# The National Earth System Prediction Capability (National ESPC)

29 August 2019

# Separate agency missions drive different modeling foci

Agency mission time scales/regions/applications and decision sectors differ

Weather, climate, space, ocean, land domains; out to multi-annual timescales; to support protection of life and property

Earth science research in data analysis, observing system and design, climate and weather prediction, and basic research

Facilitate advancement of knowledge in Earth system science and computing technology

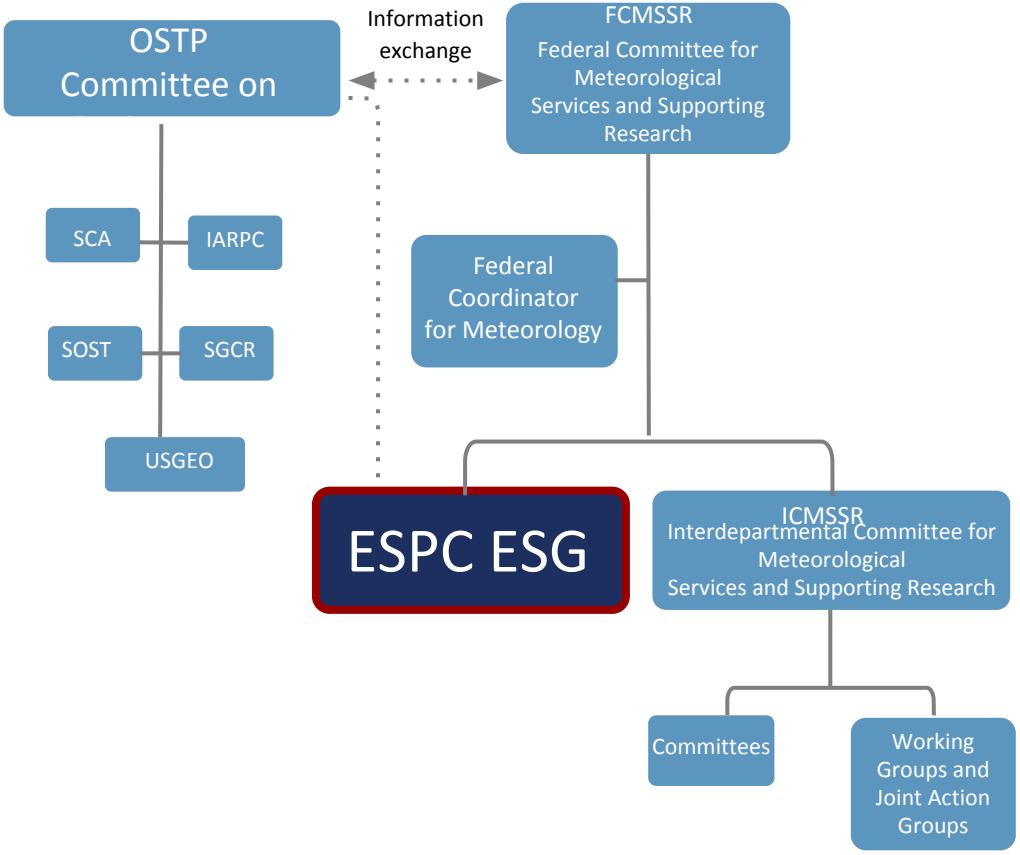
Weather to climate prediction for Air Force and Army operations support; cloud forecasts; resource protection; space environment

Earth system predictions for operational weather, ocean, littoral; nowcast to inter-annual; support global national security

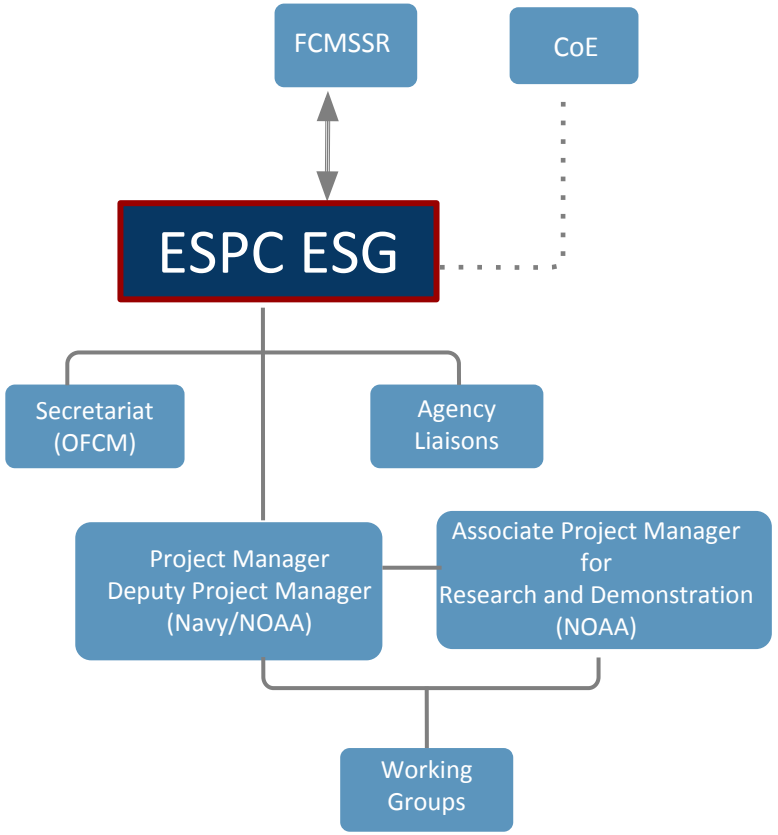
Accurate, computationally advanced representations of fully coupled Earth system for energy and infrastructure planning

**Advance common science ▪ Leverage expertise ▪ Coordinate Earth system prediction strategy ▪ Provide National capability**

# Federal Coordinating Structure



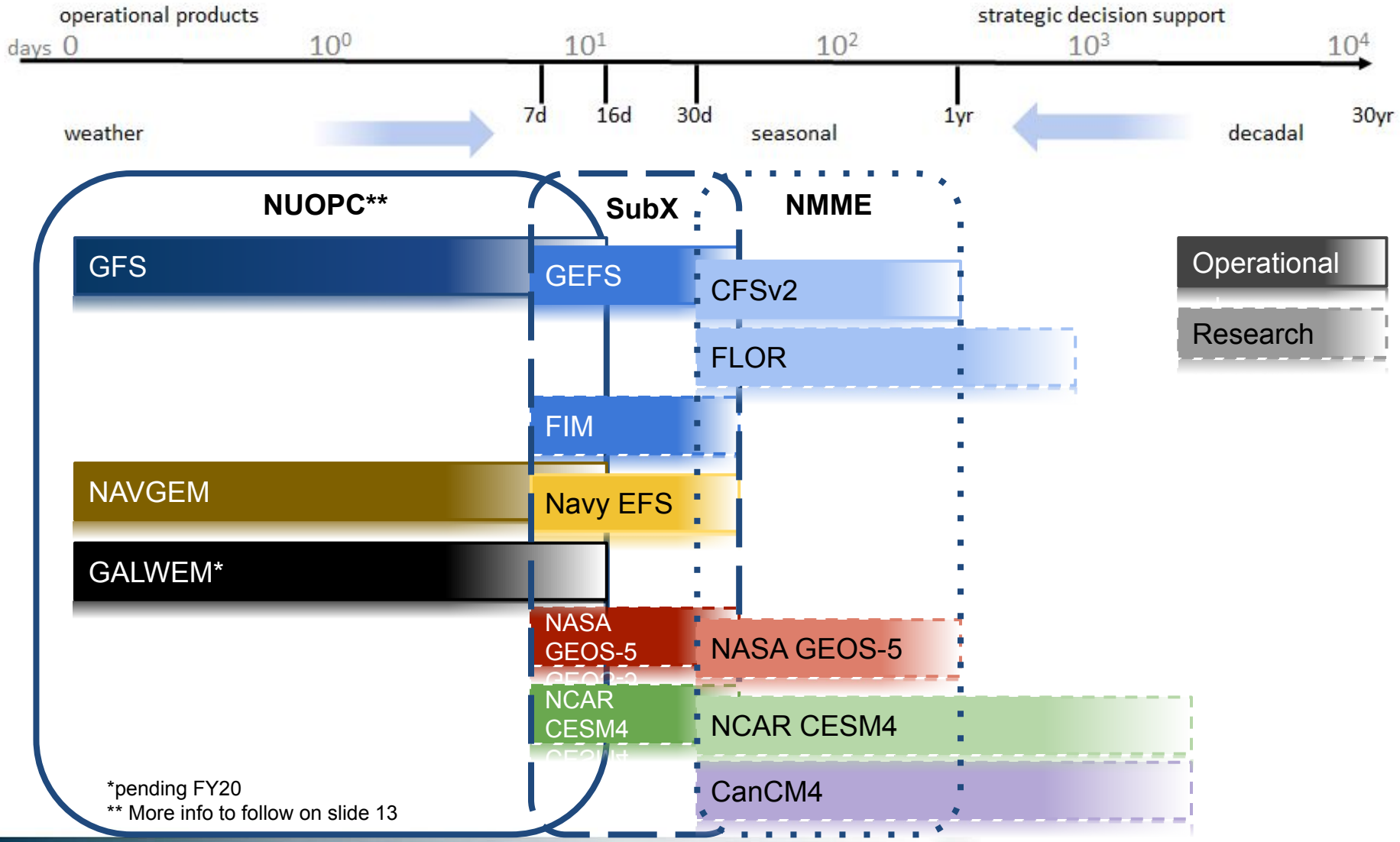

# ESPC Staff Organization Structure



# National ESPC Goals

- An integrated National Capability meeting the U.S. Federal need for Earth System Prediction for the provision of operational products and services for
  - Protection of life and property in the US
  - Economic development, aviation, maritime, shipping, agriculture of the US
  - National defense, homeland security and strategic decisions
- Includes:
  - Near term, medium range and extended range weather (< 90 days)
  - Seasonal and inter-annual climate (90 Days+)
  - Sub-decadal to decadal (out to 30 years)
- Leverages existing and planned Agency operational capabilities, and research and development programs and projects
- Strong Inter-Agency Coordination

# Prediction/decision support across time scales



# Working Groups

**High Performance Computing (HPC)**

- Enterprise architecture and requirements
- Best practices
- New technology
- Cloud computing, AI, and machine learning

**Program Managers (PM)**

- Potential multi-agency funding calls
- Coordinated research strategy
- Research to Operations transitions, including interagency

**Coupled Global Modeling (CGM)**

- Weakly and Strongly coupled data assimilation
- Global ocean modeling
- Reanalysis and reforecast datasets

**Common Model Architecture (CMA)**

- ➔ **Content Standards Committee (CSC)**
- ➔ **Physics Interoperability Committee (PI)**
- ➔ **Model Component Liaisons (MCL)**

NUOPC Inter-operability layer, Common Physics Driver, Common Community Physics Package (CCPP), NUOPC Field Dictionary, Earth System Modeling Framework, Physical Constant Dictionary (in progress), Workflow and CAPS

# Foster Common Model Architectures

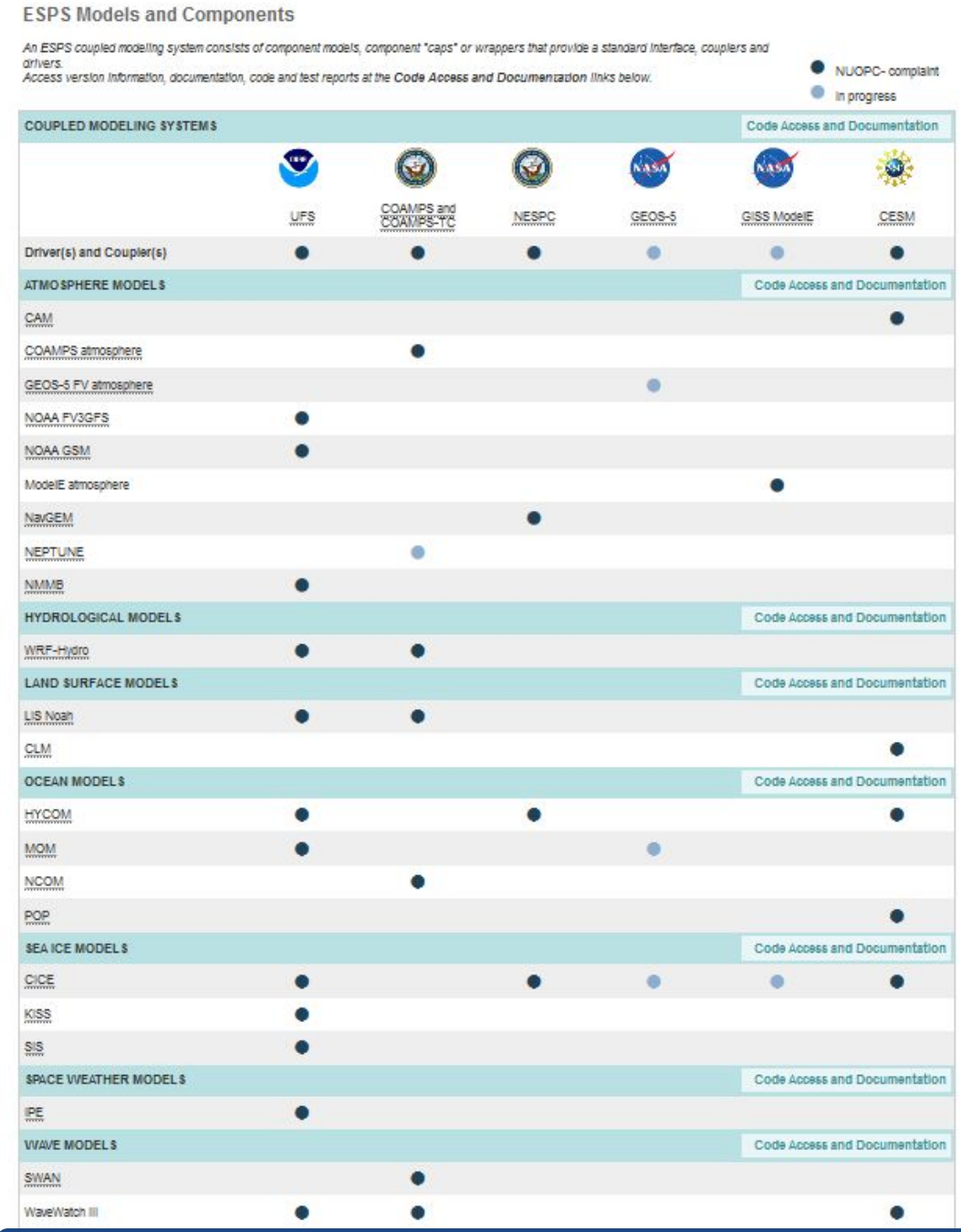
## ESMF/NUOPC layer

Provides interoperability between model components, code documentation

**What does it take to be in ESPS?**

1. Components and systems are *NUOPC-compliant*.
2. ESPS codes are *versioned*.
3. *Documentation* provided for each version of components or system.
4. ESPS codes have *terms of use* and have access for credentialed ESPC collaborators.
5. *Regression and verification tested.*
6. Commitment to *continued NUOPC compliance and ESPS participation* for new versions of the code.

https://www.earthsystemcog.org/projects/esmf/




22 model components - interoperable across 6 global systems

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Earth System Prediction Capability

# Examples: Coordinating Development

| ESMF/NUOPC | CCPP | WW3 | CICE |
|---|---|---|---|
| Earth System Modeling Framework - Common modeling infrastructure, component interface standards allow coupling modules developed in multiple centers; Couples between atmosphere, ocean, ice, wave components | Common Community Physics Package - Originated with ESPC's Physics Interoperability group; now in use by multiple centers | WaveWatch III - Originally developed by NOAA: model framework used in multiple implementations for different purposes; Community model with international team of wave developers | Los Alamos Sea Ice model - Originally developed by DOE: computationally efficient sea ice component for fully coupled, atmosphere-ice-ocean-land global circulation models |
| ESPC coordinates through Model Component Liaison Working Group | ESPC connects CCPP with broader Physics Interoperability Working Group | Now becoming part of the NUOPC ensemble and the NAEFS working Group | ESPC assists cross-working group coordination and provides staffing support |
| https://www.earthsystemcog.org/projects/esmf/ | https://dtcenter.org/community-code/common-community-physics-package-ccpp | https://github.com/NOAA-EMC/WW3/wiki/About-WW3 | https://github.com/CICE-Consortium/About-Us |


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# Significant ESPC Accomplishments

**NUOPC Operational Ensembles**

Since 2011, long-term operational interagency Multi-Model Ensemble

**ESMF NUOPC Layer**

Provides interoperability between model components

**Interoperable Physics**

Framework for small number of physical parameterization suites to be supported and easily share

**North American Multi-Model Ensemble Continuation**

**Consortium Efforts**

i.e. CICE: DOE Sea ice modeling effort, now in community development and used by multiple research and operational models

**High Performance Computing**

Interagency experts coordinating statements of need and potential directions in support of Earth Systems Prediction

# Challenges: R2O

- What are the most significant barriers to efficient R2O and how is the ESPC addressing them?
  - Common model architectures can expedite cross-agency improvements BUT . . .
    - Information Assurance: differing agency missions drive separate constraints
  - Accelerate return on investments through community development
  - Sufficient HPC capacity appropriate for R&D and operations
  - Need strategically coordinated, accepted/implemented interagency development plan
    - Research community foci driven through agency programs; need better engagement across agencies
  - Strengthen connection between process-level advances and technology transitions
  - The ESG and working groups are a forum for addressing these issues

# Earth System Prediction Computing Needs

- Earth system models are becoming increasingly more complex in order to simulate the climate system - increases in resolution (e.g. Navy ESPC, E3SM, ocean and ice) **necessitate HPC increases and computational efficiency**, as do predictions on longer or extended range time-scales
  - Current computational efficiency is 1-2% of available compute power. Software and hardware solutions are required to fully utilize HPC resources.
- Predict hazards at short time ranges *and* enable decision making in weather-to-climate overlap
  - Weather predictions:
    - Strict time requirements (1 model day ≤ 8 min wall time)
  - Seasonal through decadal predictions:
    - Short run times for evaluation, development, reforecasting
- Future computing needs will exceed 1000 times of today's existing computing and possibly require custom built hardware & software
  - Need accurate forecasting of local floods at catchment level and to resolve hurricane structure/rainbands.
  - Significant investment will be needed to port our models to exascale systems.
- White paper (Carman, et al. "Position Paper on High Performance Computing Needs in Earth System Prediction." National Earth System Prediction Capability (ESPC) program. April 2017. https://doi.org/10.7289/V5862DH3)

# Challenges: Collaboration

- OMB and OSTP are interested in inter-agency collaboration and sharing of best practices and components of earth system prediction models.
- Near- and mid-term barriers to increased collaboration in this field . . .
  - National ESPC is a partnership of the willing, developed from a recognized need. The only place this effort occurs in legislation is where the Weather Act of 2017, focused on NOAA, calls for NOAA to "participate in the interagency ESPC". Additional recognition of the benefits of this effort would strengthen the partnership.
  - A structure for interagency program ventures
  - Increase agency flexibility to leverage each other's emerging initiatives
- ESPC Staff agrees with a need for more and better internal NOAA collaboration, particularly related to extended range decision support (*not just NOAA*)

# The NUOPC Ensemble

# Current NUE Model Configurations (Oct. 2018)

| | NCEP | CMC | FNMOC | NUE | Air Force |
|---|---|---|---|---|---|
| **Model** | GFS | GEM | NAVGEM v1.2 | NCEP+CMC+FNMOC | GALWEM (evaluating) |
| **Initial uncertainty** | EnKF F06 | EnKF | 2 layer, 9 Band ET w/analysis error adjustments | | Global analysis + 44 member ETKF perturbations |
| **Model uncertainty Stochastic** | Yes (STTP) | Yes (multi-physics and Stochastic) | SKEB w/moisture convergence mask | | SKEB and Random Parameters, Stochastic Physics, SST and soil-moisture perturbations |
| **Tropical storm** | Relocation | None | None | | None |
| **Daily frequency** | 00,06,12 and 18UTC | 00 and 12UTC | 00 and 12UTC | 00 and 12UTC | 00 and 12 UTC |
| **Resolution** | T574L64 (d-d8) ~34km<br>T382L64 (d816)~55km<br>Q2 2020 – 25km/L72 | 39km/L45 | T259L60 ~ 37km | 1*1 degree<br>0.5*0.5 degree | 640 by 480<br>~ 40 km/L70 |
| **Control** | Yes | Yes | Yes | Yes (3) | Yes |
| **Ensemble members** | 20 for each cycle<br>30 for each cycle | 20 for each cycle | 20 for each cycle | 60+3 for each cycle | 20 for each cycle |
| **Forecast length** | 16 days<br>35 days once/week | 16 days<br>32 days once/week | 16 days | 16 days | 16 days |
| **Post-process** | Bias correction for ensemble mean | Bias correction for each member | Bias correction for member mean | Yes | No |
| **Last implementation** | December 2015 | September 2018 | March 2017 | | Est. Feb 2019 |

# Timeline to add GALWEM Members

**5 Apr** Test data provided to NCEP for compatibility testing

**31 May** Real time streaming data available – Centers setup verification and metrics

**27-29 Aug** Ensemble Workshop at NCEP - Review Metrics

**1 Oct** Review Metrics

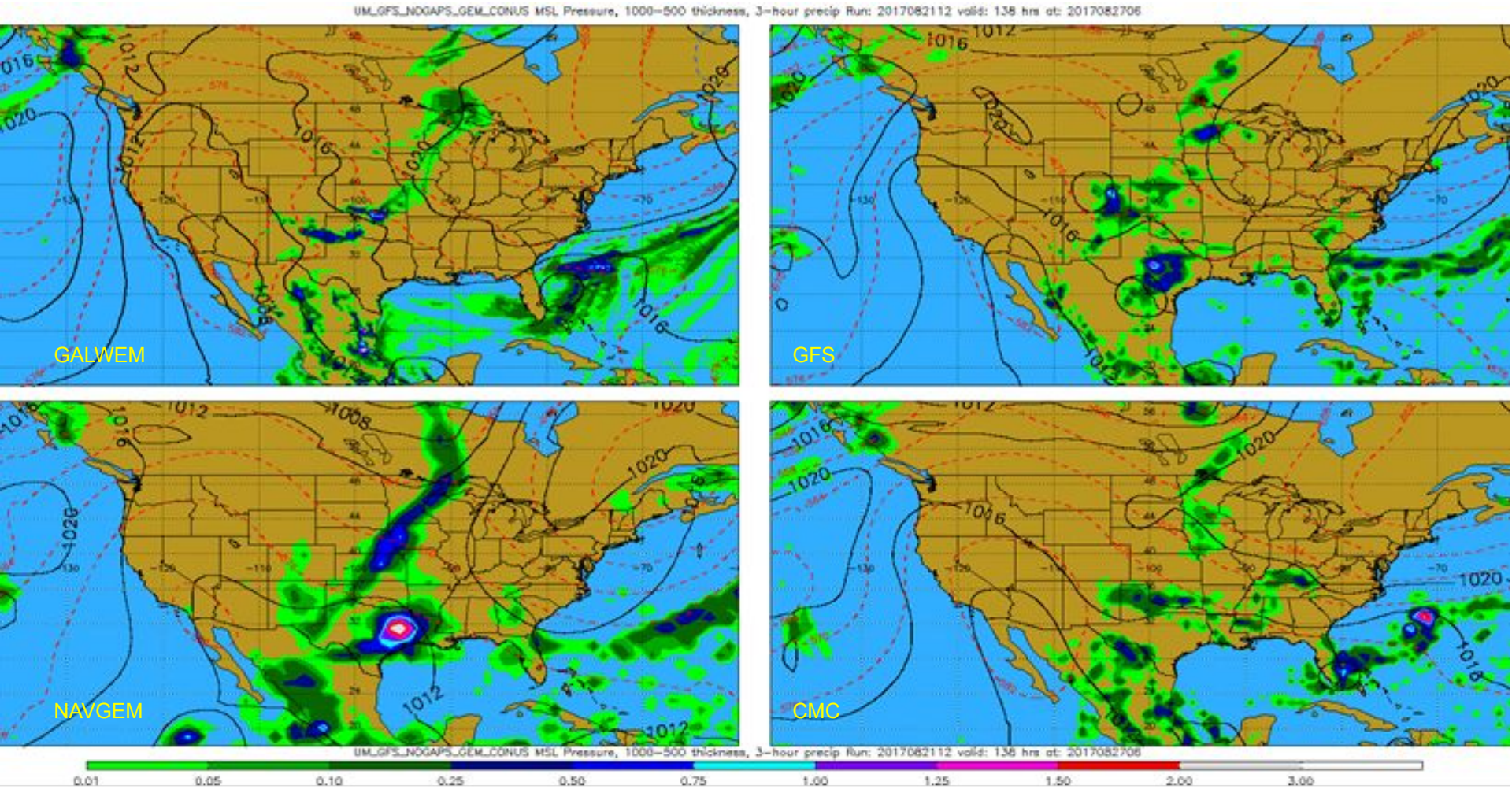
**1 Dec** Review for implementation

**Possible issues/concerns**: NCEP/NCO moratorium on changes, may impact ability to host the data streams on NOMADS for use by others - other comms paths being explored.

# Challenges:

- Multi - model  system to support the Federal enterprise
- Metrics  -
  - Value from models when it matters
- Big Data  -  data tools
  - Best Data
- Smart system -  adaptive

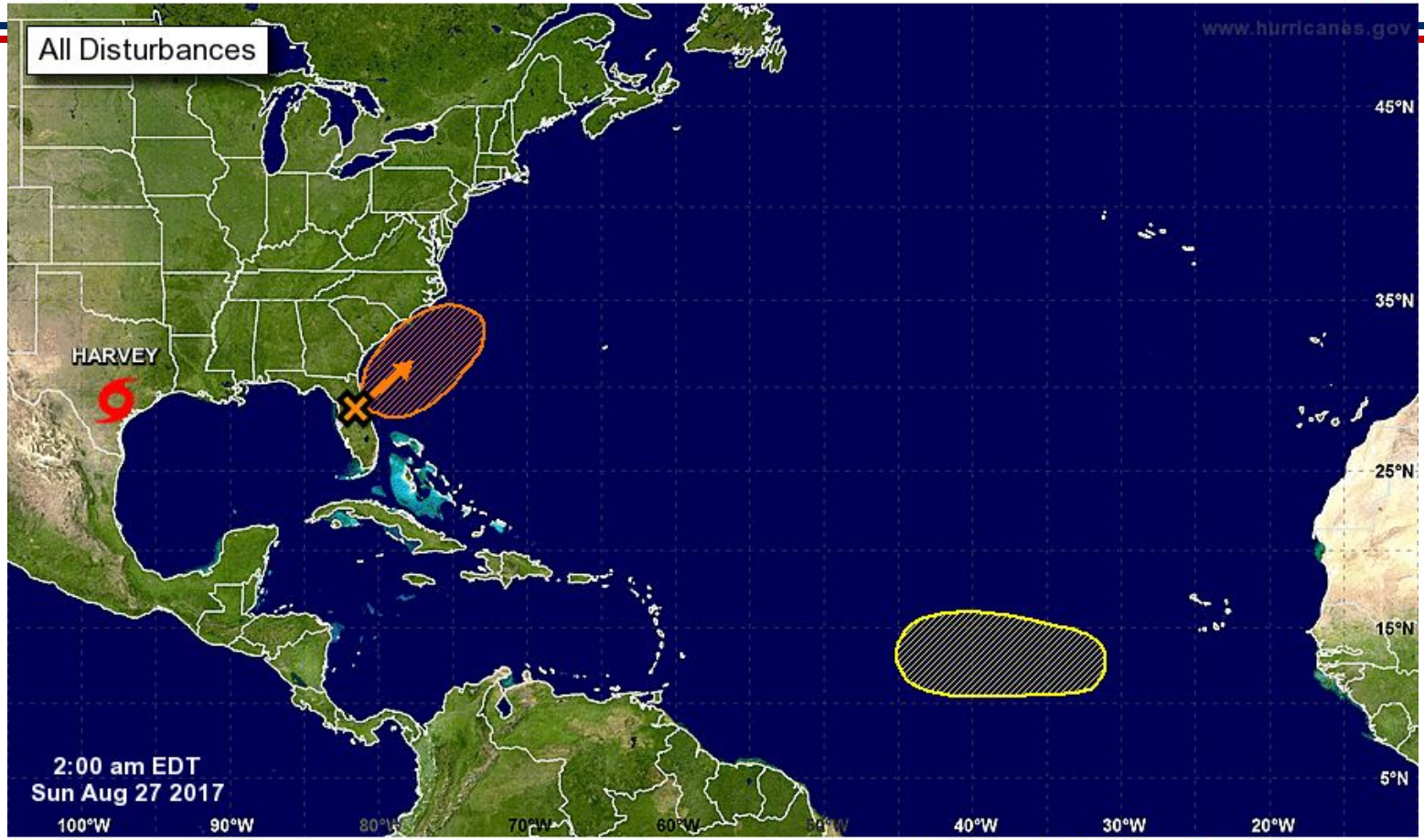
# Deterministic Models
# Hurricane Harvey



# Questions?

# Five-Day Graphical Tropical Weather Outlook

National Hurricane Center Miami, Florida




Current Disturbances and Five-Day Cyclone Formation Chance: < 40% 40-60% > 60%

Tropical or Sub-Tropical Cyclone: Depression Storm Hurricane

Post-Tropical Cyclone Remnants

National ESPC Earth System Prediction Capability