products created by the implementing solutions rather than addressing requirements ….

Roadmap Fig. 2

Roadmap: 5 year “end state”

Focus on transition to Unified System

Roadmap Table 2

Element	Cadence	Range	Resol.*	Ens.	Update	RR
SFS	7 d	9-15 mo	50 km (g)	28	4 y	1979-present
SSFS	24 h	35-45 d	35 km (g)	31	2 y	20-25 y
GFS	6 h	7-10 d	13 km (g)	26	1 y	3 y
RRFS	1 h 6-12 h 6-12 h	18 h 30 h 60 h	3 km (r)	26	1 y	TBD
WoFS	5-15 min	2-4h	1 km (r)	26	1 y	TBD
Analyses						
Trad.	6-24 h	---	Var. (g)	---	6 mo	N/A
RUA	15 min	---	TBD (r)	---	6 mo	

(g) Global
(r) regional
Red: uncharted territory

SFS= Seasonal Forecast System
SSFS= Sub-Seasonal (Outlook) Forecast System
GFS= Global Forecast System
RRFS= Rapid Refresh Forecast System
WoFS = “Warn on Forecast” System
RUA = Rapidly Updating Analysis

Changing use of WCOSS
Needing ~ 37 PFlop machine

*Resolutions for atmosphere, other component models may have different resolutions

Roadmap: 10 year “best system”

Focus on becoming best in the world

Roadmap Table 4

Element	Cadence	Range	Resol.*	Ens.	Update	RR
S3FS	7 d	12 mo	15 km (g)	200	TBD	1979-present
	24 h	45 d		100		
GFS	1? - 6 h	7-10 d	5 km (g)	50	1 y	3 y
RRFS	1 h 3 h 6 h	24 h 48 h 72 h	1.5 km (r)	50	1 y	TBD
WoFS	5 min	2h	0.5 km (r)	50	1 y	TBD
Analyses **Trad.** **RUA**	 6-24 h 5 min	 --- ---	 Var. (g) TBD (r)	 --- ---	1 y	N/A

S3SFS= (Sub-) Seasonal Forecast System
GFS= Global Forecast System
RRFS= Rapid Refresh Forecast System
WoFS = “Warn on Forecast” System
RUA = Rapidly Updating Analysis

SFS / SSFS use single model
Needing ~ 730 PFlop machine

*Resolutions for atmosphere, other component models may have different resolutions

II. Strategic Implementation Plan (SIP)

- SIP, execution at NCEP 1-3 year
- Execution level approval / planning
- Annual upgrade through SIP working groups

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

NGGPS Goals and Objectives[1]

Next Generation Global Prediction System

- Design/Develop/Implement NGGPS global atmospheric prediction model
  - Non-hydrostatic scalable dynamics
- Improve data assimilation and physics
- Position NWS for next generation high performance computing
- Engage community in model/components development
- Reduce implementation time
- Increase effectiveness of product distribution
  - Post-processing, assessments, and display

World's Best Global Forecast Guidance

[1]From NWS Budget Initiative proposal to OMB

SIP for Unified Forecast System

Common Goal: Single integrated plan that coordinates activities of NOAA + external partners in common goal of building a national unified modeling system across temporal and spatial scales

- NGGPS: foundation to build upon
- Activities include R&D, testing/eval, V&V, R2O, shared infrastructure, etc.

Approach for SIP development:

- Began with existing core R&D partners to organize in functional area Working Groups (WGs) responsible for drafting respective functional SIP components
- SIP version 1.0 finalized Nov. 2017, a 3-year plan (FY 2018-2020)
- FY18 and following : SIP to be rolling 3-year plan to be updated annually

SIP Working Groups Leads

Governance: UFS Steering Committee
- UMich, OAR/GFDL, NASA/GSFC, NCAR/CGD

Communications and Outreach
- NWS/STI, CalU (PA)

System Architecture
- OAR/ESRL, GMU

Infrastructure
- NWS/EMC, OAR/GFDL, GMU

Verification & Validation (V&V)
- NWS/STI, NWS/EMC, NCAR

Post-Processing
- NWS/MDL, NWS/EMC, SUNY

Dynamics and Nesting
- NWS/EMC, OAR/GFDL, OAR/AOML, UMich

Model Physics
- Navy/NRL, OAR/ESRL, NWS/EMC, UW, OU/CAPS, CSU, CU, UUt

Data Assimilation
- JCSDA, NWS/EMC, OAR/ESRL, NASA/GSFC

Ensembles
- OAR/ESRL, NWS/EMC, SUNY

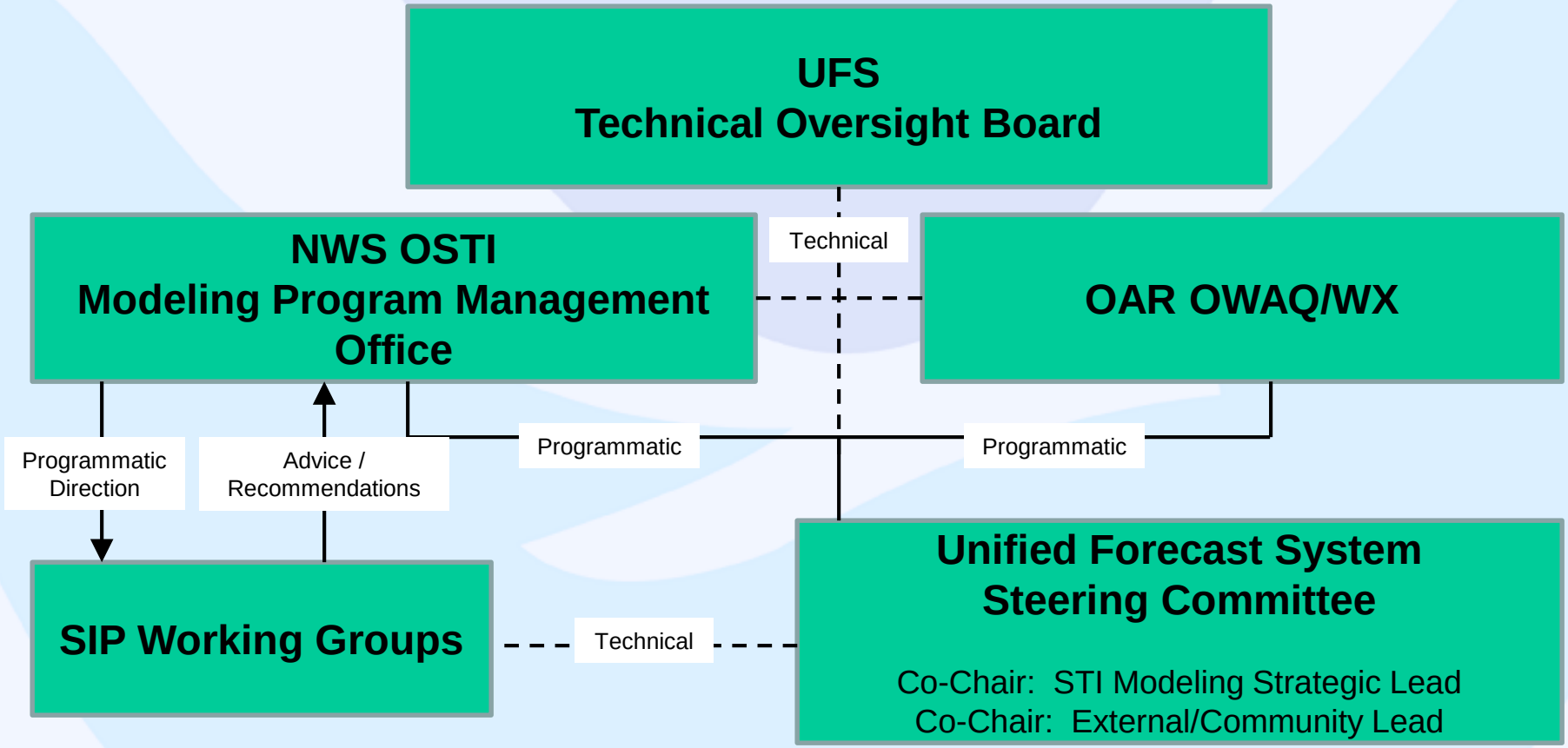
Marine Models
- NWS/EMC, OAR/GFDL, NOS/COOP&S, Navy/NRL, FSU

Land Surface and Hydrology
- NWS/EMC, NASA/GSFC

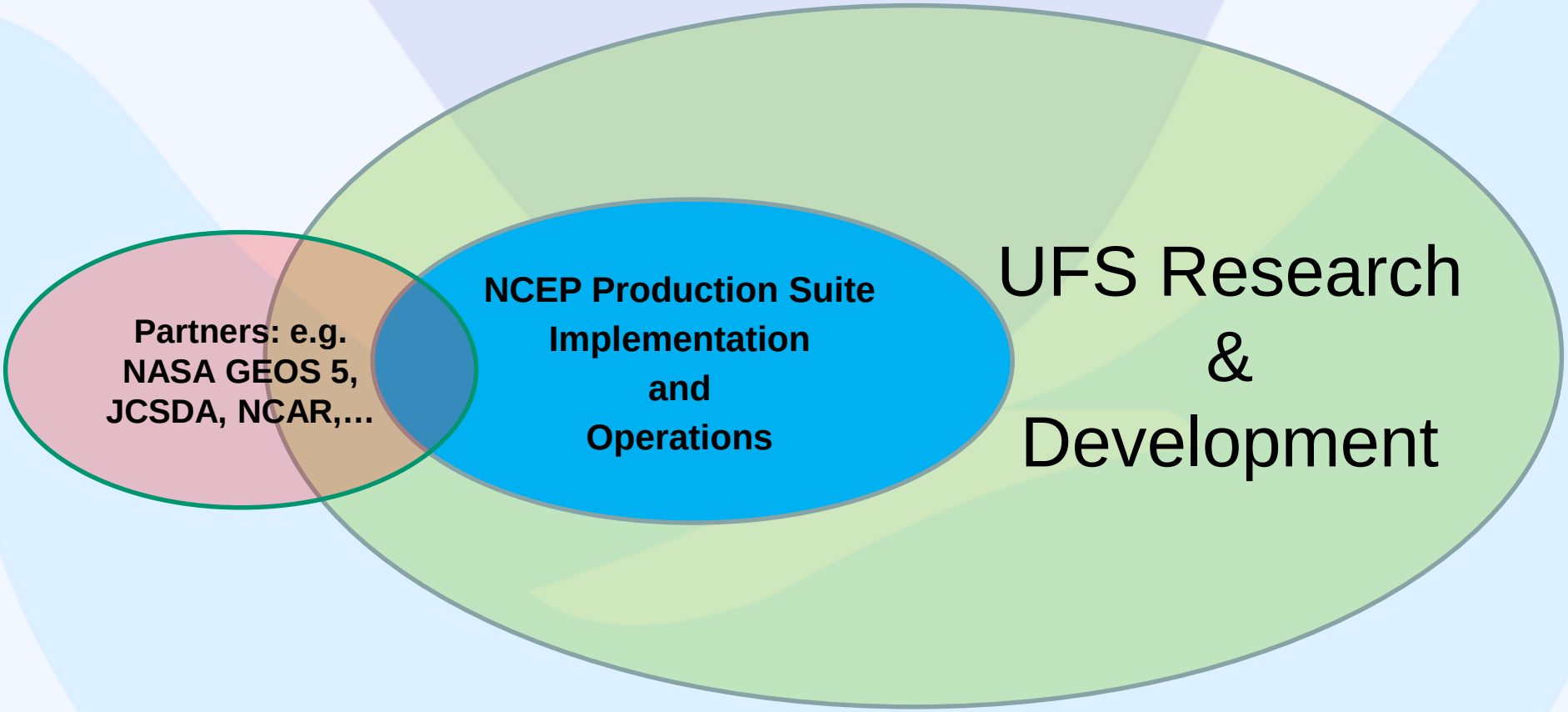
Aerosols
- NWS/STI, OAR/ARL, NASA/GSFC, NCEP/EMC, SUNY

Convective Allowing Models (CAMs)
- OAR/ESRL, OAR/GFDL, NWS/SPC, OU/CAPS, Penn State, OAR/NSSL

UFS Management and Oversight



Unified Forecast System Governance



Governance functions at the interface of the NCEP Production Suite, the broader UFS and the broader research and development community. What is being governed is: a community-based, unified, coupled modeling system suitable for application in NCEP's Production Suite (UFS).

SIP Vision for Community Partnership

Engage community on several layers for varying roles:

- **Researchers, Users, Stakeholders:** Conducts research and testing on publicly available model baseline; long-term science contributions; builds next-gen STEM workforce
- **Trusted Super-users:** Select R&D users that test/evaluate prototype models under development by core development partners prior to baselining and public release
- **Core Development partners:** Orgs actively involved in development of next-gen operational unified modeling system. Orgs include (but not limited to):
  - NOAA ops, R&D and program offices; NCAR; NASA/GMAO; Navy/NRL; JCSDA
- **Operations:** Centers that own/operate operational version of Unified Forecast System.
  - For NOAA, this equates to the NCEP Production Suite

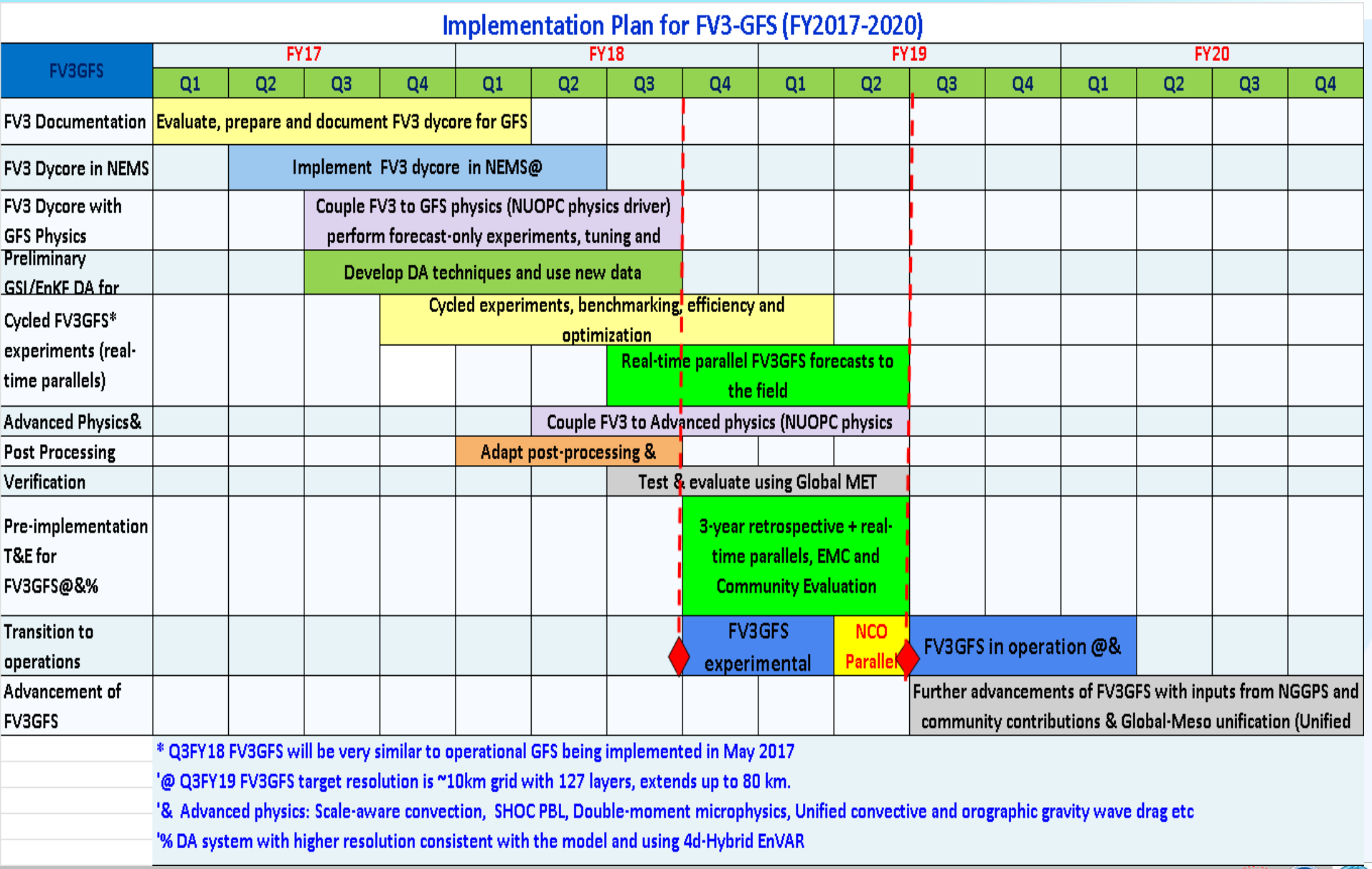
This is a partnership, not a contract

NCAR – NOAA MoA

- Letter of Intent for collaboration between NCAR, NWS, and OAR, signed July 28, 2017
  - "…to develop a Memorandum of Agreement (MOA) that will describe how both organizations will work collaboratively toward the design and construction of a community unified modeling infrastructure. "
  - Identified benefits include
    - Synergies
    - Common repositories
    - Access to NOAA operational models
- Team for writing MoA formed in November 2017
  - Draft identifies background, scope, infrastructure elements, roles and responsibilities, resources and prioritization, governance, and limitations.
  - The draft MOA is under review by signatories at this time.

III. NGGPS Progress (EMC)

FV3GFS Implementation Plan (original)



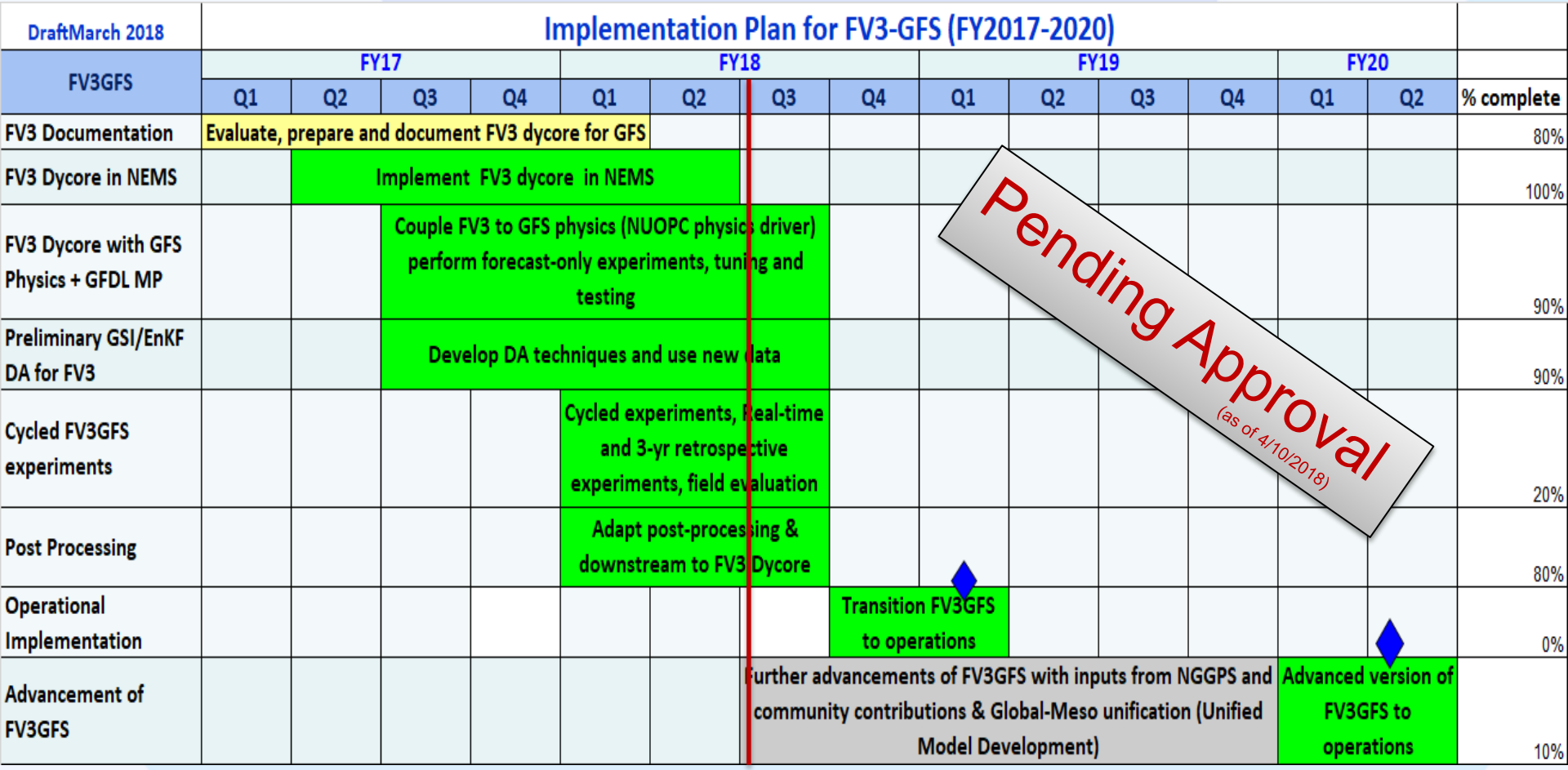
* Q3FY18 FV3GFS will be very similar to operational GFS being implemented in May 2017

'@ Q3FY19 FV3GFS target resolution is ~10km grid with 127 layers, extends up to 80 km.

'& Advanced physics: Scale-aware convection, SHOC PBL, Double-moment microphysics, Unified convective and orographic gravity wave drag etc

'% DA system with higher resolution consistent with the model and using 4d-Hybrid EnVAR

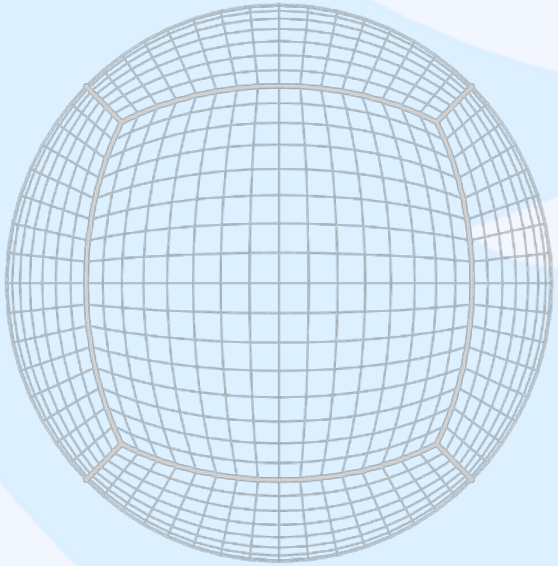
FV3GFS Implementation Plan (revised)



FV3 dycore and global models: GFS/GDAS

Completed

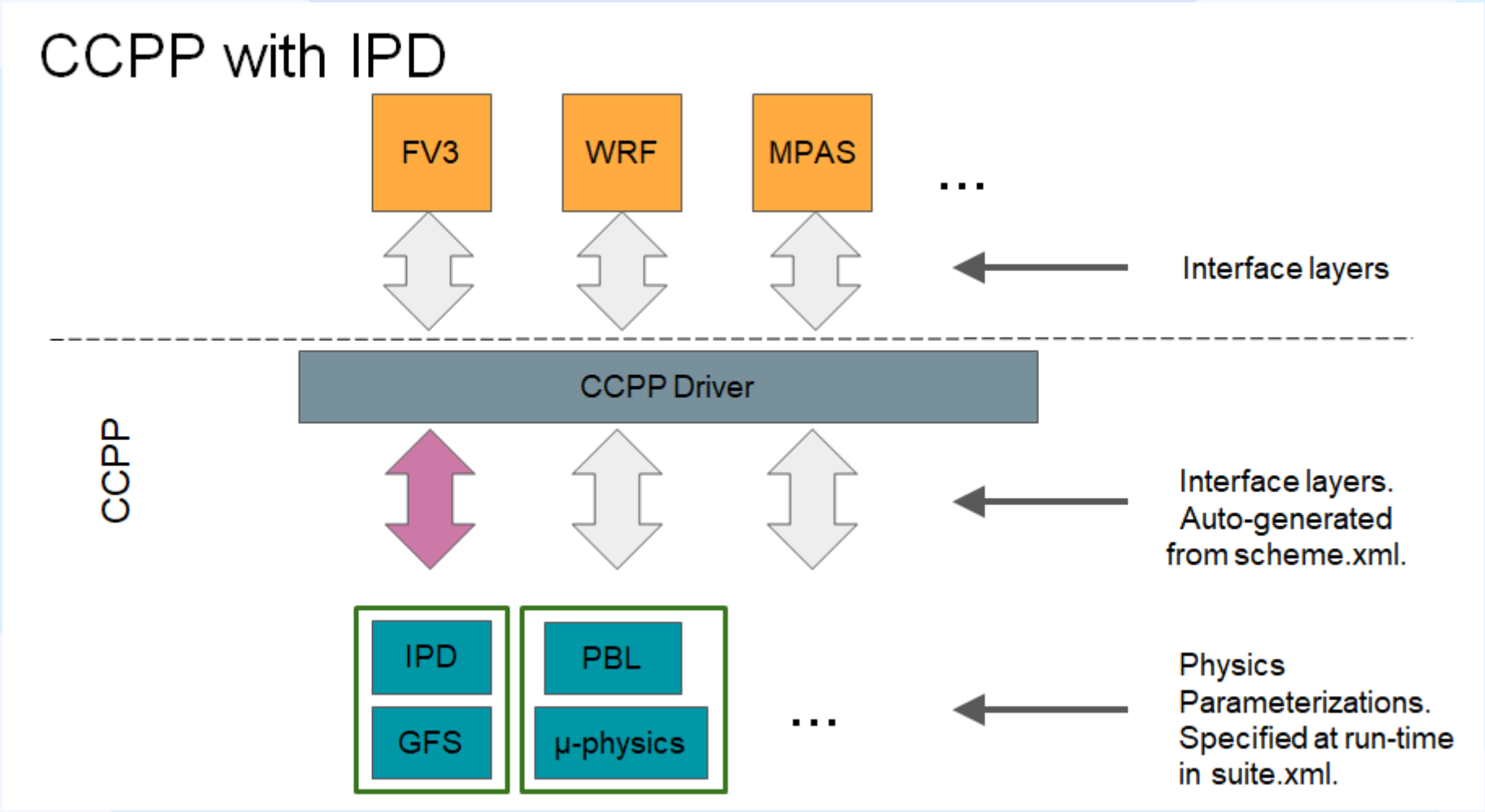
- Q3FY17: Implement FV3 into NEMS
- Q4FY17: Couple FV3 to GFS Physics & complete forecast only exp.
- Q4FY17: Adapt existing DA techniques for FV3



Near-term Milestones

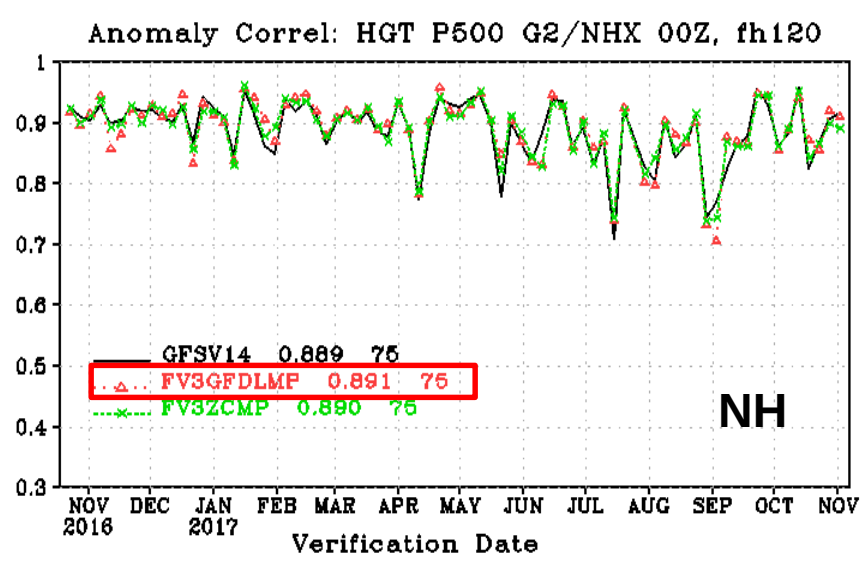
- Q1FY18: Evaluate and prepare FV3 documentation
- Q2FY18: Complete Pre/Post processing, verification, & downstream
- Q3FY18: Conduct real-time parallels and 3-year retrospective experiments
- Q1FY19: Implement FV3GFS into operations
- Q2FY19: Advanced physics; increased resolution and enhanced DA
- Q3FY19: Finalize FY20 FV3GFS implementation configuration
- Q4FY19: Conduct real-time parallels and 3-year retrospective experiments
- Q1FY20: Complete 3 year retro & real time parallel and Evaluation
- Q2FY20: Implement Advanced FV3GFS into operations

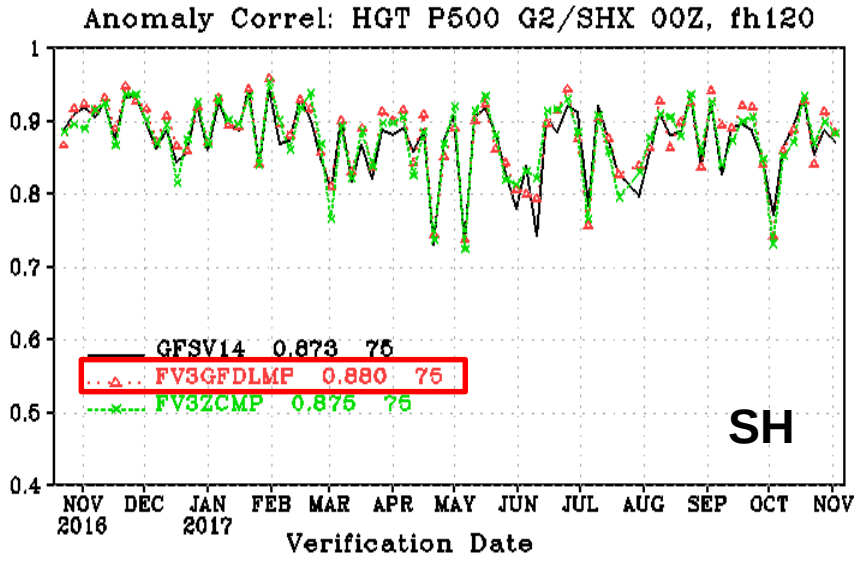
CCPP: Advanced Physics Infrastructure

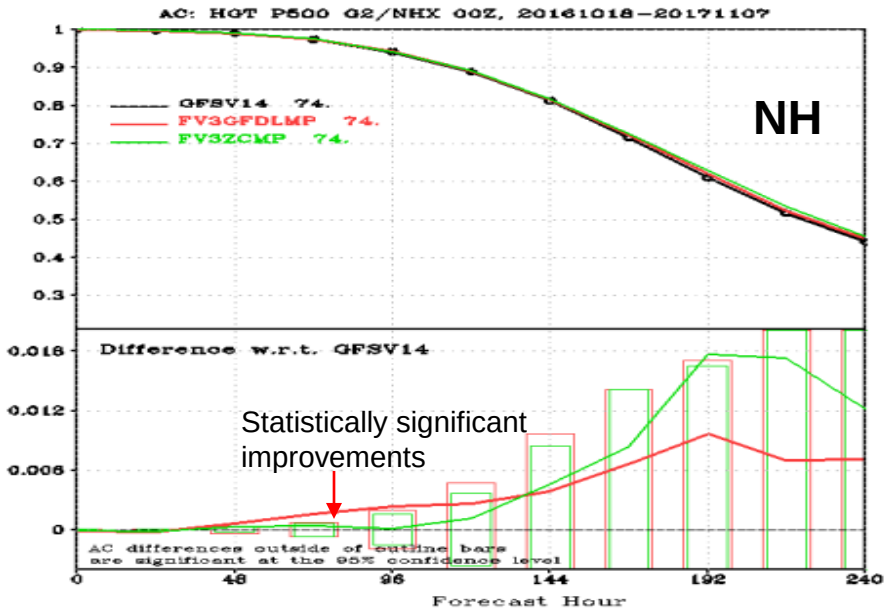


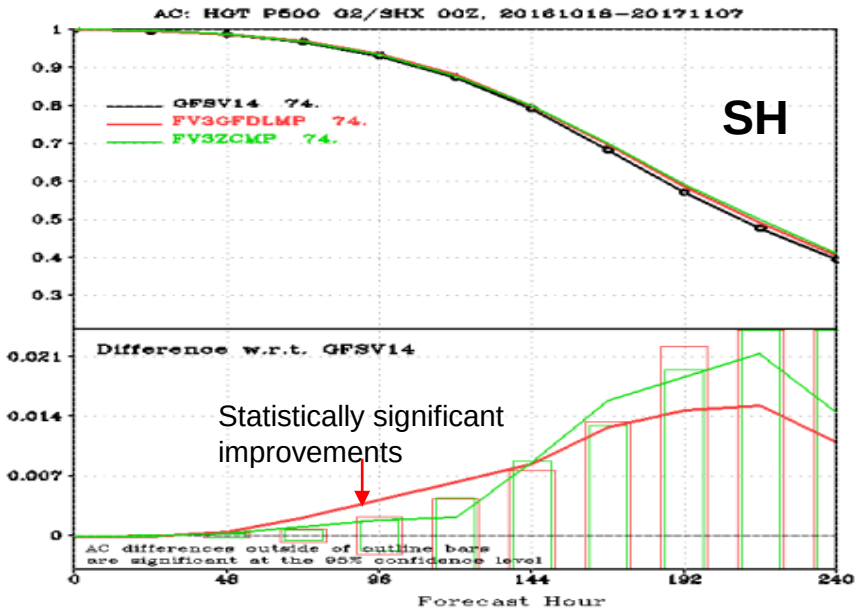
IPD = Interoperable Physics Driver
CCPP = Common Community Physics Package

Forecast only experiments with FV3GFS+GFDL MP; 500-hPa HGT ACC

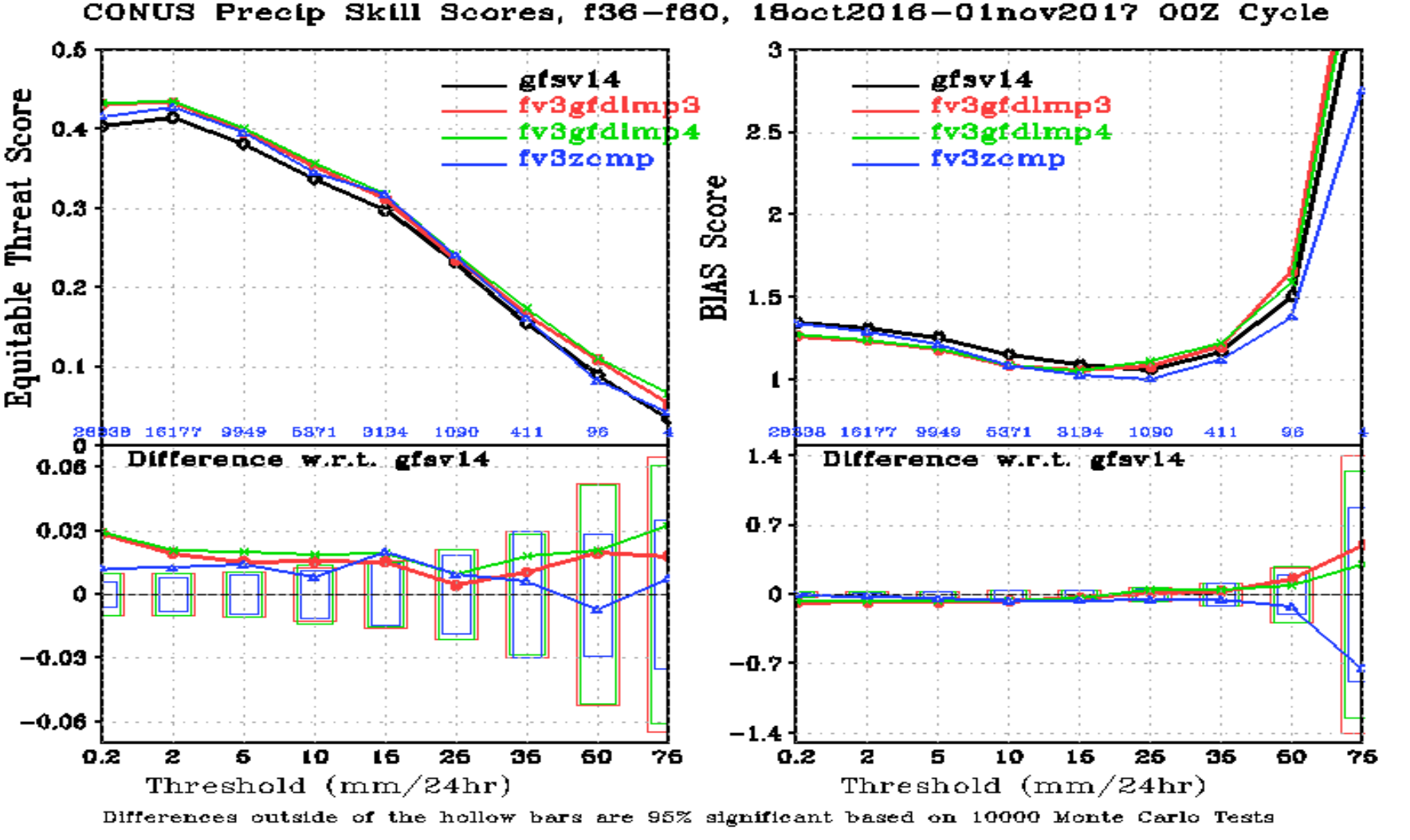






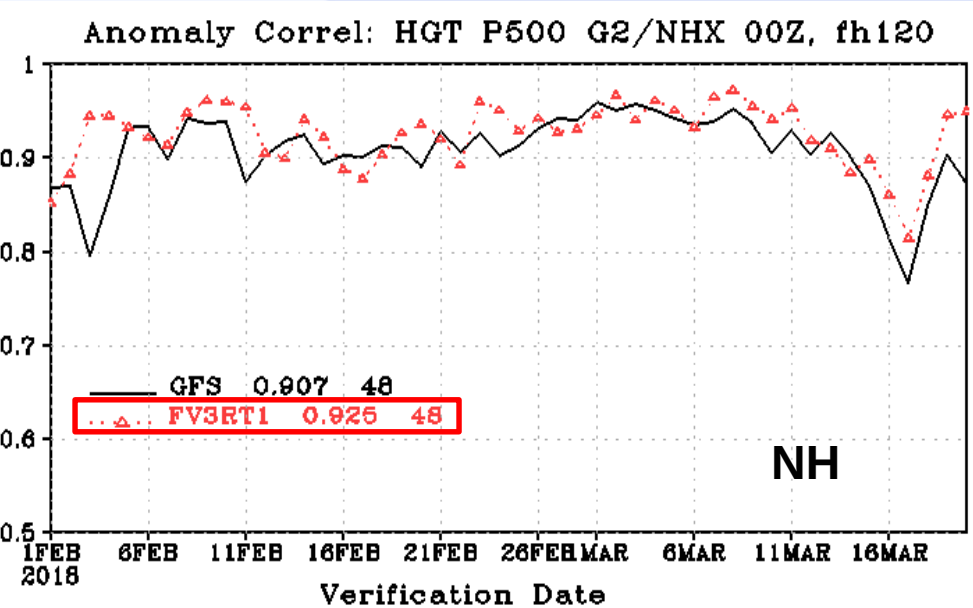


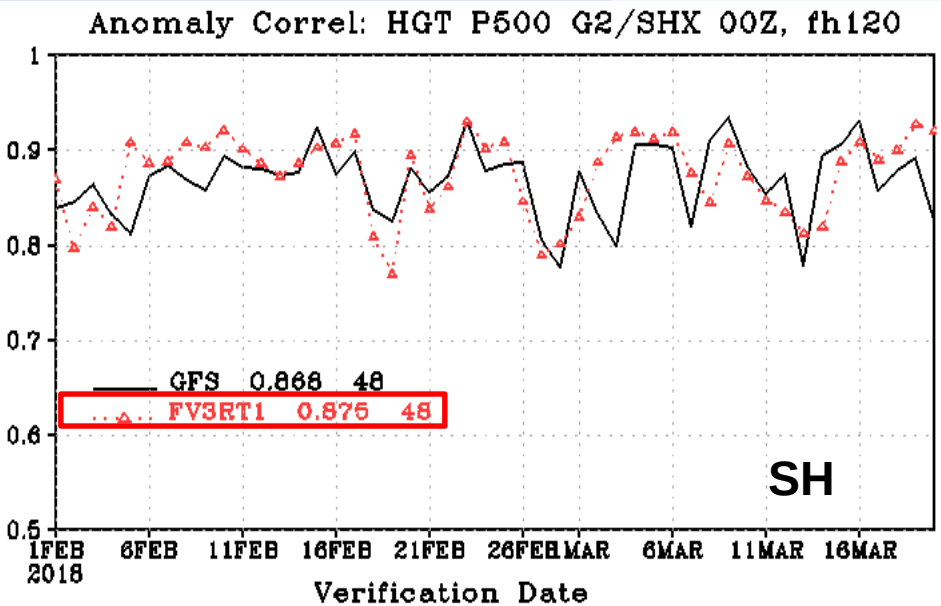
Forecast only experiments with FV3GFS+GFDL MP
CONUS Precip ETS and Bias Scores

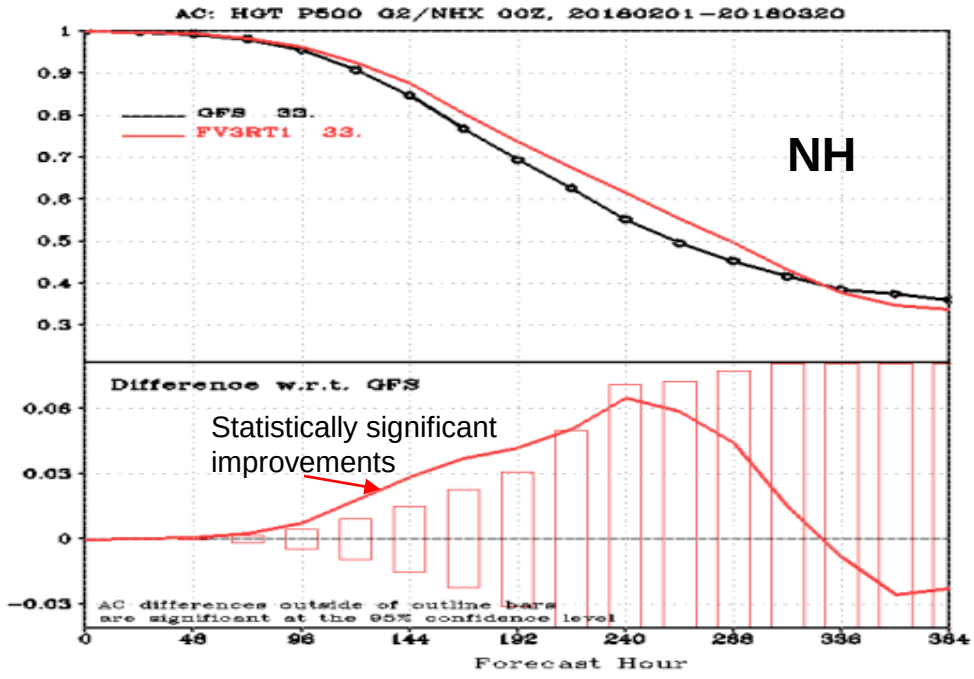


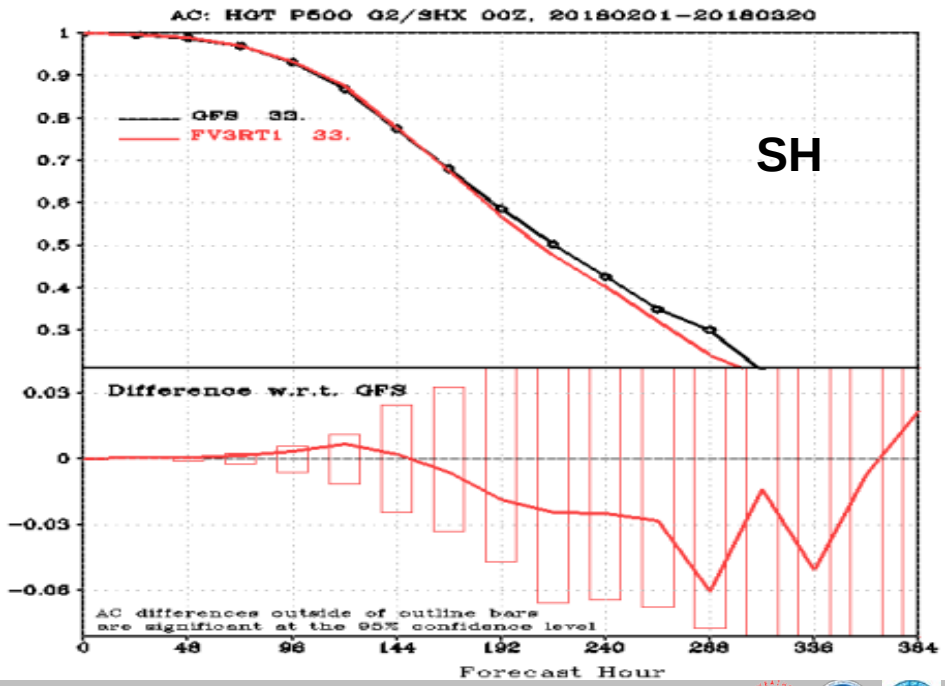
Compared to operational GFS, FV3GFS with either Zhao-Carr MP or GFDL MP improved precipitation scores over the CONUS.

Real-time experiments with fully cycled FV3GFS+GFDL MP; 500-hPa HGT ACC



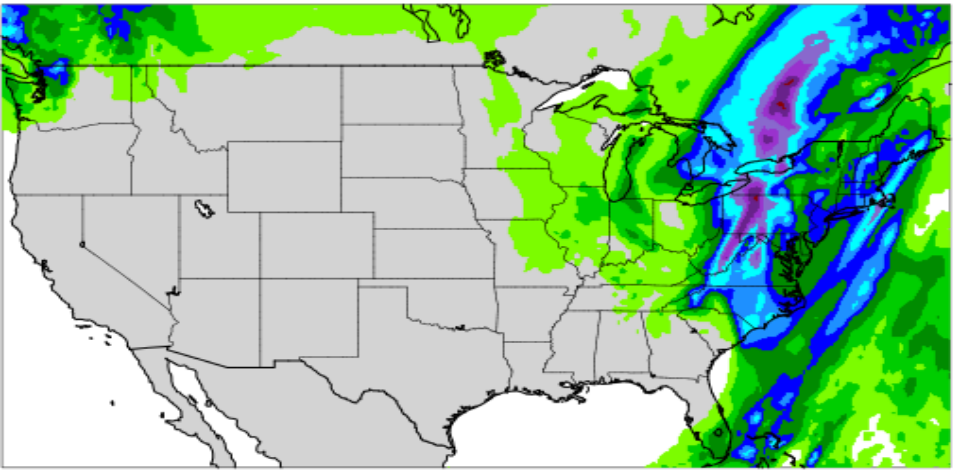


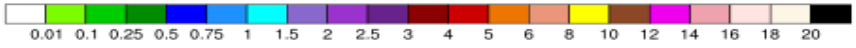




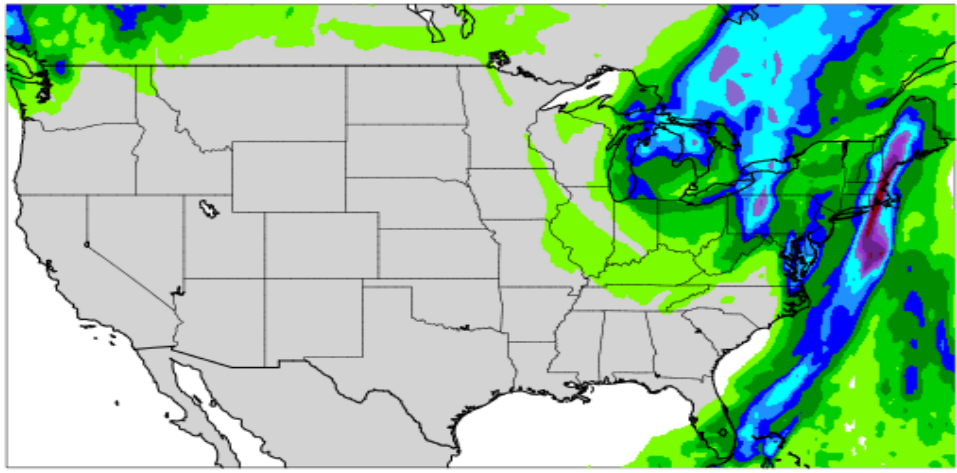
GFS / FV3 examples: Heavy precip case for New England

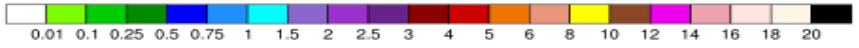
GFS initialized 12Z 20 October 2017 valid 12Z 25 October 2017 (F120) 24-h accumulation

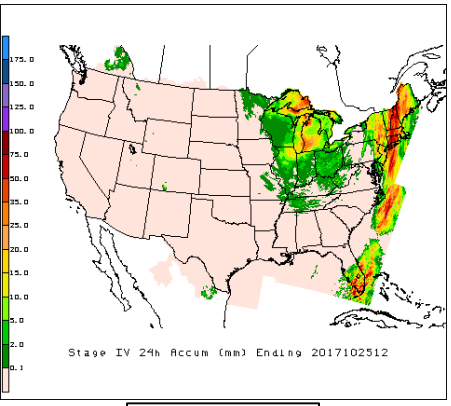




FV3 initialized 12Z 20 October 2017 valid 12Z 25 October 2017 (F120)

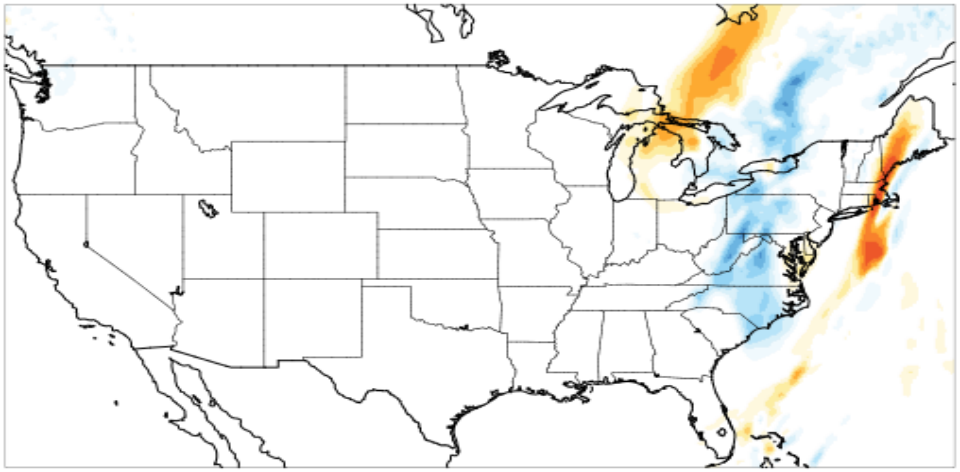


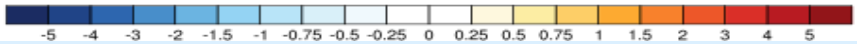




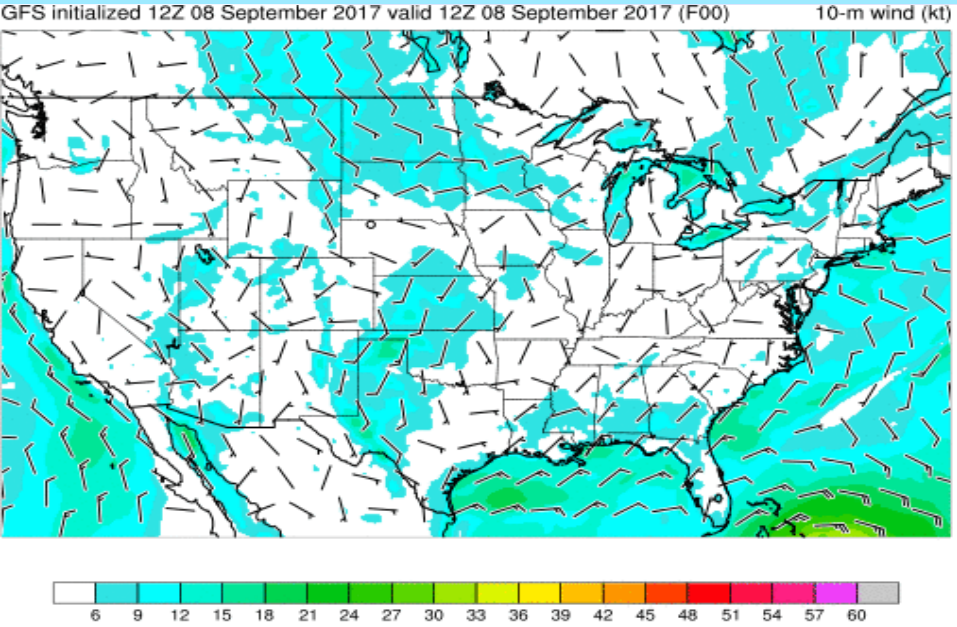
verification

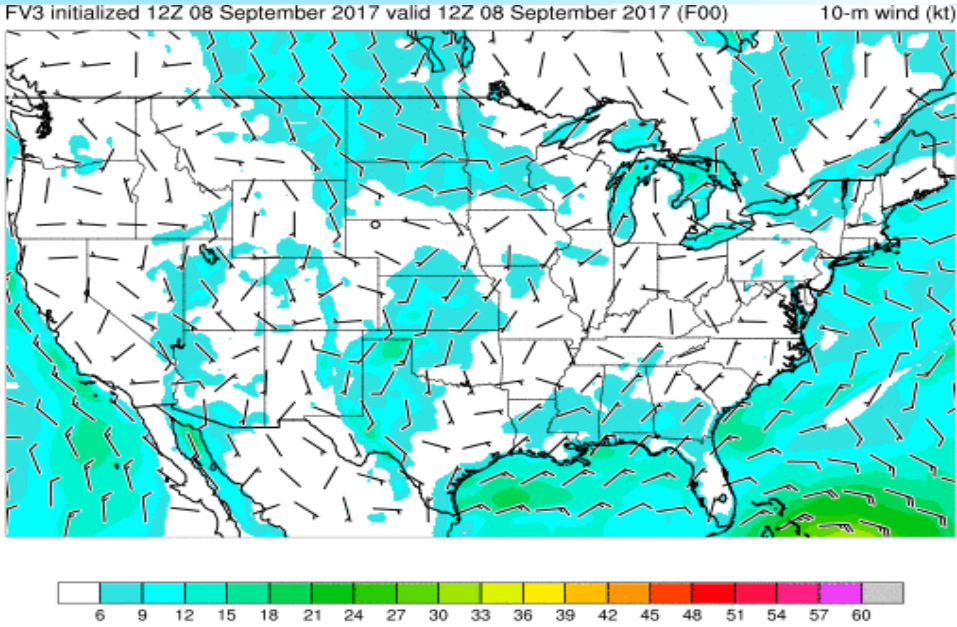
FV3 minus GFS valid 12Z 25 October 2017 (F120)

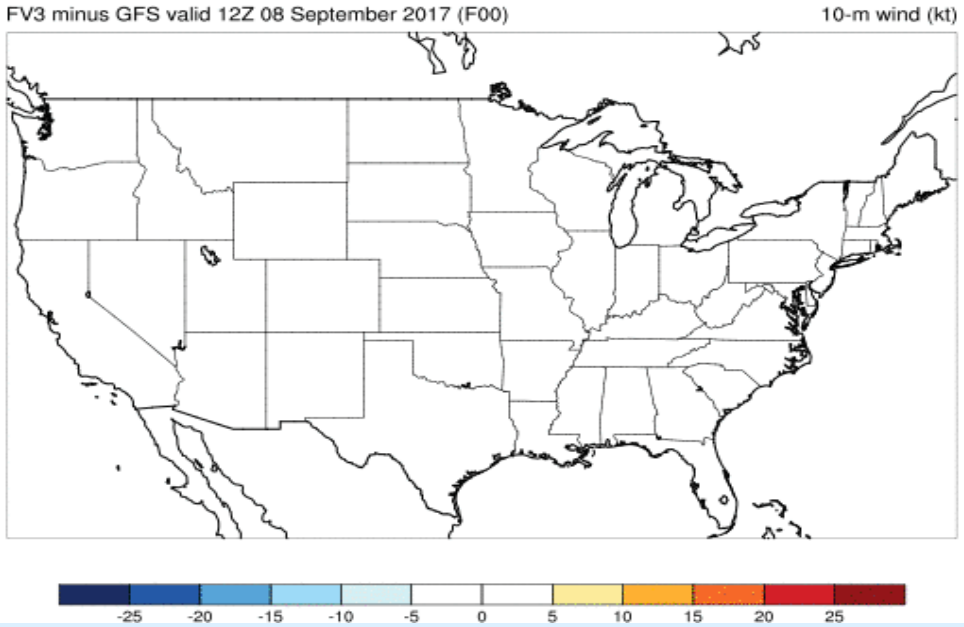




GFS / FV3 examples: Irma animation







FV3GEFS Implementation Plan (Sub-seasonal Forecasts)

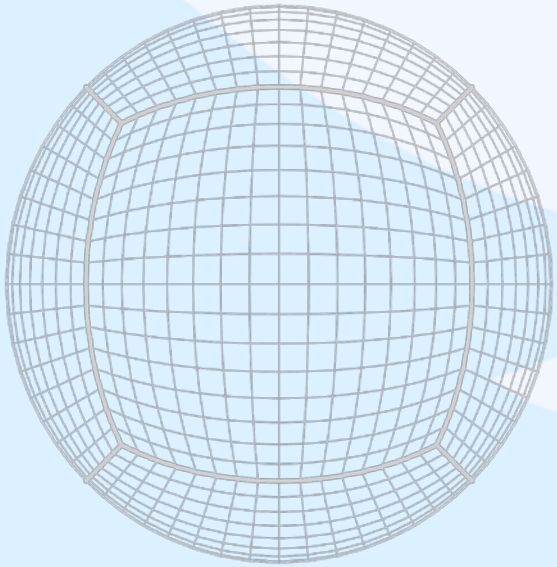
Version 1.2 March 2018	Implementation Plan for FV3-GEFS (FY2017-2020)															
FV3GEFS	FY17				FY18				FY19				FY20			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
FV3GEFS Reanalysis Development			Develop and test low resolution FV3GFS with FV3GDAS, configure it for reanalysis (ESRL)													
FV3GEFS Ensemble Configuration		Configure FV3GFS ensemble resolution, members, physics, coupling to ocean and sea-ice, and extend forecasts to weeks 3&4 (EMC)														
FV3GEFS Reanalysis Production							Produce ~20-year reanalysis datasets using FV3GFS/GDAS (ESRL)									
FV3GEFS Reforecasts								Finalize FV3GEFS V12 configuration* & produce ~20-year reforecasts (extended to 35 days)								
FV3GEFS V12 Evaluation										Evaluate FV3GEFS V12 forecast performance out to weeks 3&4						
FV3GEFS V12 Implementation													FV3GEFS V12 in operation			
Advancement of FV3GEFS													Further advancements of FV3GEFS (GFS/GEFS unification, ensemble			

* Proposed changes for GEFS V12: 1) Produce FV3 based reanalysis in FY18 using the same configuration as Q2FY18 FV3GFS (ESRL); 2) Reforecasts will be based on FV3GEFS configured with 2-Tier SST approach; and 3) FV3GEFS Reforecasts extended to 35 days to include weeks 3&4 guidance.

FV3 dycore and global models: GEFS

Completed

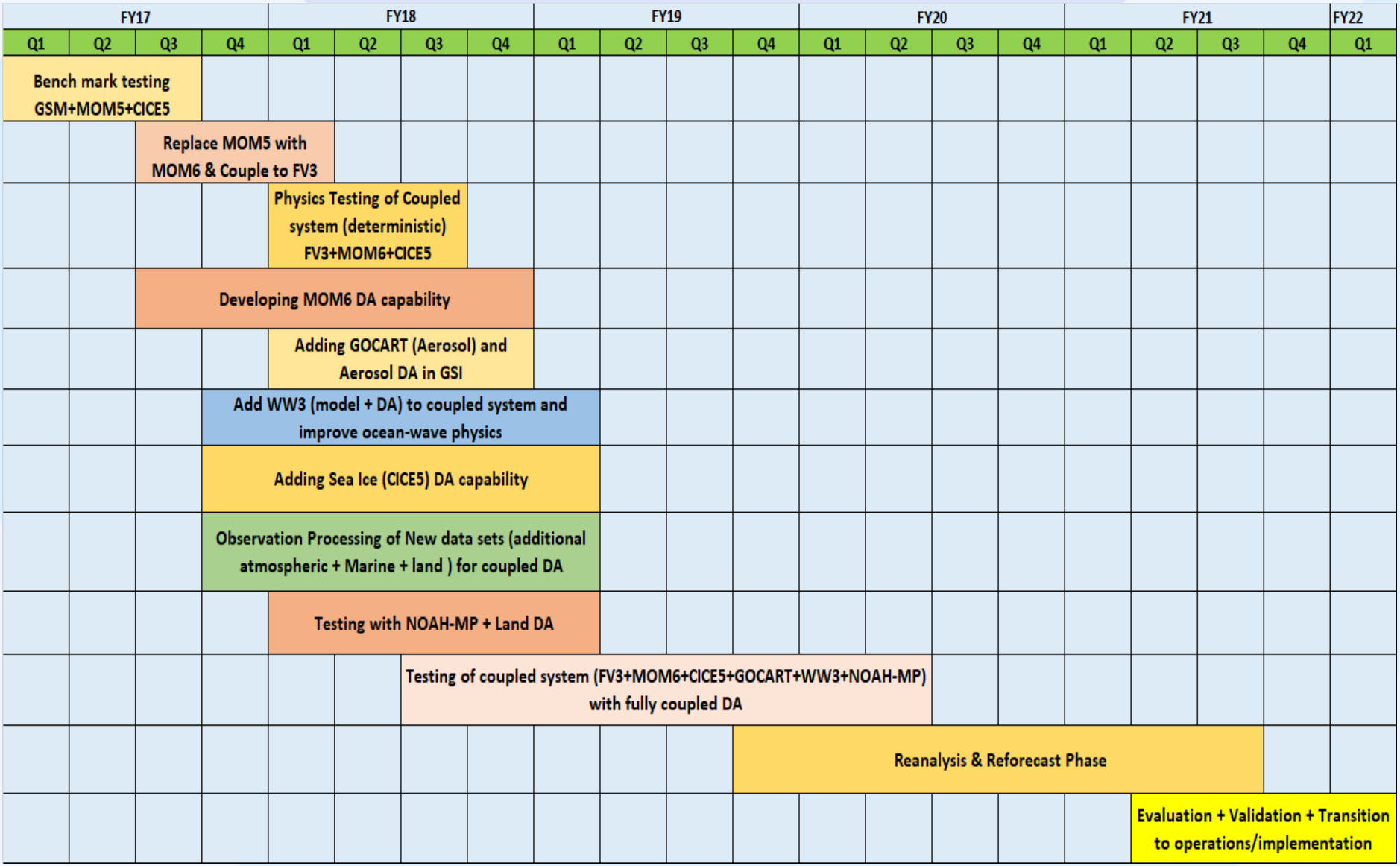
- **Q2FY18: Prepare FV3-GFS for reanalysis project (ESRL/PSD)**



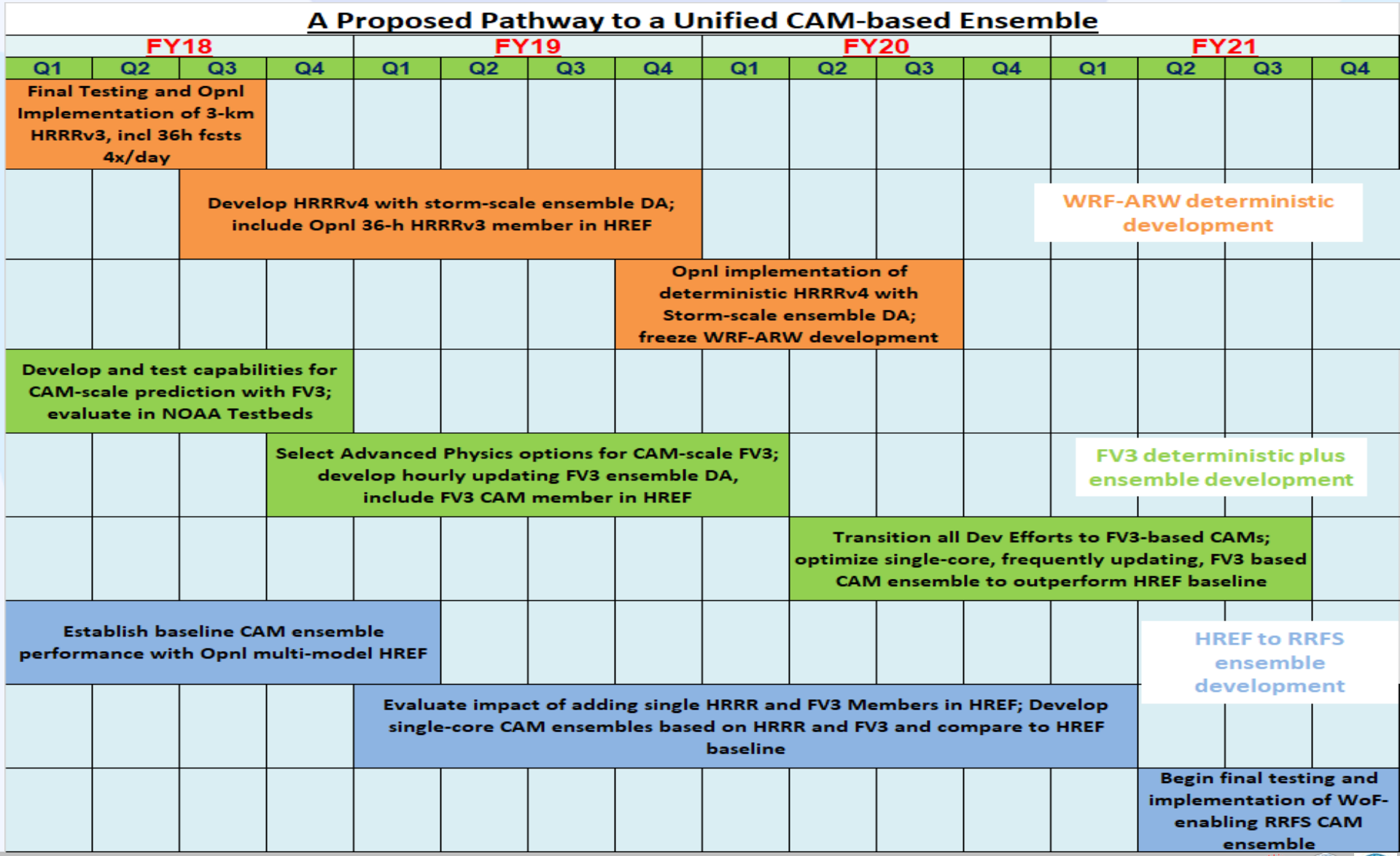
Near-term Milestones

- **Q3FY18: Determine ensemble configuration for FV3-GEFS**
- **Q2FY19: Produce ~20-year reanalysis datasets (ESRL/PSD)**
- **Q3FY19: Produce ~30-year reforecast datasets for FV3-GEFS**
- **Q3FY19: Couple FV3-GEFS to Wave Watch III ensembles (NPS unification)**
- **Q3FY19: Integrate NGAC into GEFS control member (NPS unification)**
- **Q4FY19: Implement FV3GEFS into operations**

FV3 Seasonal Forecast System Implementation Plan



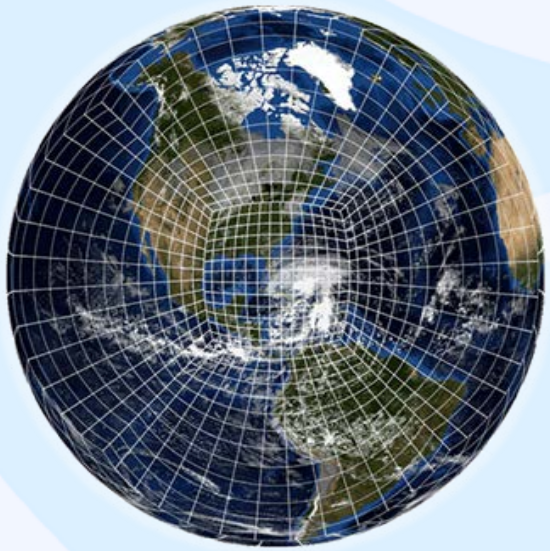
FV3 based CAM and CAM Ensemble Implementation Plan



FV3 for Convection Allowing Models

Completed

- **Q3FY17: Initial concept ensemble test case with FV3 nesting on a stretched cube (manually run)**



Near-term Milestones

- **Q1FY18: More testing with global FV3 with a 3 km CONUS nest on a stretched cube including ensemble display tools**
- **Q3FY18: Develop a standalone regional FV3 capability**
- **Q4FY18: Static nests running in standalone regional FV3**
- **Q4FY18: Integration/testing of advanced physics in nested FV3**
- **Q2FY19: Compare pure FV3-based HREF with multi-model HREF**

A Word on Verification ("V&V")

UFS Community is unifying its V&V Activities around the MET+ Package (and you should too!)

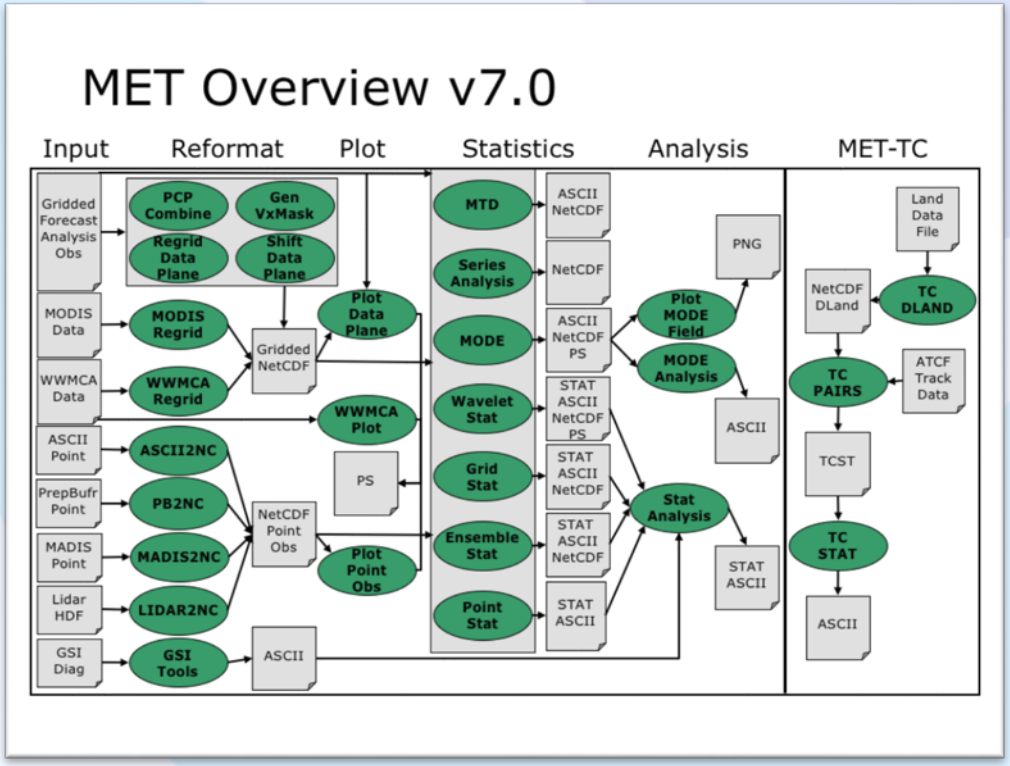


Figure: Flowchart representation of METv7.0 structure. https://dtcenter.org/met/users/index.php

IV. Getting Involved

You can contribute too…

Accessing the code.

Github.com and NOAA Virtual Lab (VLab) to host FV3GFS V1 Code Public Release

- Access FV3GFS Project on VLab
- Code repositories set up on

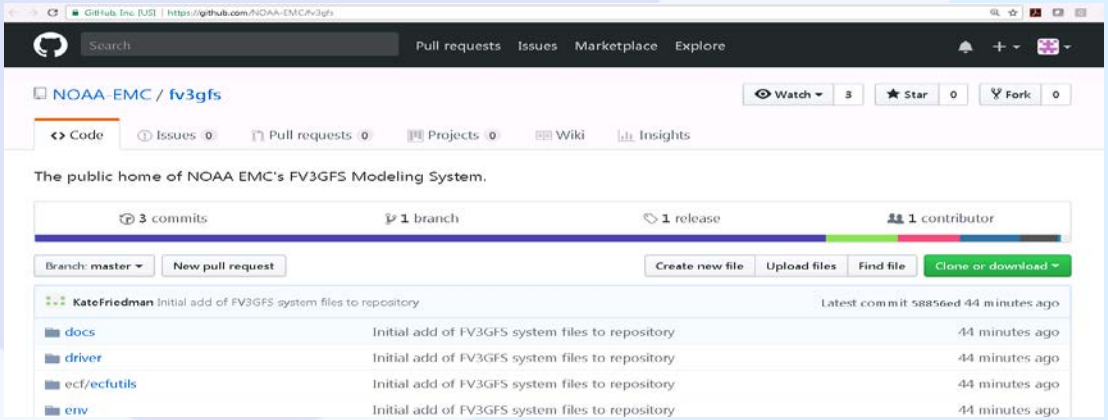
Github.com & VLab GIT

- Community Wiki page, Forums and Developers Pages on VLab
- ICs for Canned Cases:

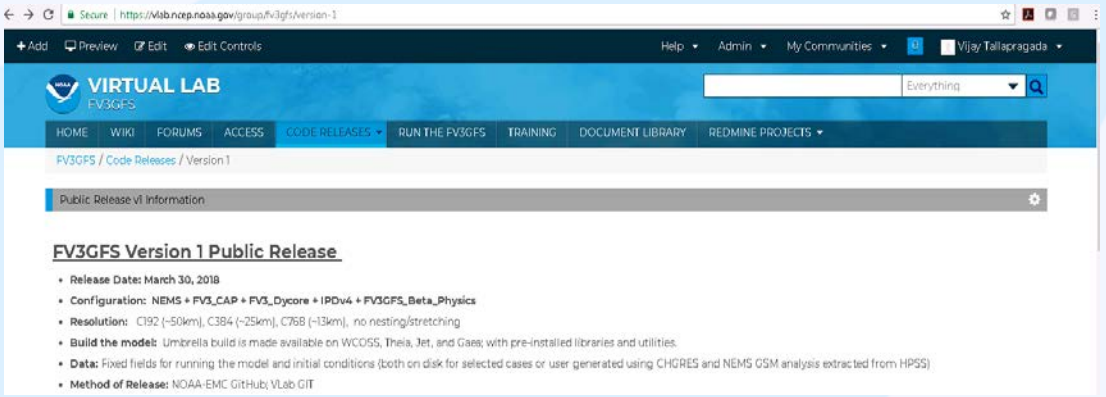
August 17, 2017 **Hurricane Harvey**
February 10, 2016 **Atmospheric River**
February 28, 2018 **East Coast Noreaster**

- Model Resolutions: C192 **(~50km)**, C382 **(~25km)** or C768 **(~13km)**

Public Version:
https://github.com/NOAA-EMC/fv3gfs



Developers Version:
https://vlab.ncep.noaa.gov/web/fv3gfs



NEMS FV3GFS Version 1 Code Release to the Community

- **Release Date: March 30, 2018**
- **Configuration**: **NEMS + FV3_CAP + FV3_Dycore + IPDv4 + GFS_Physics + GFDL Microphysics**

  This is the same NEMS FV3GFS currently running in experimental mode at NCEP in real-time using fully cycled 4D-EnVar Hybrid Data Assimilation.
- **Resolution**: C192 (~50km), C384 (25km), C768 (~13km), no nesting/stretching
- **Build the model:** Umbrella build capability currently supported on NOAA operational and research supercomputers WCOSS, Theia, Jet, and Gaea; with pre-installed libraries and utilities.
- **Data**: Initial conditions for selected cases, and fixed fields for running the model
- **Method of Release:** github.com; VLab GIT
- **Running the model**: CROW front-end and rocoto workflow utilizing simple shell scripts and configuration files for running forecast-only experiments for selected and user-defined cases.
- **Post Processing**: NCEP Unified Post Processing (UPP) software producing master and half degree grib2 output.

Take Aways…

- NGGPS is making great strides towards a Unified Forecast System
- We have coherent and coordinated strategies
  - Backed by vetted plans and governance
- We are simplifying and unifying the NCEP production suite
- Community engagement has been brought to the fore
- *You can get engaged,* and if we are to to build the best forecast guidance possible, we need you to

The remaining talks in this session will address in greater detail several themes touched on only briefly herein.


Thank You!

Backup Slides

I. Planning Overview

Unified Modeling Committee

NOAA-wide, long term

Under NOAA Research Council

Policy rather than requirements

ftp://ftp.library.noaa.gov/noaa_documents.lib/NOAA_UMTF/UMTF_overview_2017.pdf

Unified Modeling Committee

NOAA Research Council forms Task Force in April 2016, to address benefits / understanding of Unified Modeling throughout NOAA

- January 2017 report on Unified Modeling *

Outcome of report, 6 focal areas:

- Task Force becomes standing Unified Modeling Committee
- Establish a NOAA wide process for information exchange
- Ensure adequate resources to execute NOAA-wide modeling
- Define best practices in NOAA modeling
- Establish regular review for model redundancy and retention
- Make HPC more accessible to all of NOAA

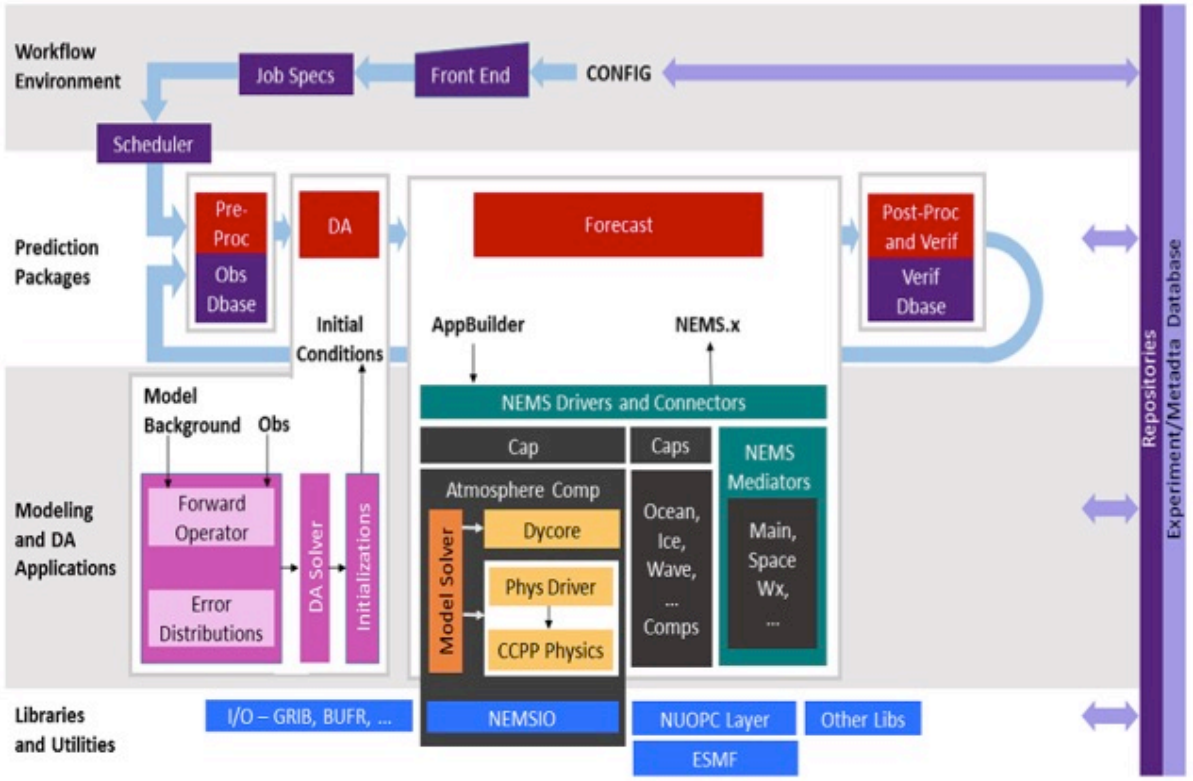
Confirms and supports Production Suite plans, but sets policies rather than requirements for Production Suite.

Roadmap: Architecture

ESMF/NUOPC/ NEMS architecture enables unified coupled modeling and DA

Consistent with broader NOAA (UMC) and US vision (National ESPC)

FV3, CCPP, CICE, MOM6 (?), WW3, GOCART, WRF-Hydro, …



Courtesy NOAA NCEP System Architecture Working Group

Roadmap Fig. 3

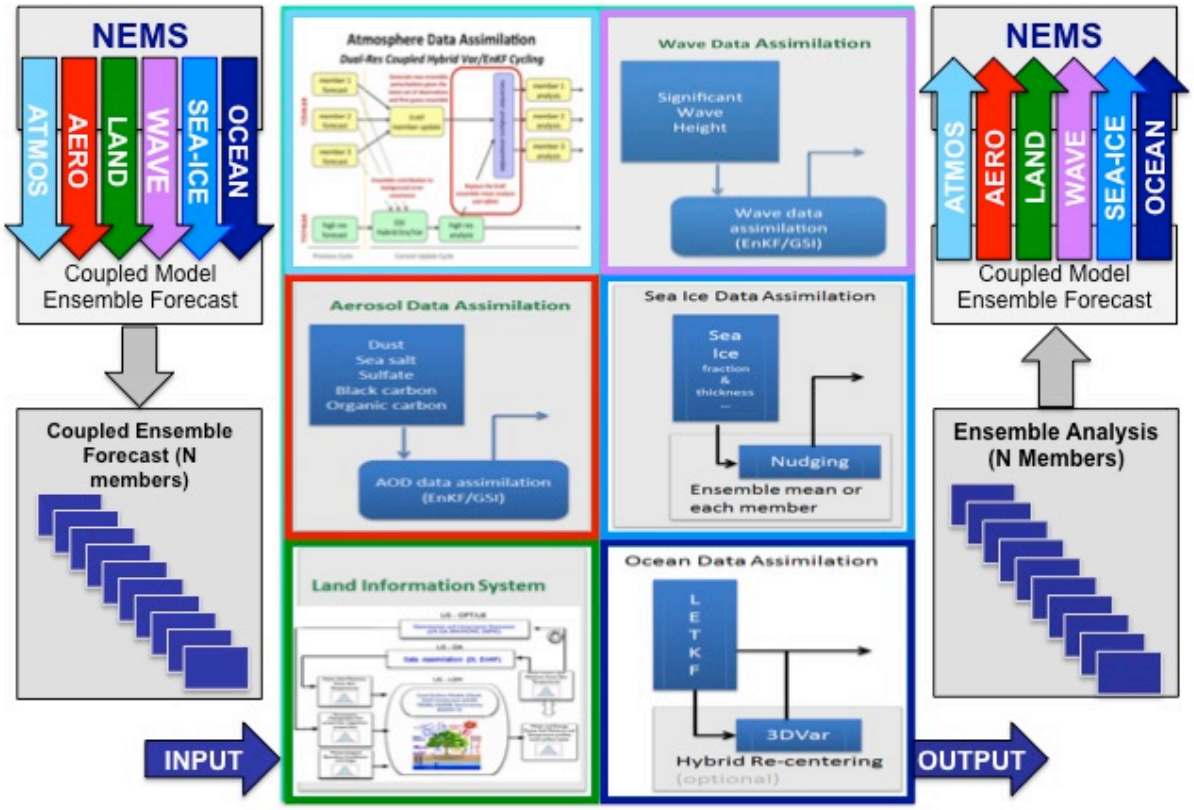
Roadmap: Fully Coupled

Moving to coupled Data Assimilation

Range of work going from weakly to strongly coupled Data Assimilation

Commitment to go there, not mature enough for hard commitment

Moving to Joint Effort on Data Assimilation Integration (JEDI)



Courtesy Suru Saha

Roadmap Fig. 4

II. Strategic Implementation Plan

SIP, execution at NCEP 1-3 year

Execution level approval / planning

Annual upgrade through SIP working groups

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

NGGPS Atmospheric Model Phased Implementation Approach

Phase 1 (FY15) – Identify Qualified Dynamic Cores

- Evaluate technical performance
  - Scalability
  - Integration of scheme stability and characteristics

Phase 2 (FY16) – Select Candidate Dynamic Core

- Integrate with operational GFS Physics/CCPP
- Evaluate meteorological performance

Phase 3 (FY17-19) – Dynamic Core Integration and Implementation

- Implement candidate dynamic core in NEMS
- Implement Common Community Physics Package
- Implement data assimilation (4DEnVar with 4D incremental analysis update and stochastic physics)
- Implement community model environment

Overall Assessment and NGGPS Program Manager Recommendation

The FV3 core represents the lowest risk, lowest cost alternative for the new NGGPS atmospheric model

Compared to the MPAS, FV3:

- Meets all technical needs
- Less expensive to implement
- Higher readiness for implementation
- Significantly better technical and computational performance
- Lower risk

Recommendation: Select GFDL FV3 and proceed to NGGPS Phase 3 dynamic core integration and implementation

SIP Working Groups

Unified Forecast System (UFS) Steering Committee

Communications and Outreach
- Common messaging strategy

Convective Allowing Models (CAMs)
- Intermediate steps to CAM ensembles, Warn on Forecast; test/eval w/community

System Architecture
- NEMS evolution; community approach

Infrastructure
- Standards/doc; CM; code repository; etc.
- Role of testbeds; regression testing; etc.

Verification & Validation (V&V)
- V&V of ops forecasts vs. R&D testing/eval
- Unified/standard tools and data formats

Dynamics and Nesting
- FV3 transition on global wx/S2S/climate
- Nests for hurricanes (moving?)

Model Physics
- Common Comm. Physics Pkg (CCPP); stochastic, scale-aware physics

Data Assimilation
- NOAA, NASA integ. w/FV3; coupled DA
- Joint Effort for DA Integration (JEDI)

Ensembles
- Strategy across scales; model uncertainty

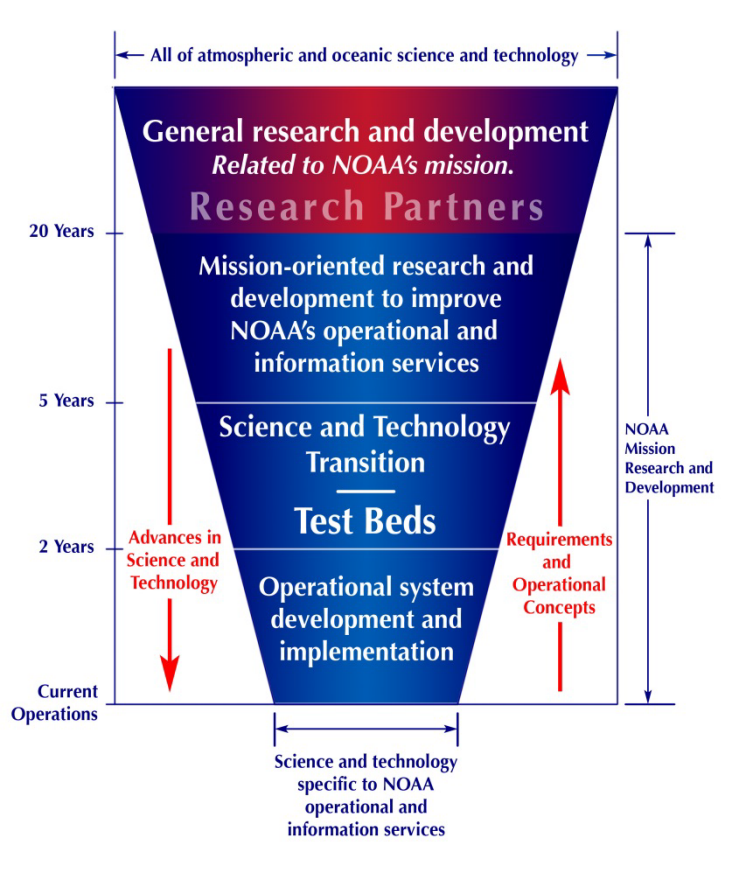
Post-Processing
- Comm. PP infrastructure; std formats/tools

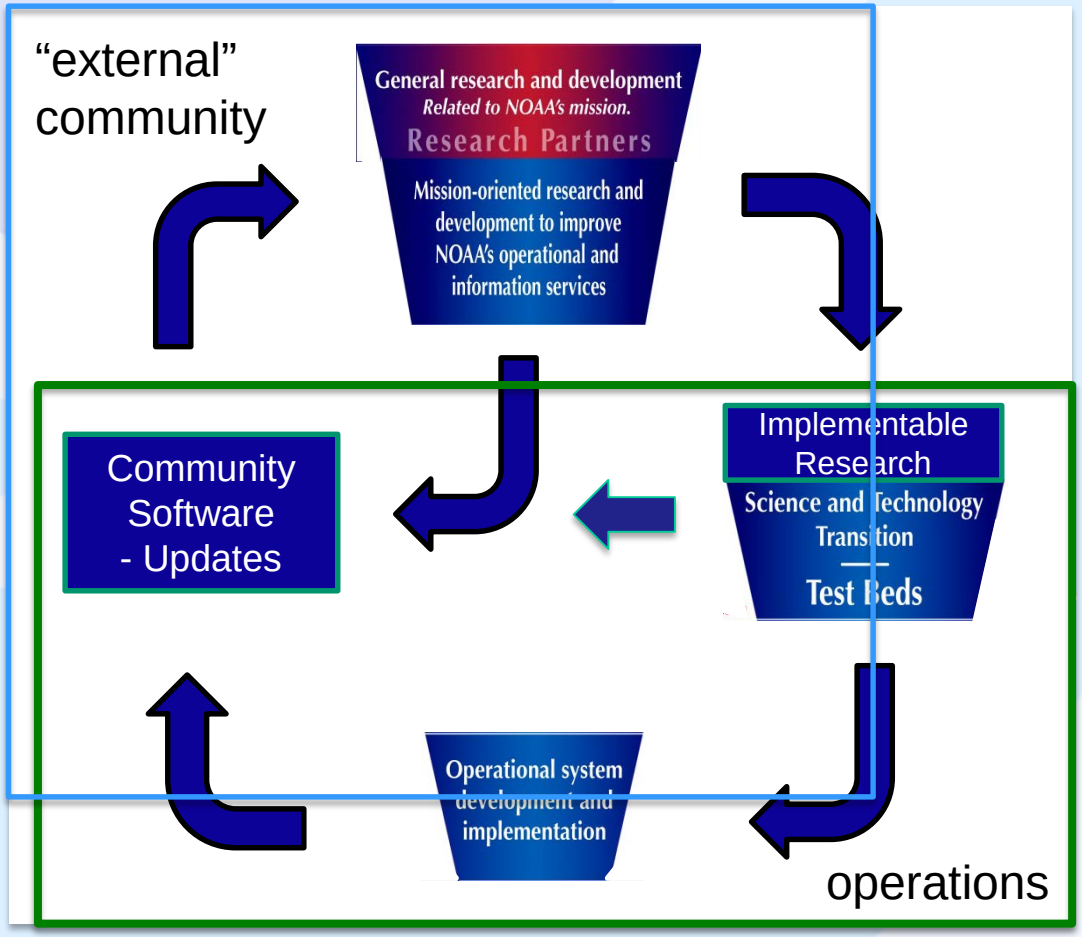
Component Model groups
- Marine models *+ NOS coastal/bay models*
- Aerosols and Atmospheric Composition
- Land Sfc Models (LSMs) *+ hydrology (OWP)*

New WG or addition (wrt NGGPS)
Augmentation of existing NGGPS group

Deconstructing the funnel

Past → Future





III. You Can Contribute Too…

Accessing the code.

Significant Enhancements to NEMS FV3GFS Public Release Version 1 compared to Version 0

- Improved Physics
  - Replacement of Zhao-Carr microphysics with the more advanced GFDL microphysics
  - Updated parameterization of ozone photochemistry
  - Newly introduced parameterization of middle atmospheric water vapor photochemistry
  - Revised bare soil evaporation scheme
  - Near-Sea Surface Temperature (NSST) model in NEMSfv3gfs
  - Replacement of TOPO30 orography with GMTED2010 orography
- Improved Infrastructure
  - IPDv4 in NEMSfv3gfs
  - Write grid component, write out model history in native cubed sphere grid and Gaussian grid
- Extensive Documentation (inline doxygen; technical and user guides)
- Pre- and Post-Processing Tools and Utilities
- Umbrella Build System and Basic Workflow (CROW)
- Release through Github.com
- Training sessions planned for summer of 2018