US Navy Global Prediction Systems






Earth System Prediction Capability (ESPC)






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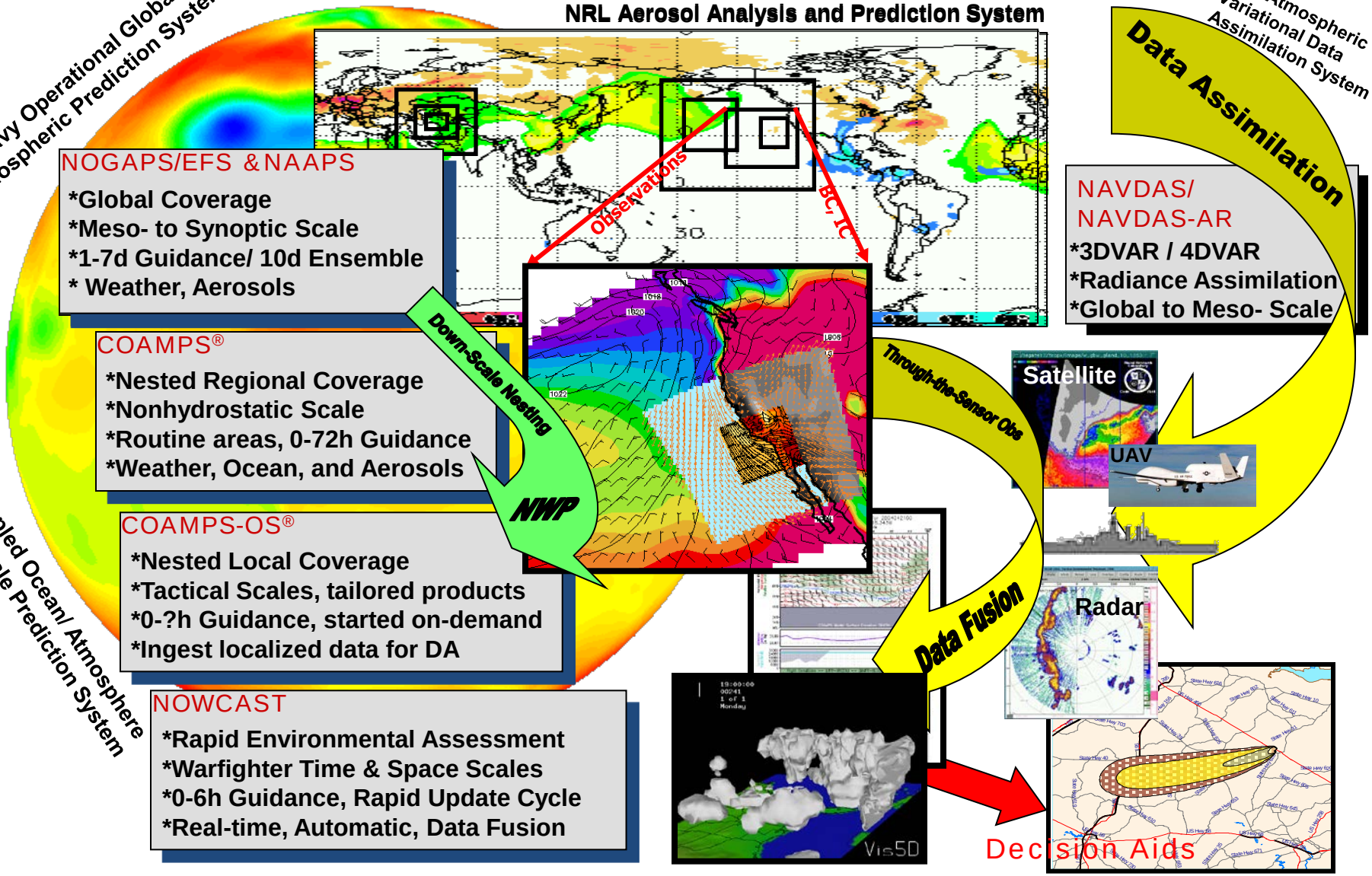
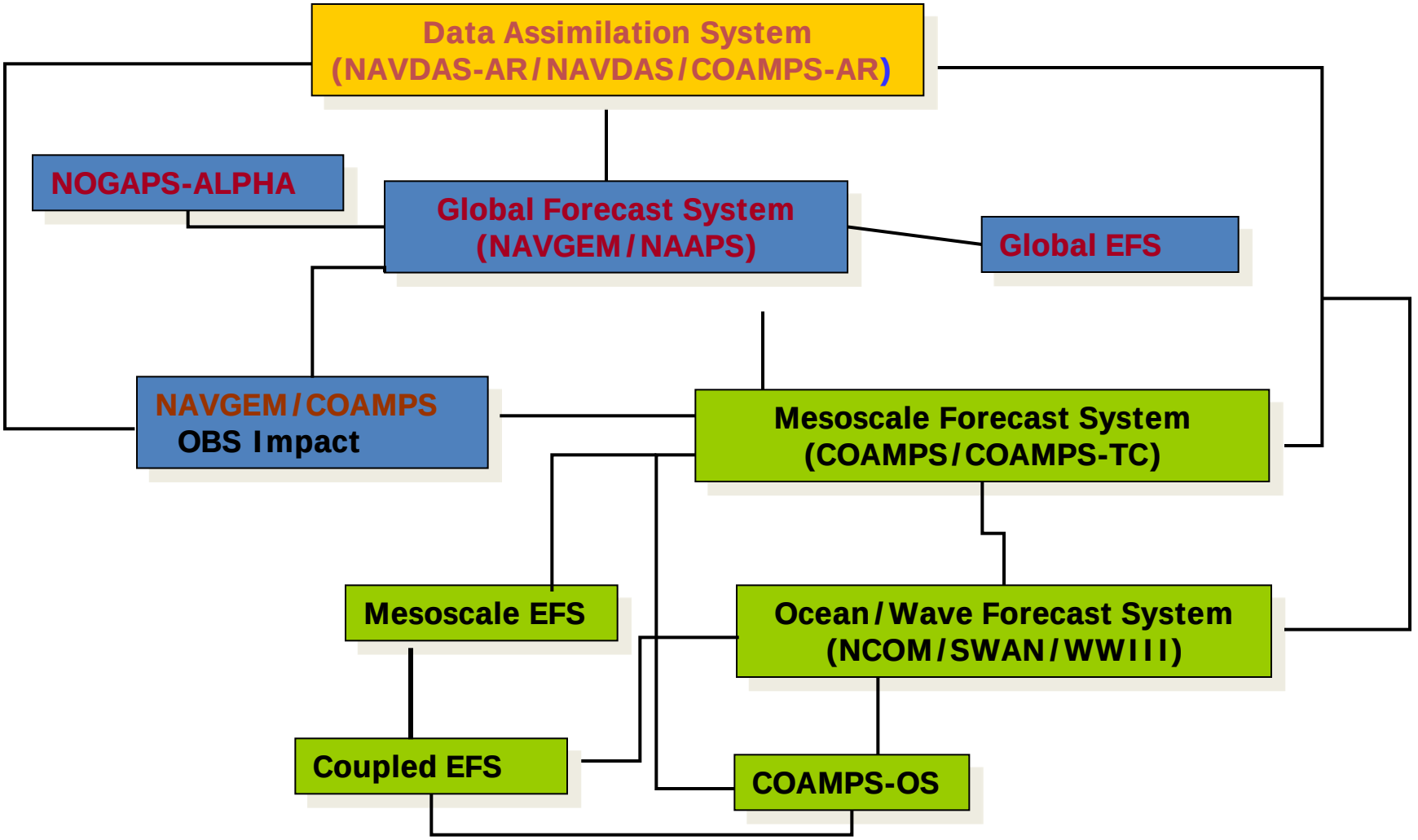
Naval METOC Enterprise

Telescoping NWP Strategy



NRL Prediction Systems Overview



MMD is responsible of developing and transition to operations the full suite of NWP systems

NRL Research

Aerosol Transport

Numerical Methods

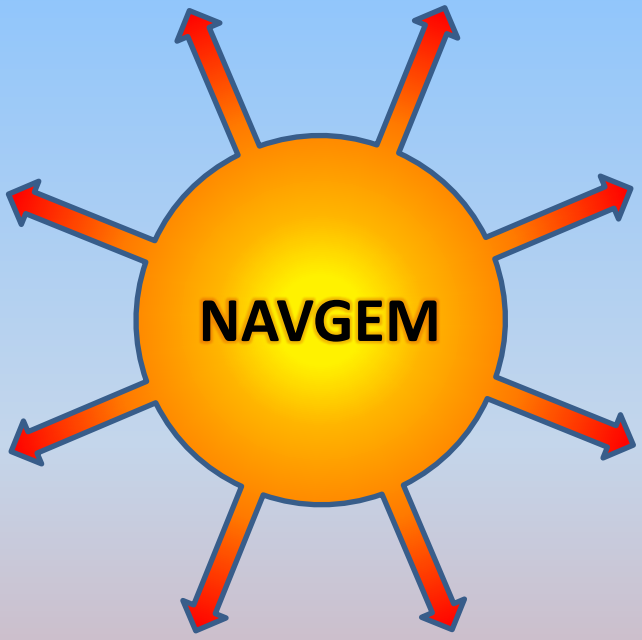
Predictability

Reanalysis

Physical Parameterization

Land Surface Modeling

Data QC
Data Assimilation
Initialization



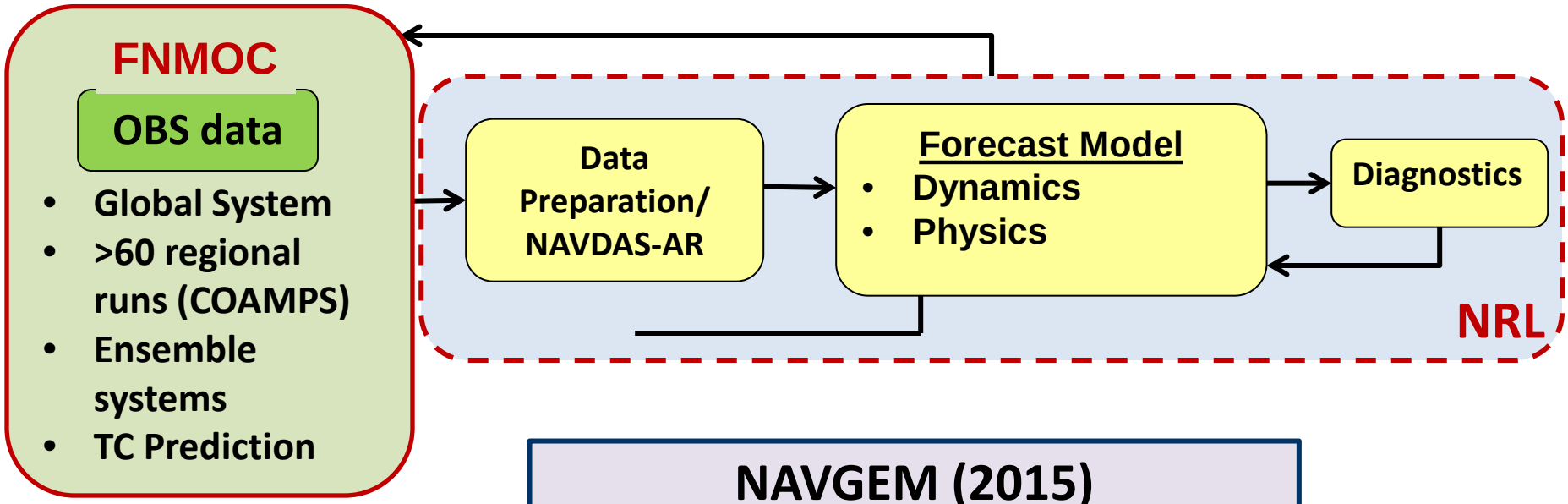
Coupled Modeling

Stratosphere
Mesosphere

Global Weather
Mesoscale Weather
Tropical Cyclones
Field Programs
Ocean, Ice, Wave
Air/Ship Routing
Ensemble
Army, NOAA
USAF, DTRA
Naval Observatory
GFDN

Operational Users

US Navy Global Prediction Systems



Operation Center

NAVGEM (2015)

- Semi-Lagrangian/Semi-Implicit
- T425L60 (31km, 0.04mb)
- Advanced physics

Global coupled system

- NAVGEM
- HYCOM
- CICE
- WWIII

NEPTUNE (~2020-2025)

- Spectral element dynamics
- Nonhydrostatic
- 10km, 100 levels
- Advanced physics

NAVGEM Version 1.1

Data Assimilation

- 4D-Var with advanced variational bias correction
- New radiative transfer model CRTM v2
- Assimilating additional GPS, SSMIS data, and NPP data (CrIS, OMPS, ATMS, VIIRS),

Dynamics

- SL/SI scheme
- Cubic interpolation
- T359L50 (Δx~37km, top at 0.04 hPa or ~70 km)
- Three-time-level integration with Δt = 360 sec

New Physics

- Simplified Arakawa-Schubert scheme
- Shallow convection
- 2-species prognostic cloud scheme
- RRTMG 4-stream radiation
- Modified cloud fraction scheme
- Modified boundary layer scheme

- **NAVGEM transitioned to FNMOC for OPTEST in September 2012**
- **The development team received the Navy Acquisition Excellence Award**

NAVGEM Development

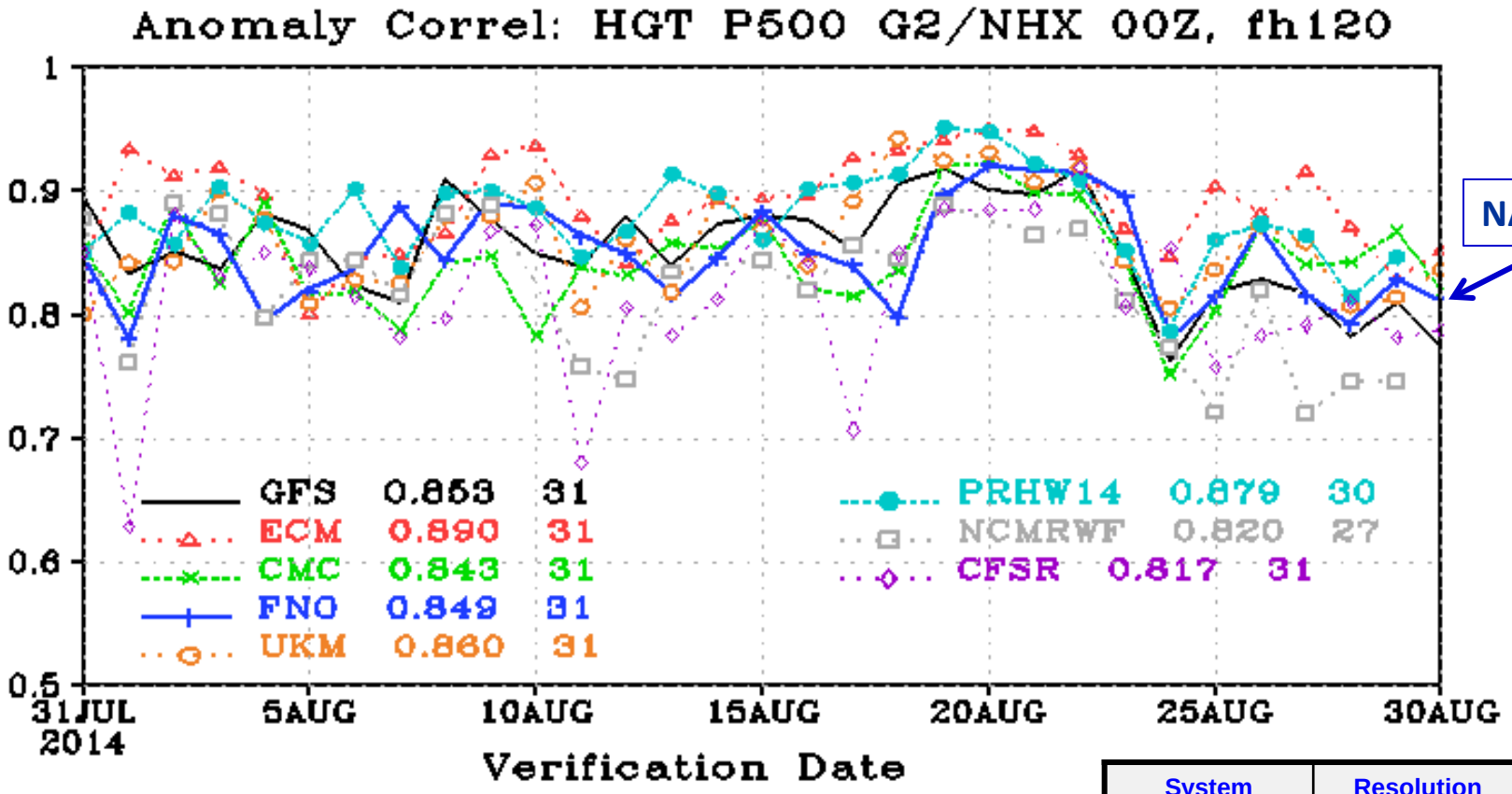
Version 1.1
- Semi-Lagrangian/Semi-Implicit dynamic core
- T359L50 (37 km) resolution, 0.04 hPa top (71 km)
- DA upgrade
- Operation at FNMOC Feb 2013 (first in the nation)
- Awarded with 2012 Navy Acquisition Excellence Award

Version 1.2
- EDMF turbulent mixing scheme
- Modified convective cloud scheme, cloud fraction scheme
- Operational at FNMOC 6 Nov 2013

Version 1.2.1
- DA upgrade
- Operation at FNMOC 8 July 2014

Version 1.2.2
- Modification of vertical interpolation
- Adiabatic correction in the dynamic core
- Operation at FNMOC on 29 July 2014

Performance of NAVGEM 1.2.2
(Current operational version)



System	Resolution
ECMWF	16kmL91
UKMO	25kmL70
NCEP	27kmL64
CMCNCEP	25kmL79
Navy	37kmL50

NAVGEM & HPC

- Strengths
  - Flexible configuration supports many research and operational platforms
  - New funded projects aimed at optimizing existing global system
- Weaknesses
  - Legacy I/O is a significant limitation to scalability
  - Limited technical resources have limited past optimization efforts

Earth System Prediction Capability (ESPC)

ESPC Overview

Introduction

- **ESPC is a US interagency collaboration among DoD (Navy, Air Force), NOAA, DoE, NASA, and NSF for coordination of research to operations for an earth system analysis and extended range prediction capability.**
- **It does not replace individual agency requirements but seeks to improve communication and synergy, in the area of global environmental forecasting at timescales of weather to climate.**

Thrusts

- **Common prediction requirements and forecast model standards that enable leveraging and collaboration.**
- **Integration of atmosphere-ocean-land-ice and space predictions into a fully coupled global prediction capability.**
- **Cooperative five-year projects to demonstrate S&T and R&D efforts by 2018.**

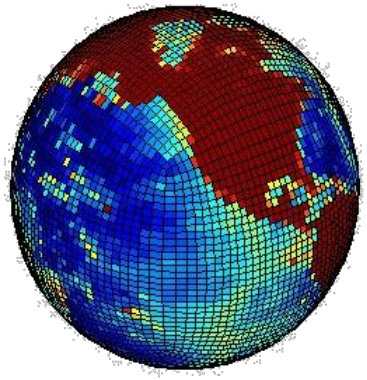
Approach

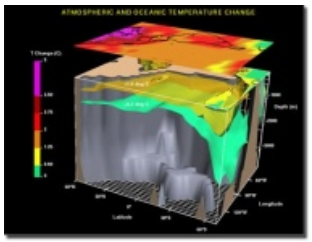
Improved Model Physics
- Coupled global modeling
- Improved resolution & parameterization

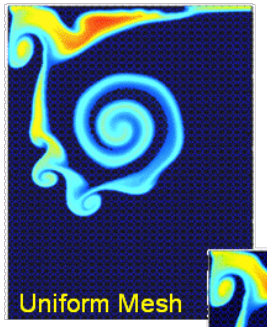
Improve Initial Value Problem through
- Joint observational retrievals
- New hybrid DA approaches

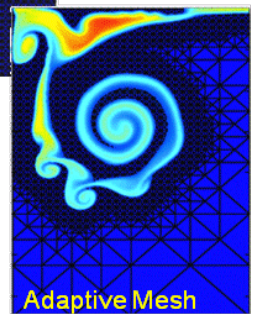
Increase Forecast Information through
- Stochastic prediction and post-model processing
- National Multi-model ensembles
- Seamless prediction

Increase System Resolution affordably through
- Efficient Computational Architectures
- Efficient Numerics/ Discretization

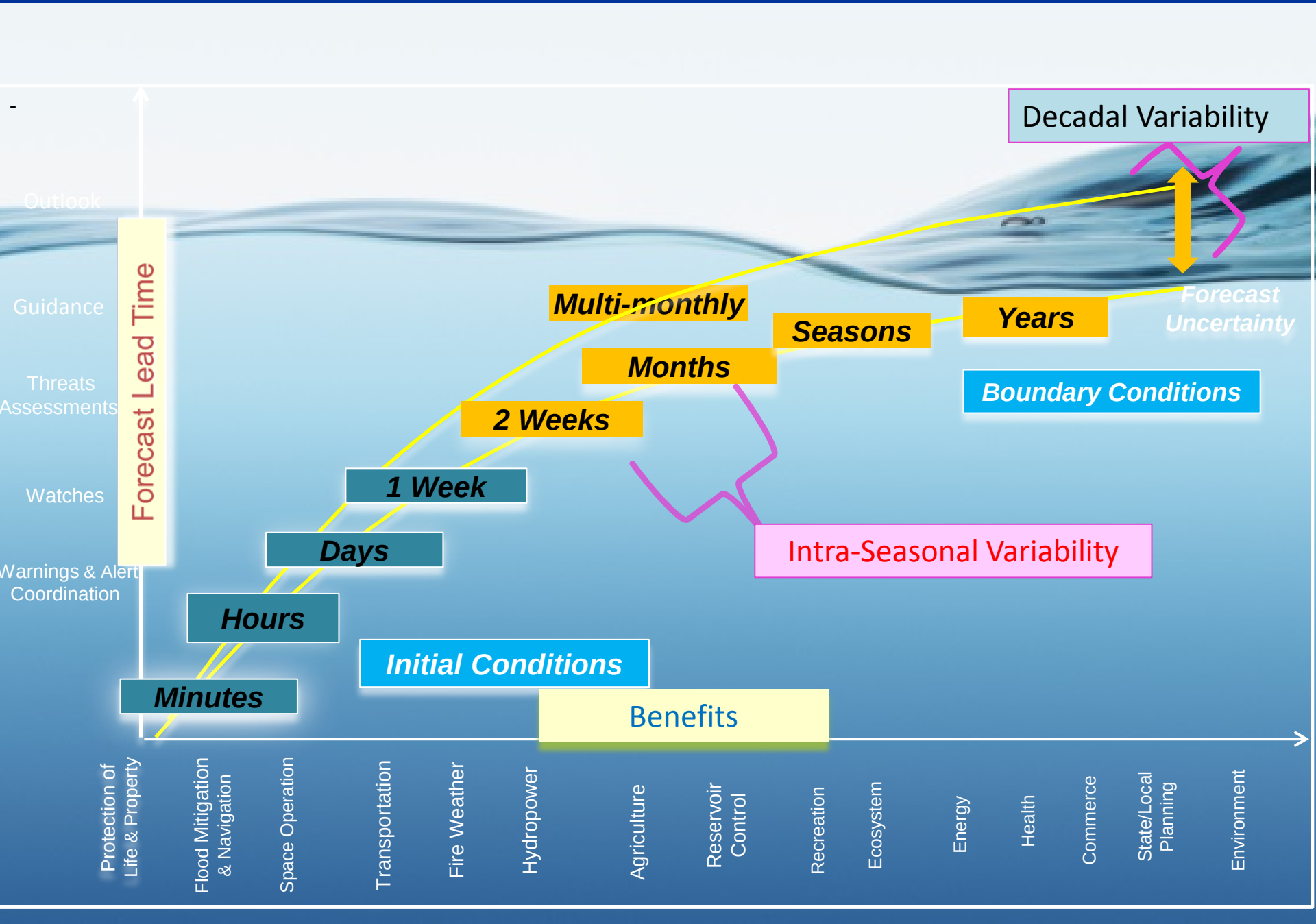








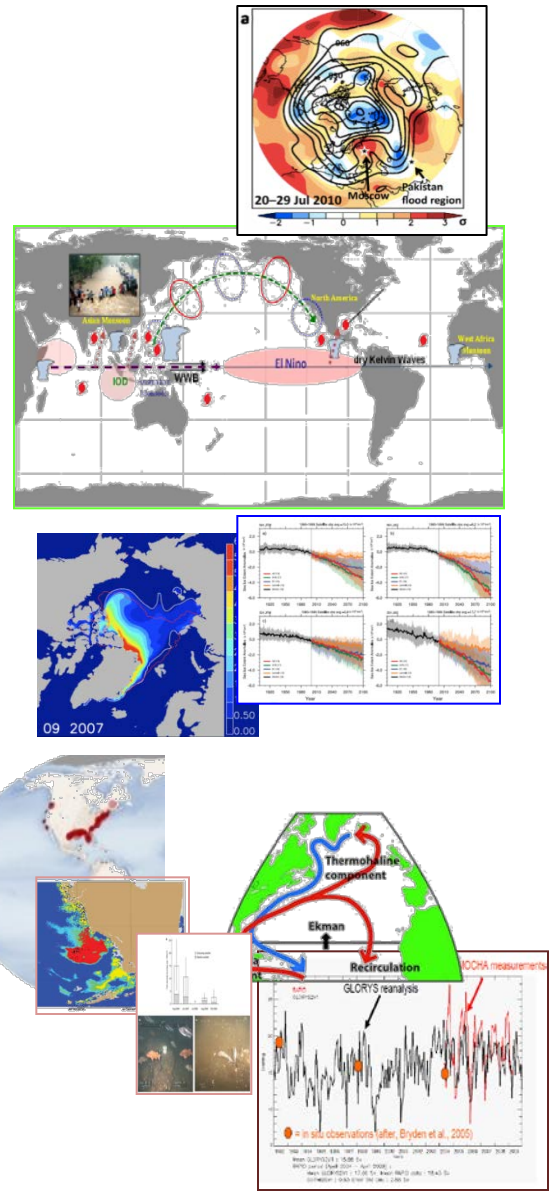
Seamless Prediction



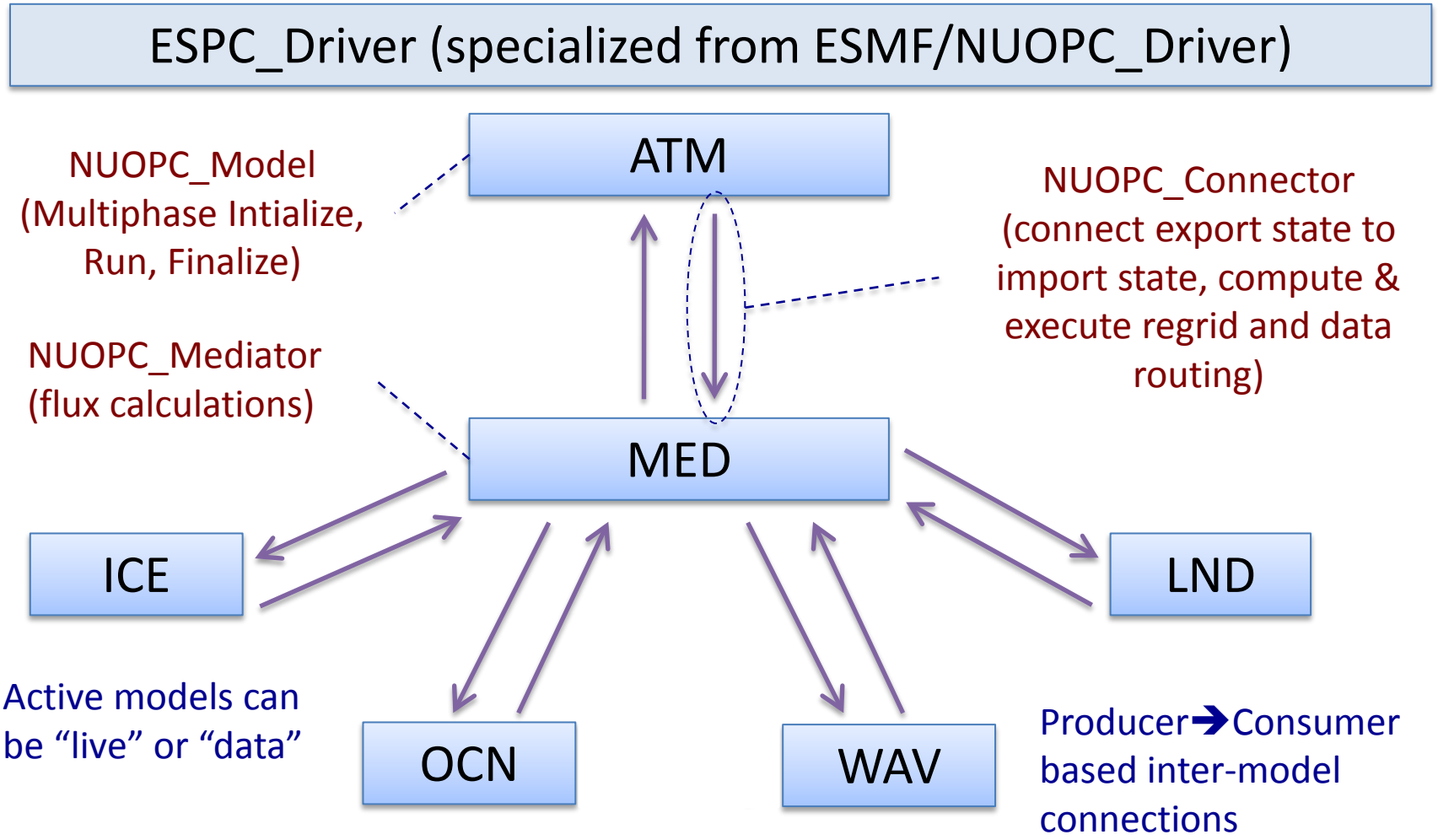
ESPC Demonstrations for IOC-2018

(10 Days to 1-2 years time scale)

- **Extreme Weather Events**: Predictability of Blocking Events and Related High Impact Weather at Lead Times of 1-6 Weeks (Stan Benjamin, NOAA/ESRL)
- **Extended lead-time for TC Predictions**: Predictability of Tropical Cyclone Likelihood, Mean Track, and Intensity from Weekly to Seasonal Timescales (Melinda Peng, NRL MRY)
- **Coastal Seas**: Predictability of Circulation, Hypoxia, and Harmful Algal Blooms at Lead Times of 1-6 Weeks (Gregg Jacobs, NRL SSC)
- **Arctic Sea Ice Extent and Seasonal Ice Free Dates**: Predictability from Weekly to Seasonal Timescales (Phil Jones, LANL)
- **Open Ocean**: Predictability of the Atlantic Meridional Overturning Circulation (AMOC) from Monthly to Decadal Timescales for Improved Weather and Climate Forecasts (Jim Richman, NRL SSC)



Navy coupled system Infrastructure



ESMF/NUOPC interface layer is being implemented into each of the Navy relevant models (NAVGEM, HYCOM, WWIII, CICE). ESMF/NUOPC based coupling infrastructure integrates the models, together with a flux exchange layer, into a flexible coupled system.

ESPC US Navy Coupled System

Operational Implementation Design

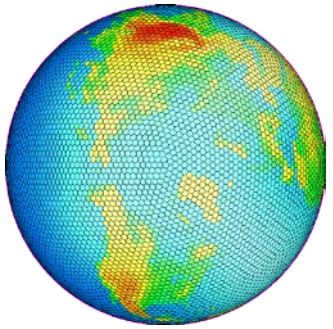
Projected horizontal and vertical resolutions of the individual ESPC system components at the IOC in 2018.

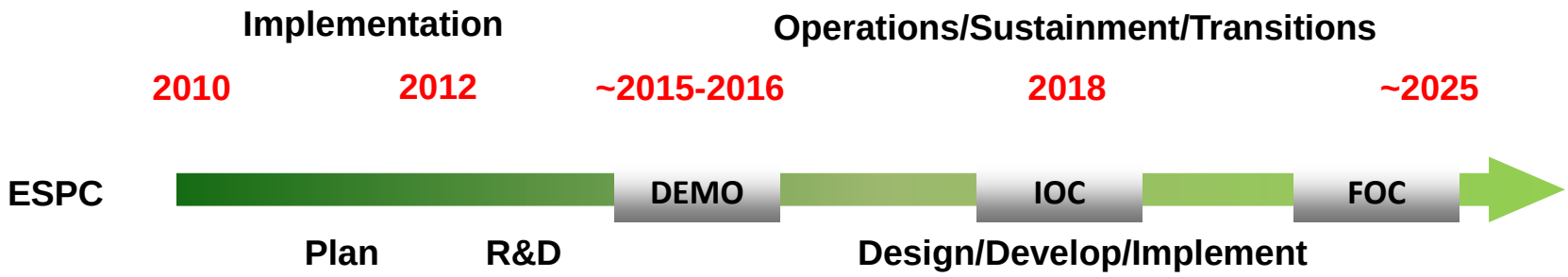
Forecast	Time Scale, Frequency	Atmosphere NAVGEM	Ocean HYCOM	Ice CICE	Waves WW3	Land-Surface NAVGEM-LSM	Aerosol NAAPS
Deterministic short term	0-10 days, daily	20 km 80 levels (T639L80)	1/25° (4.5 km) 41 layers	1/25° (4.5 km)	1/8° (14 km)	3/16° (21 km)	3/16° (21 km)
Deterministic long term	0-30 days, weekly	20 km 80 levels (T639L80)	1/12° (9 km) 41 layers	1/12° (9 km)	1/4° (28 km)	3/16° (21 km)	3/16° (21 km)
Probabilistic long term	0-90 days, weekly	37 km 50 levels (T359L50)	1/12° (9 km) 41 layers	1/12° (9 km)	1/4° (28 km)	1/3° (37 km)	1/3° (37 km)

ESPC Time Table

Next-generation Earth Prediction System

- Global Atmospheric Cloud Resolving forecast system
- 10-15km initially, ultimately 4km or finer resolution
- Adaptive/unstructured mesh allows computational efficiency
- Fully coupled air-ocean-land-ice-wave-space system
- Improved prediction at weather to climate scales





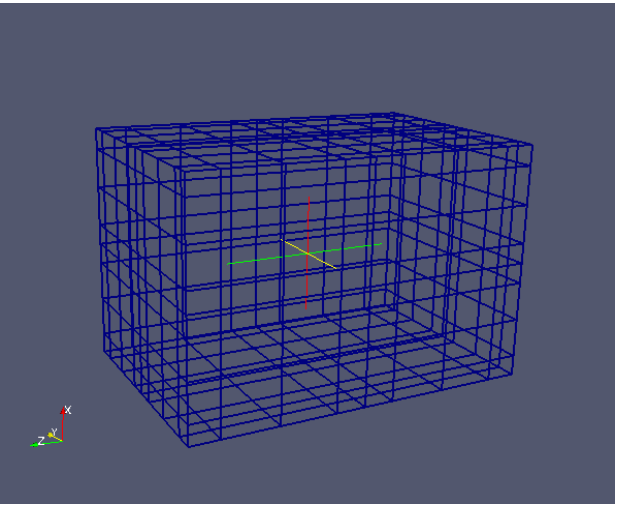
NEPTUNE- Next Generation Model

NRL is developing and evaluating a new NWP system based on the NUMA (NPS) core as an ESPC candidate

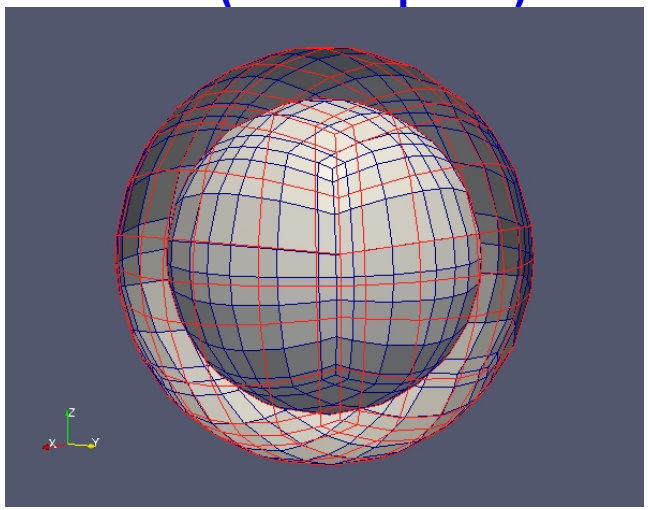
- **NEPTUNE**: **N**avy **E**nvironmental **P**rediction sys**T**em **U**tilizing the **N**UMA Cor**E**
- 3D spectral element model
- Highly accurate and scalable
- A suite of physical parameterizations has been added
- Real data initialization capability
- Flexible grids (cube sphere, icosahedral, etc.)
- Eventually, will have Adaptive Mesh Refinement (AMR)
- Coordinating with both HIWPP and DCMIP
- Evaluate and learn about other cores too – MPAS, NMM-B, HIRAM, NIM, etc.
  - We can't be a part of the dynamical core community without a "a horse in the race".

6.4 ESPC Next Generation Model

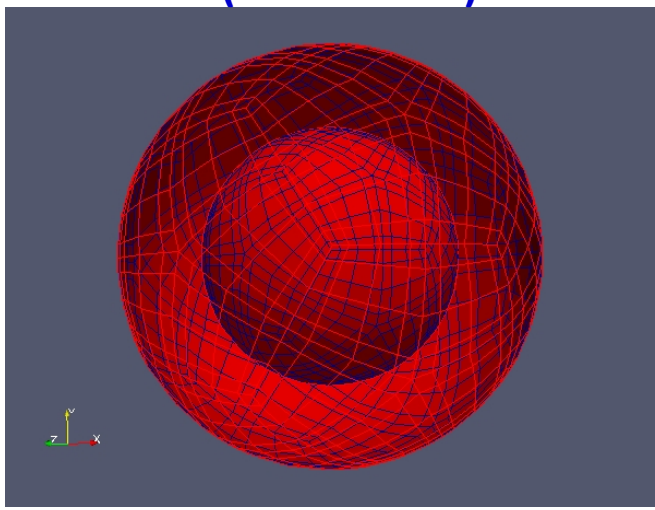
Limited-Area Mode

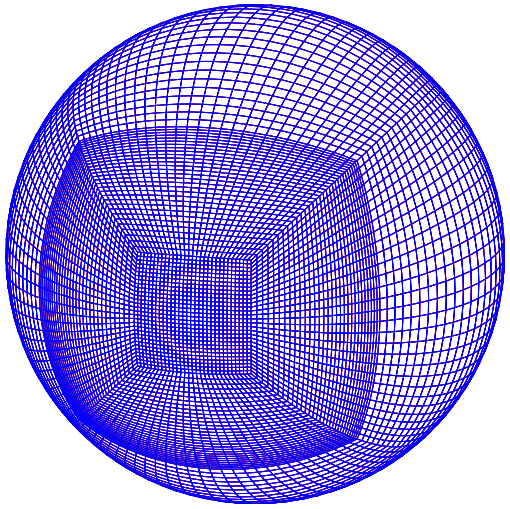


Global Modeling Mode (Cubed-Sphere)

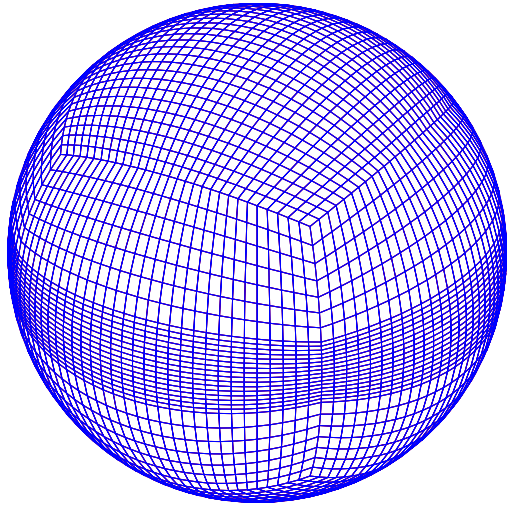


Global Modeling Mode (Icosahedral)

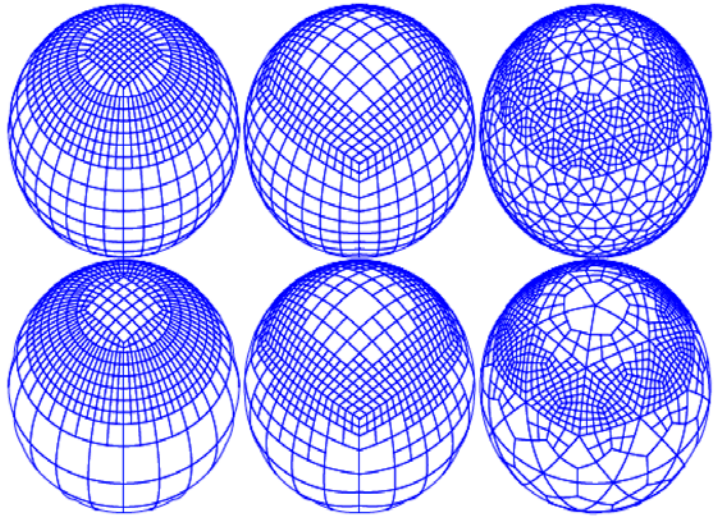




Telescoping Grid



ITCZ Grid

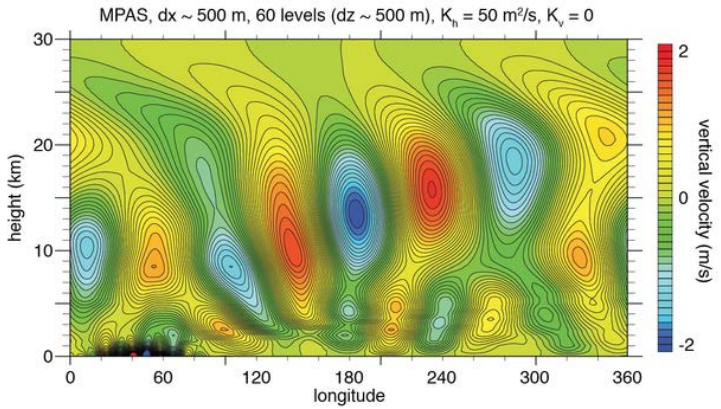


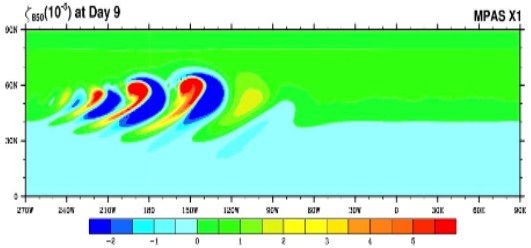
F. Giraldo (NPS)

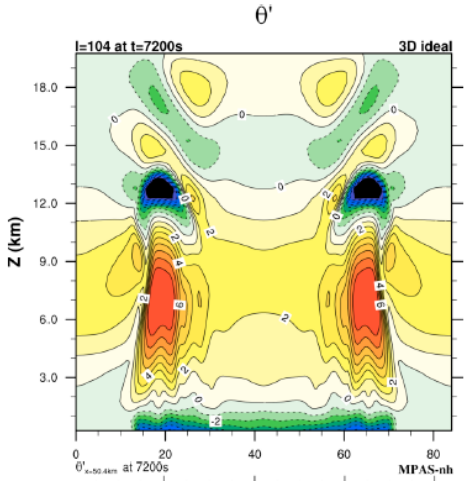
Coordinating with NOAA HIWPP next generation nonhydrostatic model group
FY14 test cases follow the DCMIP (dynamical core model inter. project)

1. Baroclinic Wave on sphere (basically completed except 60L tests)
2. Nonhydrostatic mountain waves on small planet (mostly complete)
3. Supercell on small planet (mostly complete)
4. Tropical cyclone (optional)

- **FY15 test cases (real data)**
  - 1 year of real-data retrospective runs on sphere
  - Limited number of high-resolution tests on sphere







Future Directions

- Tackle future high-resolution requirements by targeting highly scalable models (e.g. NEPTUNE)
- Invest in end-to-end optimization of current coupled system (especially I/O)
- Leverage operational investment in DoD HPC programs and associated increased resources for deterministic and probabilistic forecasting
- Continue to support model development consistent with requirements driven by operational resources
- Strengthen existing and establish new collaborations with the broader NWP HPC community