An Overview of the Environmental Modeling Center (EMC)

Environmental Modeling Center
NOAA/NWS/NCEP

June 19, 2018

National Weather Service (NWS) Vision and Mission

Vision

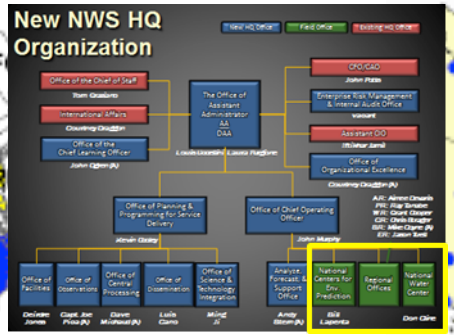
Build a Weather-Ready Nation where Society is prepared for & responds to Weather-Dependent Events

Mission

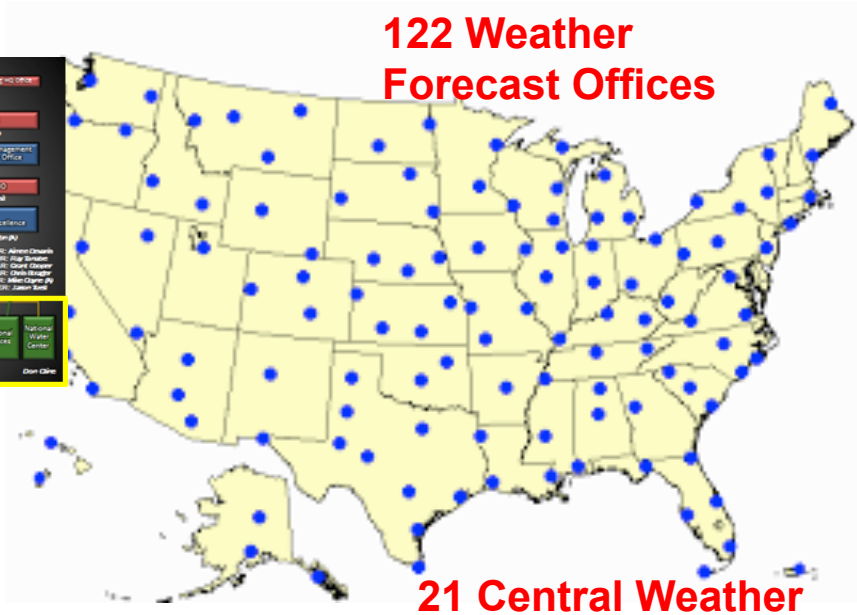
The National Weather Service (NWS) provides weather, water, & climate forecasts & warnings for the United States, its territories, adjacent waters & ocean areas, for the protection of life & property & the enhancement of the national economy. NWS data & products form a national information database & infrastructure which can be used by other governmental agencies, the private sector, the public, & the global community.

Connecting the NWS Organization to Deliver Accurate & Consistent Products and Services

13 River Forecast Centers



122 Weather Forecast Offices



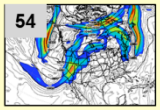
National Water Center

9 National Centers

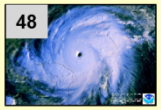
- 490 FTE
- 237 Contractors
- 40+ Visiting Scientists
- 6 NOAA Corps Officers
- $137M Budget

Aviation Weather Center
Kansas City, MO

Climate Prediction Center
College Park, MD



Environmental Modeling Center
College Park, MD



National Hurricane Center
Miami, FL

NCEP Central Operations
College Park, MD
(Supercomputers in Reston & Orlando)

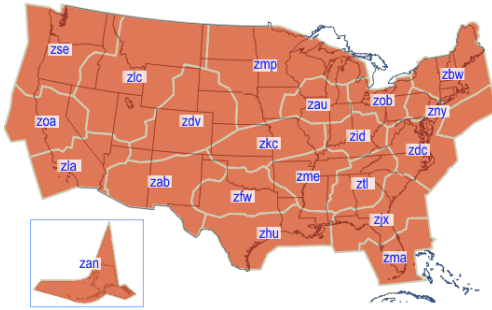
Ocean Prediction Center
College Park, MD

Space Weather Prediction Center
Boulder, CO

Storm Prediction Center
Norman, OK

Weather Prediction Center
College Park, MD

21 Central Weather Service Units



National Centers for Environmental Prediction (NCEP)
Vision and Mission

490 FTE
237 Contractors
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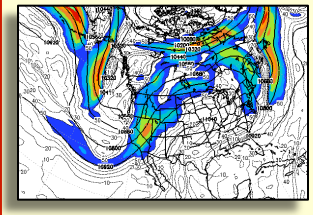
$137M Budget

Aviation Weather Center
Kansas City, MO

Climate Prediction Center
College Park, MD



Environmental Modeling Center
College Park, MD

National Hurricane Center
Miami, FL

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(Supercomputers in Reston & Orlando)

Ocean Prediction Center
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Boulder, CO

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Norman, OK

Weather Prediction Center
College Park, MD

Vision

The trusted source for environmental predictions from the sun to the sea, when it matters most.

Mission

NCEP delivers national and global operational weather, water and climate products and services essential to protecting life, property and economic well-being.

Environmental Modeling Center (EMC)

Environmental Modeling Center

Director

Deputy Director

Director's Office Staff: Budget, HR, Admin

Verification, Post-processing and Product Generation Branch

Modeling and Data Assimilation Branch

Engineering and Implementation Branch

Data Assimilation and Quality Control Group

Model Physics Group

Model Dynamics and Coupling Group

NOAA Operational Numerical Guidance Supports the Agency Mission

- Forecasts are made by people:
  - Weather Forecast Offices (WFOs).
  - Service Centers within the National Centers for Environmental Prediction (NCEP).

- Models provide guidance.
  - Prediction is now inherently linked to numerical models.
  - Most models are run at NCEP.
    - More than 20 major simulation codes.
    - More than 1600 support codes and scripts.
    - Billions of data ingested daily.
    - Millions of products delivered daily.
  - Sharing with world wide partners:
    - DoD, ECMWF, UK Met Office, JMA, …

NOAA Operational Numerical Guidance Supports the Agency Mission

- **Numerical Weather Prediction at NOAA**
  - Required for agency to meet service-based metrics

- **National Weather Service GPRA* Metrics**

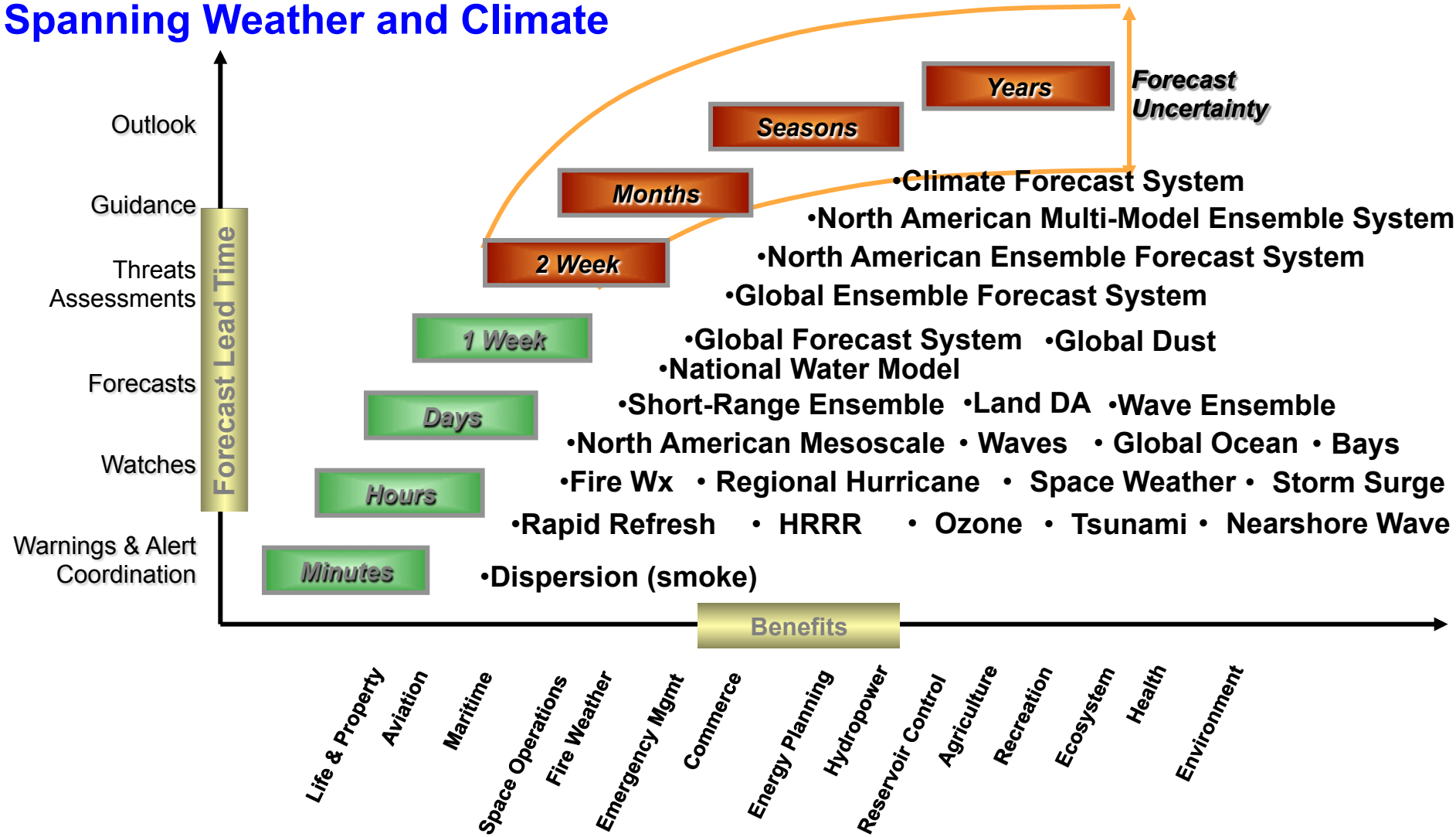
  (* Government Performance & Results Act)
  - Hurricane Track and Intensity
  - Winter Storm Warning
  - Precipitation Threat
  - Flood Warning
  - Marine Wind Speed and Wave Height

Lead Time and Accuracy!

- **Operational numerical guidance:**
  - Foundational tools used by government, public and private industry to improve public safety, quality of life and make business decisions that drive U.S. economic growth

Seamless Suite of Operational Numerical Guidance Systems

Spanning Weather and Climate



Summary of EMC's modeling systems

Global models *(currently based on Spectral dynamics)*

- **Global Forecast System (GFS):** Single deterministic run, 4x/day; length = 16 days; res = 13 km (27 km after day-10)
- **Global Ensemble Forecast System (GEFS):** 21 ensemble members; 4x/day; length = 16 days; res = 34 km (54 km after day-8)
- **Climate Forecast System (CFS):** Seasonal-to-Subseasonal (S2S) time scales; run length varies from 45 days, 1 season, 9 months
  - Coupled system with atmosphere, ocean, sea ice, land surface
  - Prime contributor to NWS Climate Prediction Center mission of seasonal outlooks (e.g., impact of El Nino on prediction of US precip and temperature, and The impact of drought for water management); Member of NMME

National Multi-Model Ensemble (NMME)

- Experimental multi-model ensemble for seasonal-interannual scales
  - Facilitated by NOAA Climate Test Bed; collaboration with NOAA, NASA, NCAR, CMC (Canada) and academia

Summary of EMC's modeling systems (cont.)

Regional Mesoscale Models

- **North American Model (NAM):** Mesoscale model w/NMMB dynamics; run 4x/day; length = 84 hours; res = 12 km for outer nest , 3-4 km inner nest
- **HiResWindows:** Two dynamical models, **WRF-ARW** and **NEMS-NMMB,** each with its own physics suites; Twice daily runs to 48 hrs over CONUS and four non-CONUS domains (Alaska, Hawaii, Puerto Rico and Guam)
  - Basis for High Resolution Ensemble Forecast (HREF)
- **Rapid Refresh/High-Res Rapid Refresh (RAP/HRRR):** Run hourly over CONUS; RAP 13-km res to 21 hours; HRRR 3-km to 18 hours; rapidly updating to assimilate timely data (e.g., radar)
- **Short Range Ensemble Forecast (SREF):** multi-model (NMMB and ARW) ensemble over N. Am. with 26 members; 6km horiz. res.; length: 87 hrs
- **Real-Time Mesoscale Analysis/Unrestricted Meso Anal. (RTMA/URMA):**
  - Hourly 2DVar 2.5 km surface analysis for National Digital Forecast Database (NDFD); analysis of record for National Blend of Models
  - NCEP Gridpoint Statistical Interpolation (GSI) Analysis; uses all available surface obs (METAR, surface synoptic, ship, buoy, mesonet) and satellite obs for sky cover, near-sfc winds, surface wave height

Summary of EMC's modeling systems (cont.)

Marine Models

- **Real Time Ocean Forecast System (RTOFS):** based on Navy's HYbrid Coordinate Ocean Model (HYCOM) and NCODA data assimilation; 1/12 degree horiz. Res.; 32 vertical hybrid layers; length = 8 days
- **Waves:** multiple domains (global, Great Lakes, on-demand high-res local) based on Wave Watch III community wave model

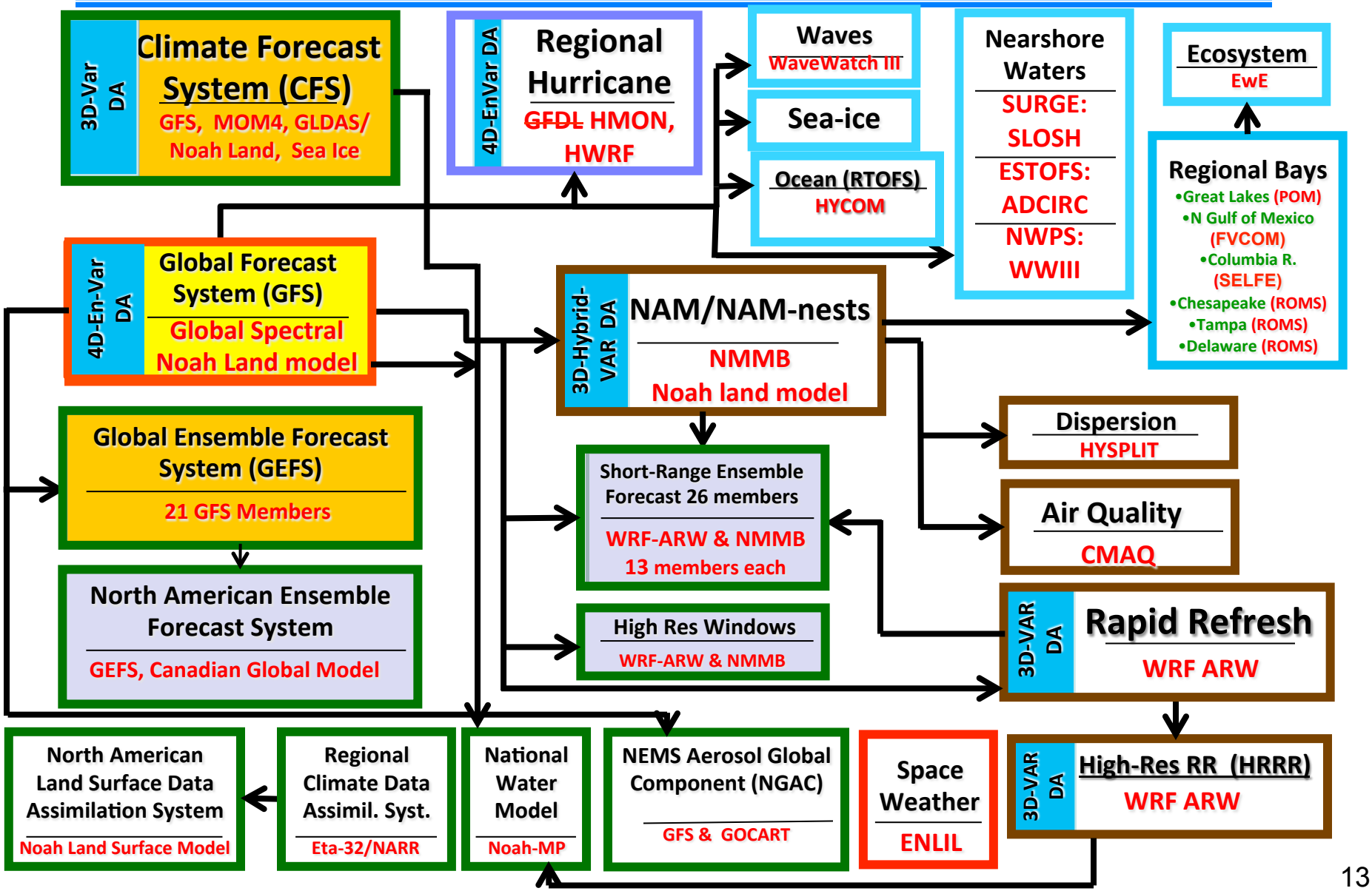
Hurricane Models

- **Hurricane WRF (HWRF):** Continuously improved as part of Hurricane Forecast Improvement Program (HFIP); successful community modeling approach for accelerated transition of research to ops
  - 3-way coupled with atmos., ocean and waves (WW III)
- **Hurricanes in a Multi-scale Ocean coupled Non-hydrostatic model (HMON):** Implements long-term strategy for multiple static and moving nests globally, with 1- and 2-way interaction and coupled to other (ocean, wave, sea ice, surge, inundation, etc.) models using NEMS-NUOPC infrastructure; replacing legacy GFDL model for 2017 season
  - Initially uses NMMB core; will transition to FV3 dynamics

FY 2018 Implementations

- **Q1 FY 2018**: High-Resolution Window Forecast System/ High-Resolution Ensemble Forecast (HiResW v7/HREF v2)
- **Q1 FY 2018**: Space Weather Modeling Framework (SWMF) v1.5.0
- **Q1 FY 2018**: RTMA/URMA v2.6.0
- **Q2 FY 2018**: GLOBAL Wave Model
- **Q2 FY 2018**: Nearshore Wave Prediction System (NWPS)
- **Q3 FY 2018**: North American Ensemble Forecast System (NAEFS)
- **Q3 FY 2018**: Rapid Update/ High-Resolution Rapid Refresh (RAP/ HRRR)
- **Q3 FY 2018**: Hurricane WRF/ Hurricanes in a Multi-scale Ocean-coupled Non-hydrostatic model (HWRF/HMON)
- **Q3 FY 2018**: Air parcel transport, dispersion, chemistry, deposition (HYSPLIT)
- **Q4 FY 2018**: Air Quality Model (AQM)
- **Q4 FY 2018**: RTMA/URMA

NOAA's Operational Numerical Model Guidance Suite

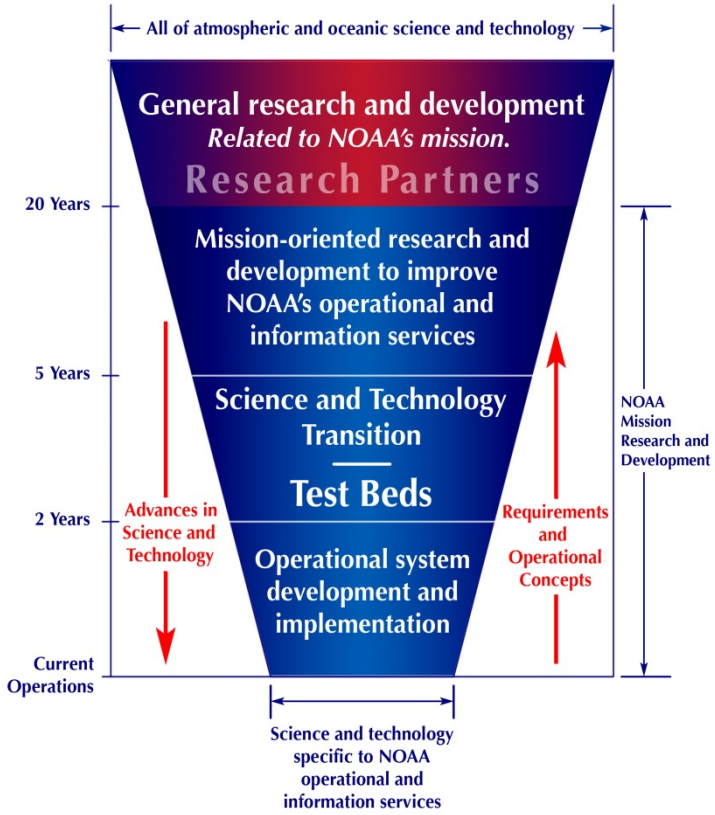


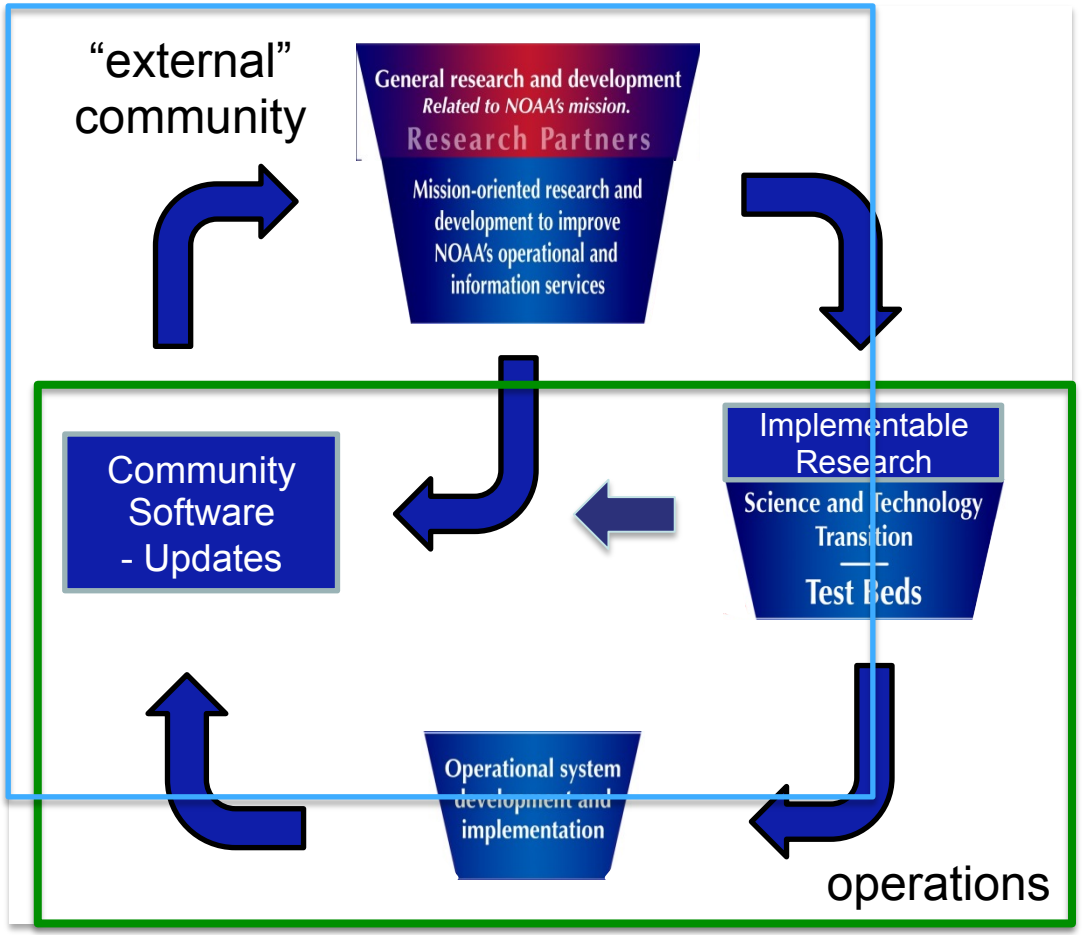
NOAA's Research-to-Operations Cycle

Courtesy Louis Uccelini

Deconstructing the funnel

Past → Future





A Hierarchy of Plans

1. UMC

- Unified Modeling Committee: High-level NOAA Unified Modeling Overview
- **Horizon:** 5-10 Years
- **Scope:** NOAA

Online [1]

2. Vision

- A Strategic Vision for the US National Environmental Modeling Enterprise
- **Horizon:** 5-10 Years
- **Scope:** US Environmental Modeling Enterprise (Federal focus, integrated with Academia)

3. Roadmap

- Roadmap for the Production Suite at NCEP
- **Horizon:** 5-10 Years
- **Scope:** NCEP Production Suite (Unified Forecast System)

4. SIP

- Strategic Implementation Plan
- **Horizon:** 0-3 Years
- **Scope:** NCEP Production Suite (Unified Forecast System)

NGGPS '+'

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

(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 Strategic Vision Document looking out 10 years and bridging US 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).

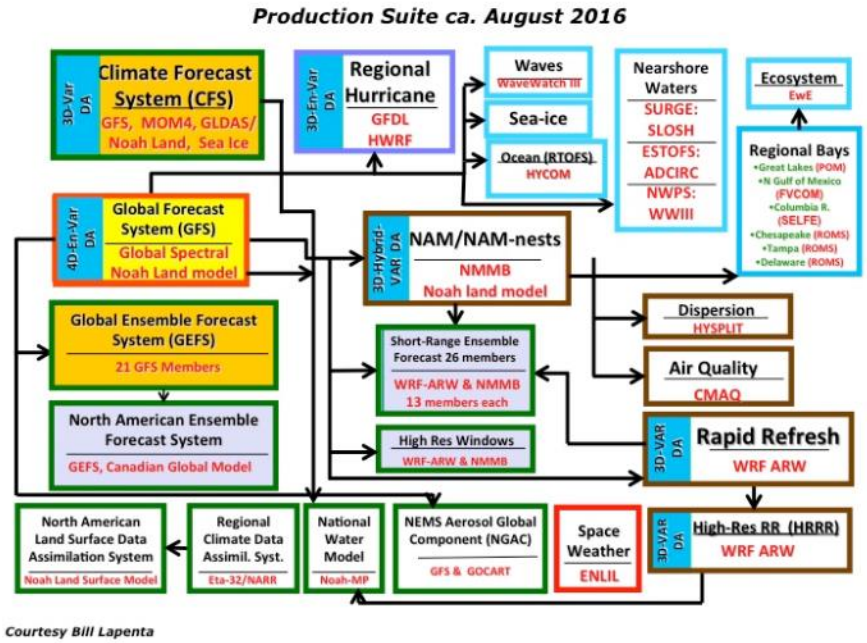
Strategic Vision
Evolution of NCEP Production Suite

- End State:
  - Simplified production suite under unified modeling framework
  - Single dycore, coupled, ensembles … for all scales
  - Active engagement from community (R&D, testing, validation)
- Transitional activities:
  - NGGPS evolution with FV3 dynamic core (GFS, GEFS, CFS)
  - Meso-unification (multi-model ensemble/HREF, eventual WoF)
  - Evolution of community modeling for ESM components (ocean, waves, land surface model, etc.)
  - Strategic Implementation Plan (SIP) with community partners
- Limiting factors (issues/risks):
  - HPC (research, development, testing, operations)
  - Scientific & Tech challenges (DA, single dycore vs. multi-model, 2-way coupling, ensemble calibration, dissemination, etc.)

Strategic Vision
Key Elements

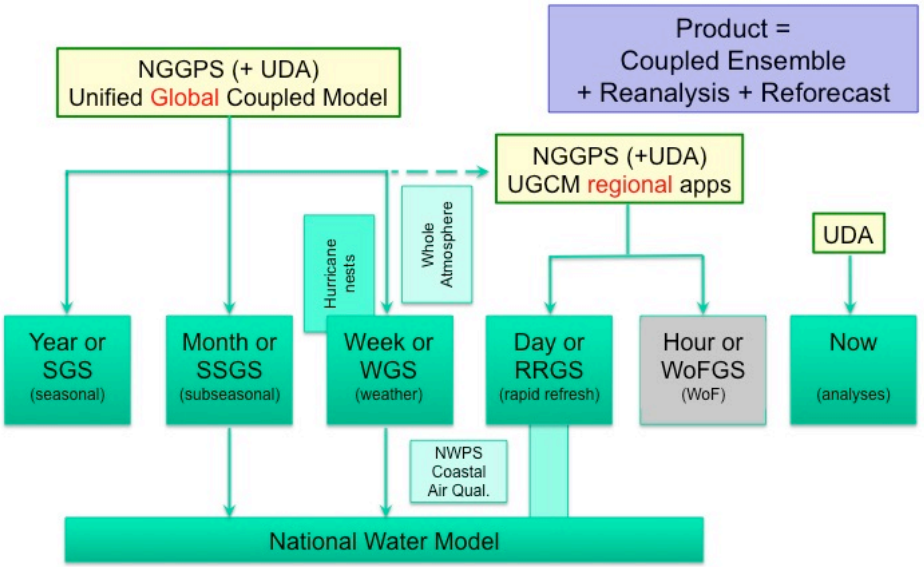
- Focus on products supporting mission requirements
  - Impact-based Decision Support Services
- Unified modeling and data assimilation
  - Coupled, ensemble based, reforecast and reanalysis
  - Including pre- and postprocessing, calibration, verification validation
  - *Use NGGPS as a foundation to evolve a Unified Forecast System*
- New system using *community* modeling, built upon:
  - Evidence-driven decisions
  - Same standards for all who contribute
  - Transparent and robust *governance*
    - Service requirements >> technical requirements / solutions
    - Collaborative prioritization and decision making
  - Coordinate partner activities under single plan

Strategic Vision
Simplify Modeling Suite



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

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



UDA: Unified Data assimilation
SGS: Seasonal Guidance System
SSGS: SubseasonalGuidance System

WGS: Weather Guidance System
RRGS: Rapid Refresh Guidance System
WoFGS; WoF Guidance System

Toward Fully Coupled Assimilation

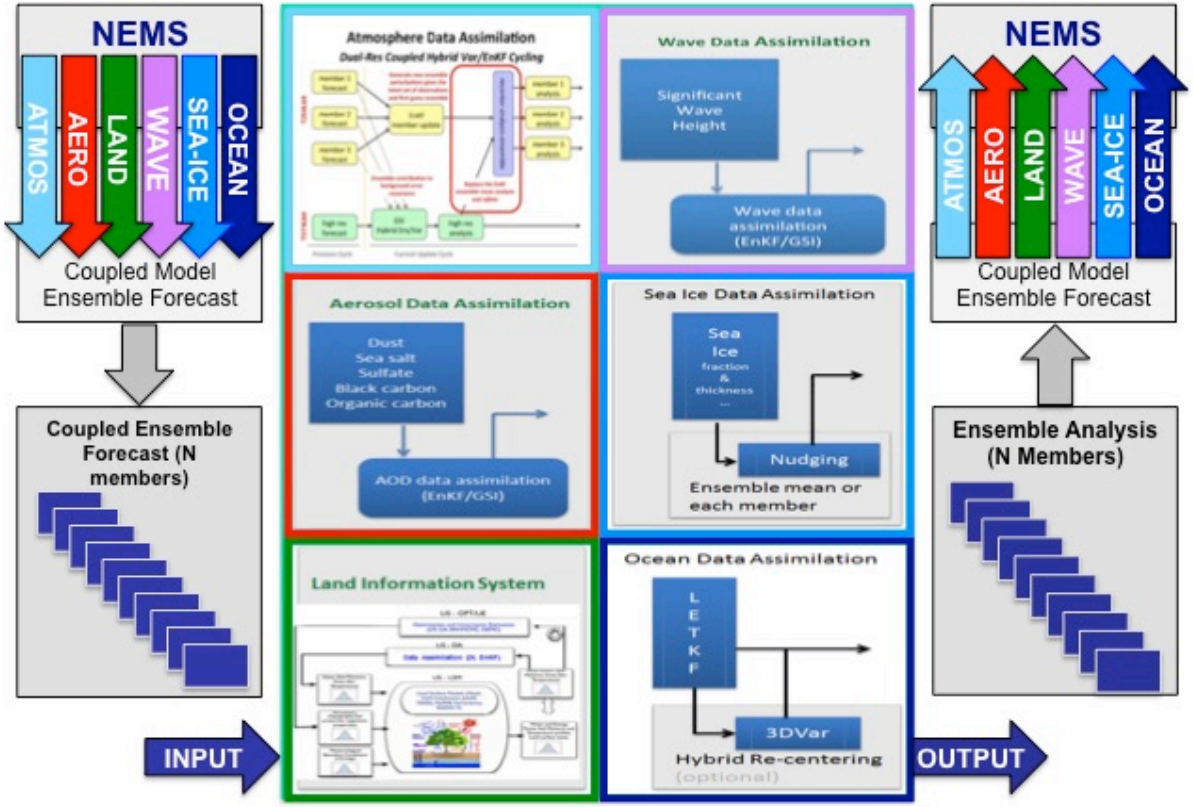
- Moving from uncoupled to fully coupled Data Assimilation
  - Uncoupled DA (the present GDAS approach)
  - Weakly coupled through first guesses from coupled models, but with independent DA per subsystem (present CFS approach)
  - Stronger coupled by addressing cross-correlations of errors between subsystems, but with independent DA per subsystems
  - Fully coupled DA, including coupled (simultaneous) assimilation in all subsystems.
- Unified under Joint Effort for Data assimilation Integration (JEDI)

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



Courtesy Suru Saha

Roadmap Fig. 4

Strategic Implementation Plan (SIP) for Unified Modeling

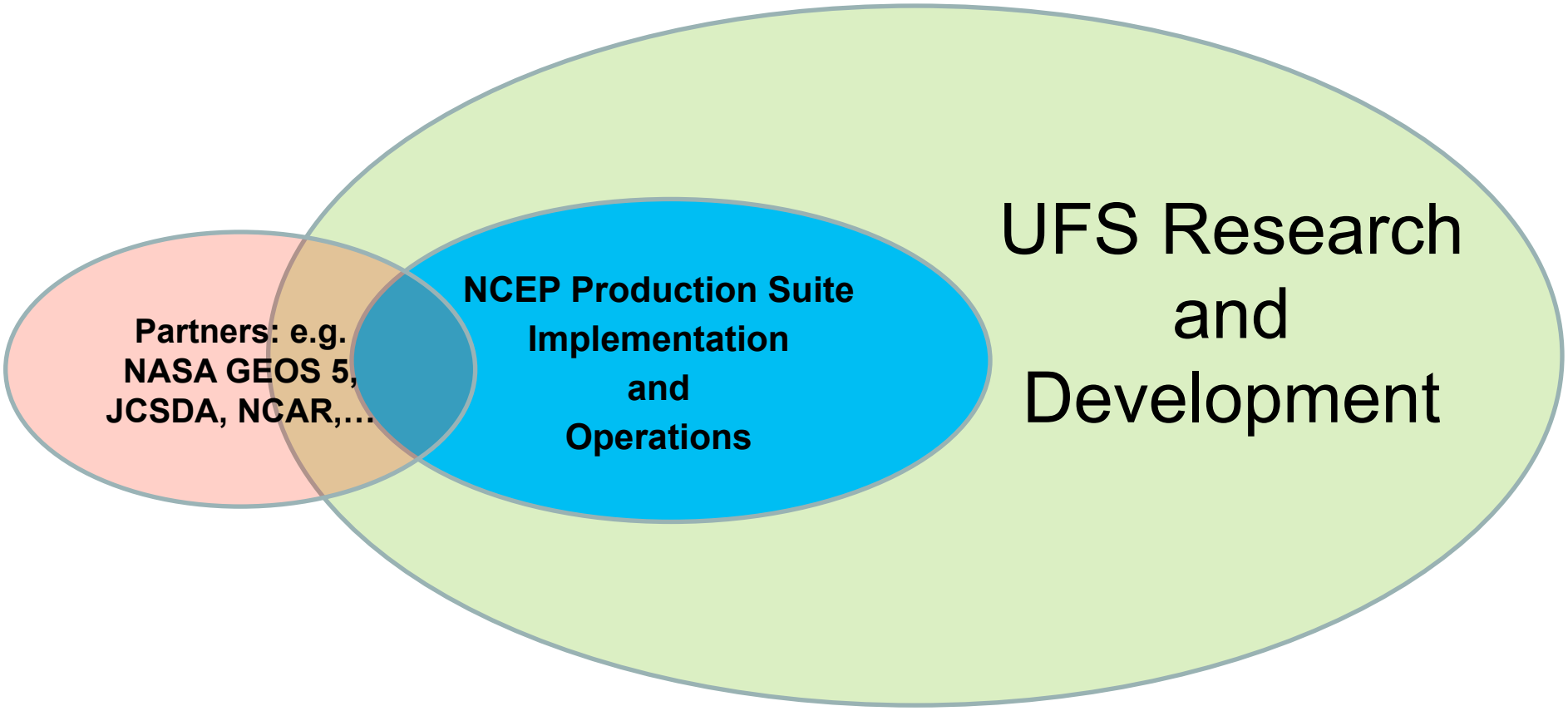
- Common Goal: ***Single integrated plan*** that coordinates activities of NOAA + external partners in ***common goal*** of building a national unified modeling system across ***temporal*** and ***spatial*** scales
  - **Next Generation Global Prediction System (NGGPS)**: *foundation to build upon for community Earth system model*
  - Activities include R&D, testing/eval, V&V, R2O, shared infrastructure
- 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
  - Bring together *broader community*, first as invited WG members, followed by *public workshops* (College Park, MD; April 2017 and August 2017)
  - ***End product will be SIP version 1.0, a 3-year plan (FY 2018-2020)***
    - Long term: SIP to be rolling 3-year plan to be updated annually
    - **Save the date: 1/31/2018 – 2/1/2018!**
  - Stand up Governance Structure

Strategic Implementation Plan (SIP)
Working Groups

- *Governance*
  - Decision making, roles/responsibilities, advisory boards, org. alignment, etc.
- *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* - Augmentation of existing NGGPS group

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).

NGGPS Goals and Objectives[1]

Next Generation Global Prediction System (NGGPS)

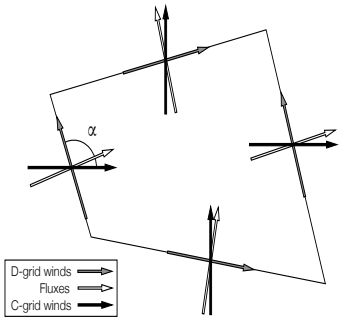
- Design/Develop/Implement the Next Generation Global Atmospheric Prediction Model
  - Non-hydrostatic Scalable Dynamics
  - Accelerated Physics Improvement Profile
- Improve Data Assimilation
- Position NWS for Next Generation High Performance Computing (HPC)

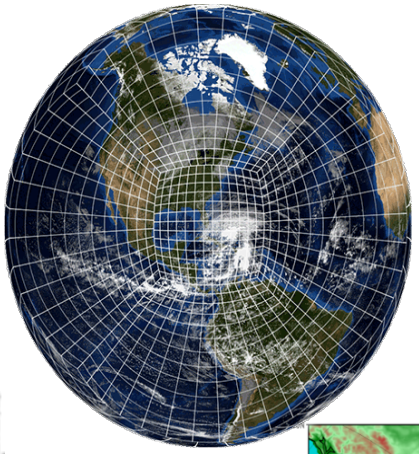
Ultimate Goal: World's Best Global Forecast Guidance!

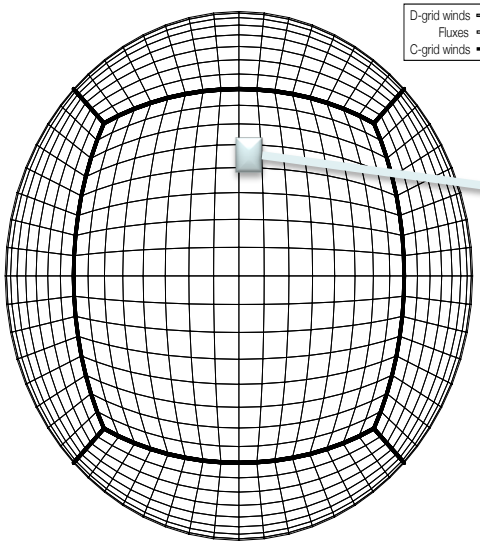
1 – From NWS Budget Initiative proposal to OMB

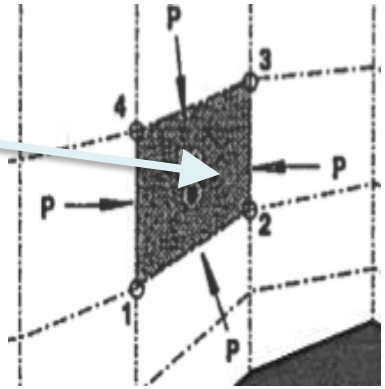
What is FV³?

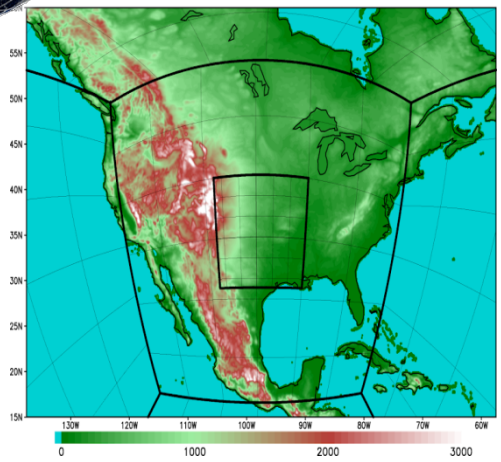
- The **Finite-Volume** Cubed-Sphere dynamical core
  - A dynamical core is the "engine" or "heart" of a weather or climate model







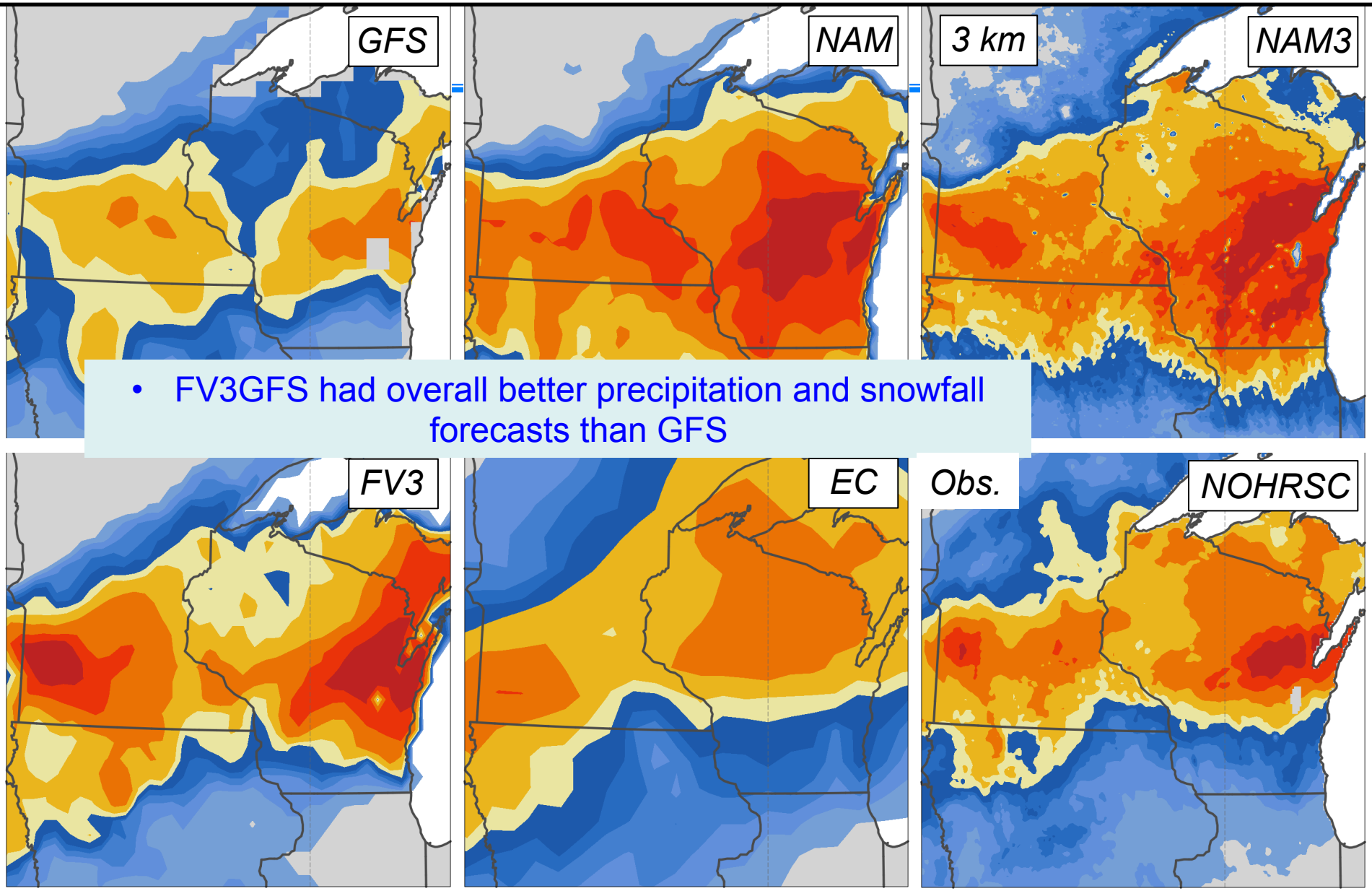




FV3-based GFS

- Working toward replacement of spectral model with FV3-based GFS
  - Target: January 2019!
  - ~13km resolution, 64 layer (same as current GFS)
  - Some advancements to data assimilation
  - Similar physics to current GFS
    - New cloud microphysics

Accumulated Snowfall [10:1] (Initialized: 1200 UTC 13 April)



- FV3GFS had overall better precipitation and snowfall forecasts than GFS

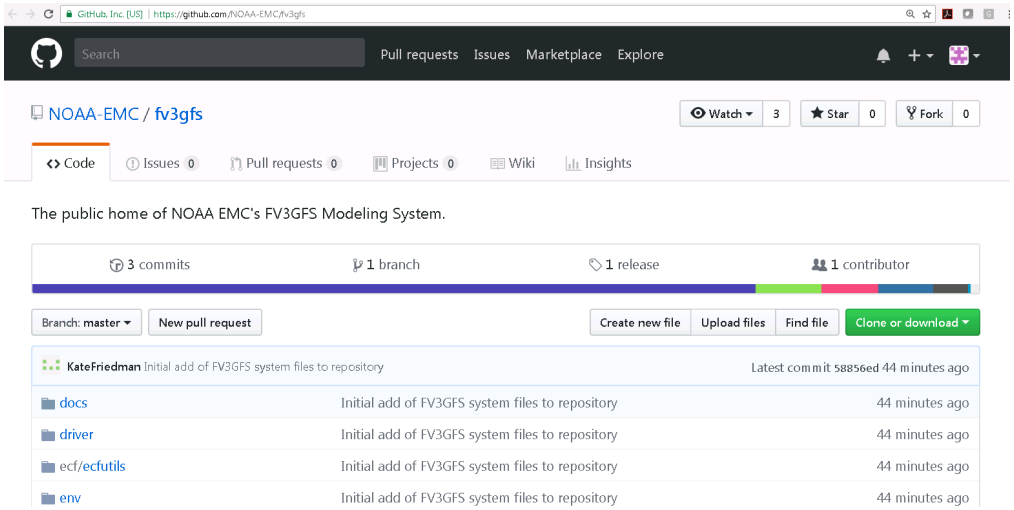
FV3GFS V1 Code Public Release through Github.com and NOAA Virtual Lab (VLab)

- 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:

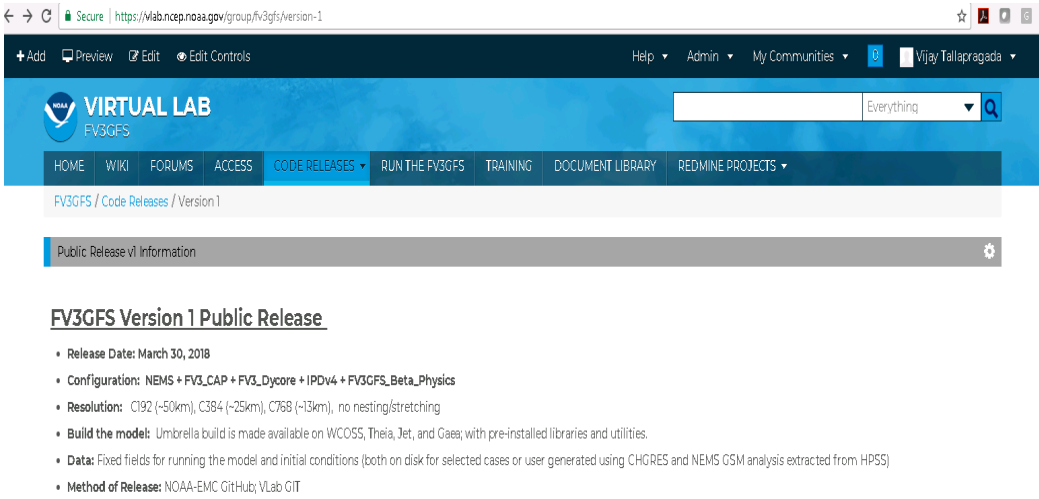
August 17, 2017 **Hurricane Harvey**
February 10, 2016 **Atmospheric River**
February 28, 2018 **East Coast Noreaster**

- Capability to generate ICs for any case
- Limited support from EMC
- Model Resolutions: C192 **(~50km)**, C382 **(~25km)** or C768 **(~13km)**

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



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



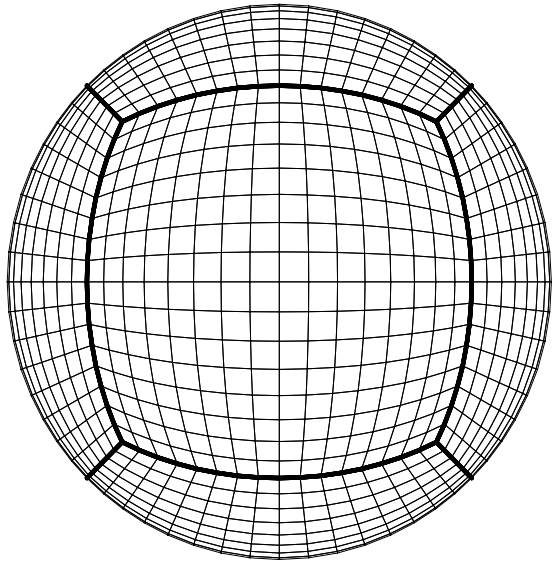
FV3GFS

Completed

- **Q3FY17: Implement FV3 into NEMS**
- **Q4FY17: Couple FV3 to GFS Physics & complete forecast only exp.**
- **Q4FY17: Adapt existing DA techniques for FV3**
- **Q1FY18: Evaluate and prepare FV3 documentation**
- **Q1FY18: Complete Pre/Post processing, verification, & downstream**

Near-term Milestones

- **Q3FY18: Configure FV3GFS for operations**
- **Q3FY18: Conduct real-time parallels and 3-year retrospective experiments**
- **Q2FY19: Implement FV3GFS operational version**



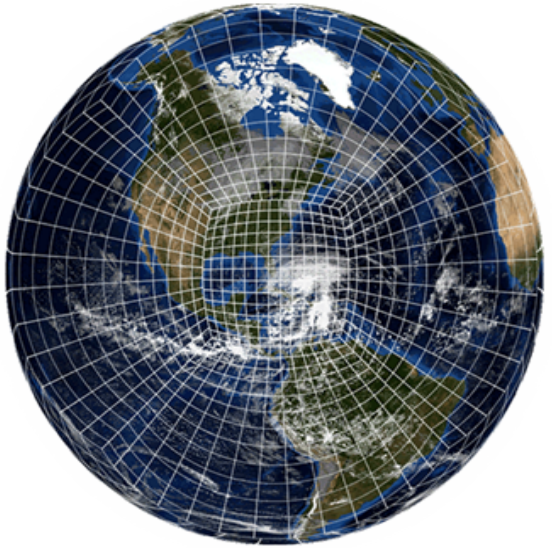
Example Projects: CAM

Completed

- **Q3FY17: Initial concept ensemble test case with FV3 nesting on a stretched cube (manually run)**
- **Q1FY18: More testing with global FV3 with a 3 km CONUS nest on a stretched cube including ensemble display tools**
- **Q1FY18: Develop a standalone regional FV3 capability**

Near-term Milestones

- **Q3FY18: 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**



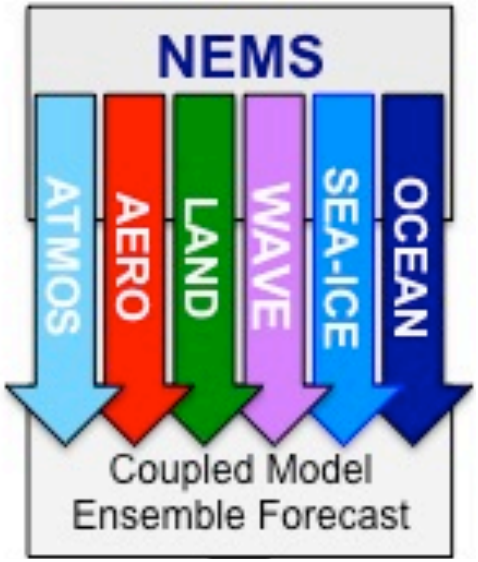
Example Projects: Coupled Models

Completed

- Q3FY17: GSM+MOM5.1+CICE5 Benchmark
- Q1FY18: Skill metrics for sea ice prediction
- Q2FY18: FV3 + MOM6 + CICE5 Set up
- Q2FY18: DA systems for FV3 and MOM6

Near-term Milestones

- Q3FY18: Validation of ice prediction (KISS vs CICE5)
- Q3FY18: Physics testing for FV3+MOM6+CICE5
- Q3FY18: Add WW3 to FV3+MOM6+CICE5
- Q4FY18: End-to-end system testing
- Q1FY19: FV3+WW3 2-way coupling

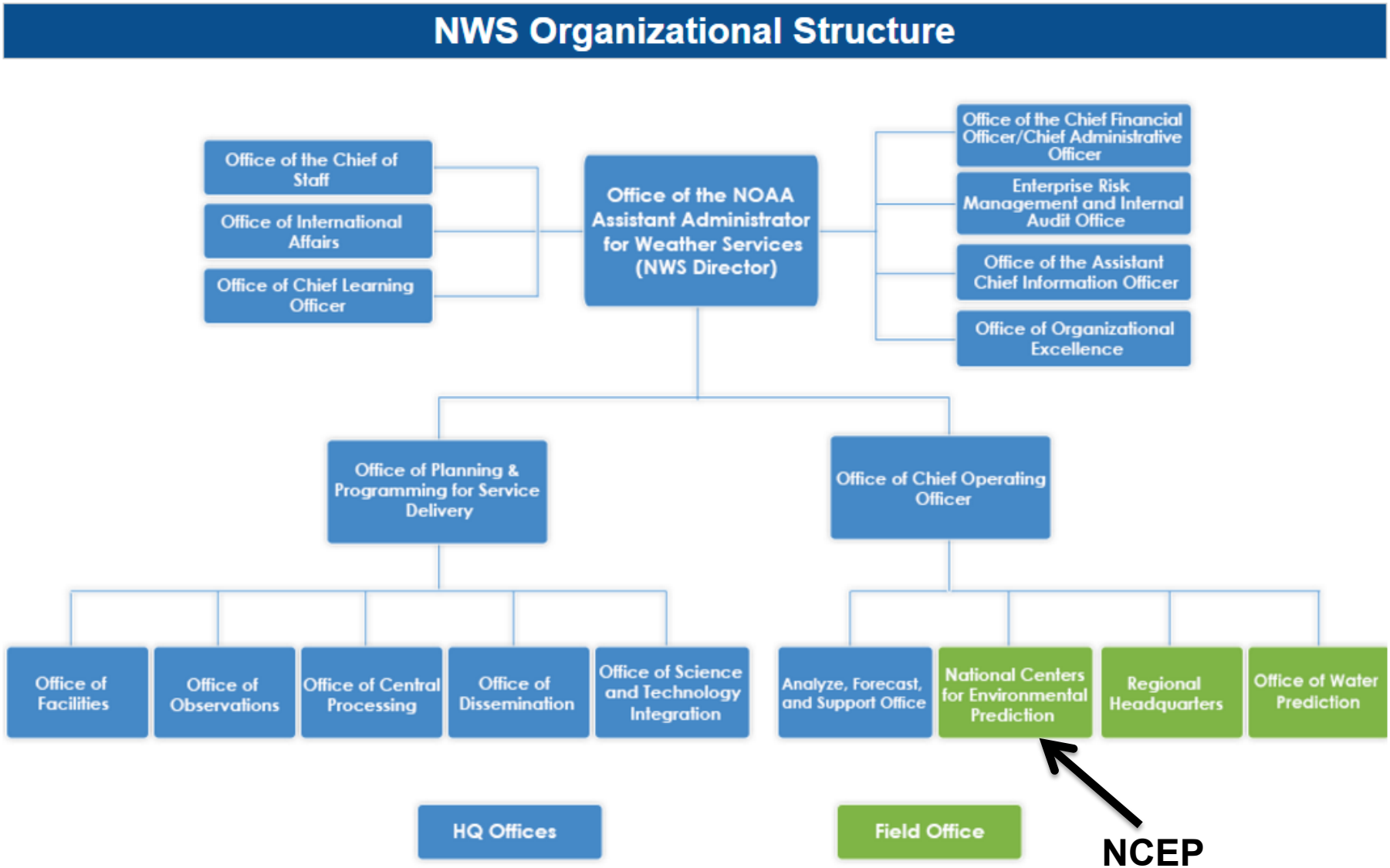


Thank You for Your Time.

Questions?

Backup

Where do NCEP and EMC fit into the overall NWS structure?



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