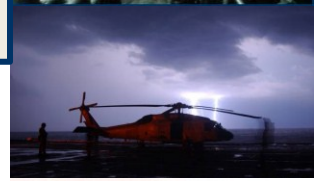
US Navy Global Prediction Systems






Earth System Prediction Capability (ESPC)



Melinda S Peng
Marine Meteorology Division
Naval Research Laboratory
Monterey, CA

HPC Workshop, ECMWF

1-5 Oct. 2012

Naval METOC Enterprise

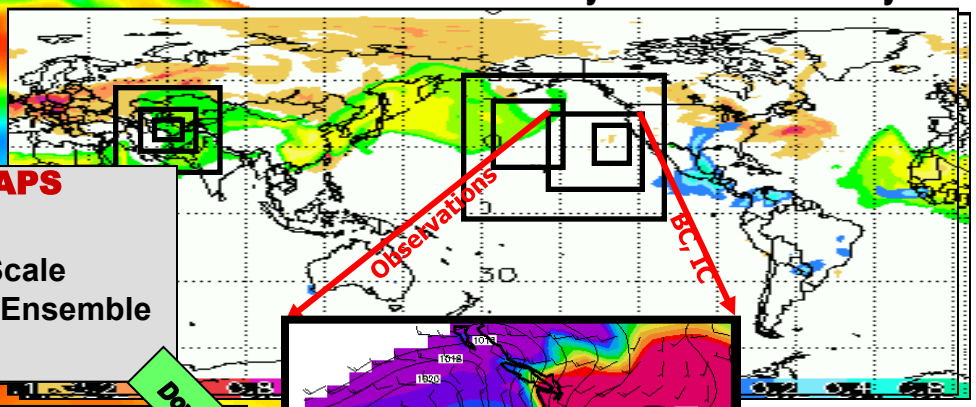
Telescoping NWP Strategy

Navy Operational Global Atmospheric Prediction System

NOGAPS/EFS &NAAPS

*Global Coverage
*Meso- to Synoptic Scale
*1-7d Guidance/ 10d Ensemble
* Weather, Aerosols

NRL Aerosol Analysis and Prediction System



NRL Atmospheric Variational Data Assimilation System

Data Assimilation

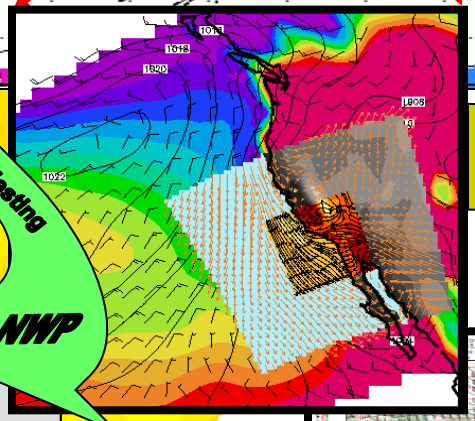
NAVDAS/ NAVDAS-AR

*3DVAR / 4DVAR
*Radiance Assimilation
*Global to Meso- Scale

Down-Scale Nesting

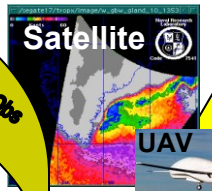
COAMPS®

*Nested Regional Coverage
*Nonhydrostatic Scale
*Routine areas, 0-72h Guidance
*Weather, Ocean, and Aerosols



NWP

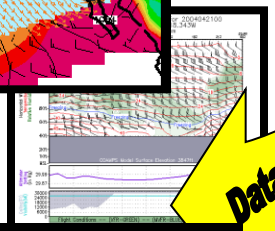
Through-the-Sensor Obs

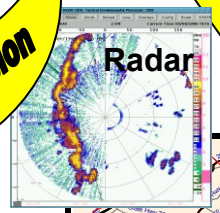


Coupled Ocean/ Atmosphere Mesoscale Prediction System

COAMPS-OS®

*Nested Local Coverage
*Tactical Scales, tailored products
*0-?h Guidance, started on-demand
*Ingest localized data for DA

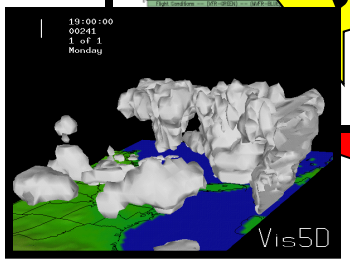


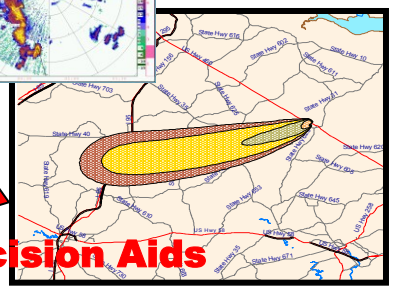


Data Fusion

NOWCAST

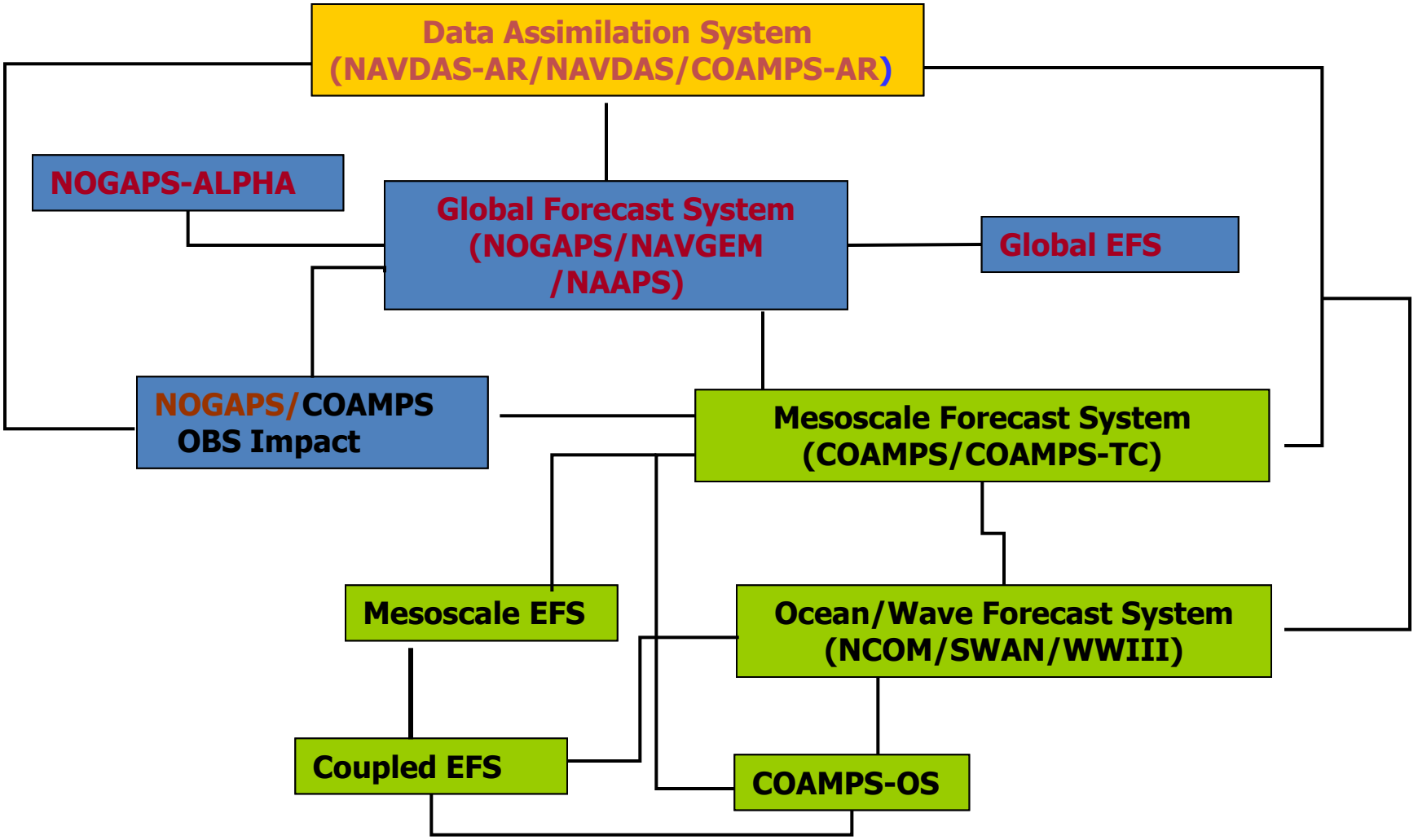
*Rapid Environmental Assessment
*Warfighter Time & Space Scales
*0-6h Guidance, Rapid Update Cycle
*Real-time, Automatic, Data Fusion





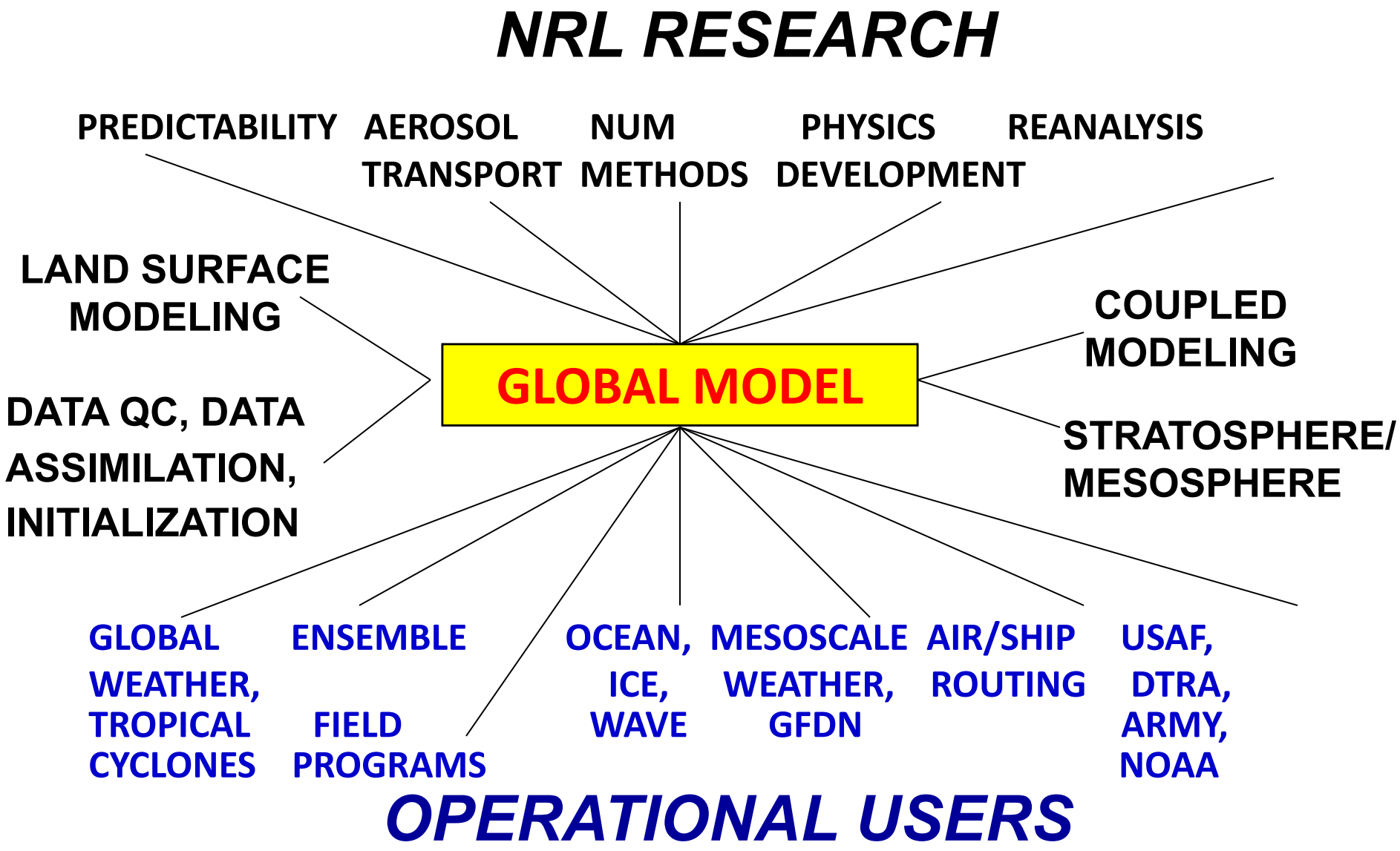
Decision Aids

NRL Prediction Systems Overview

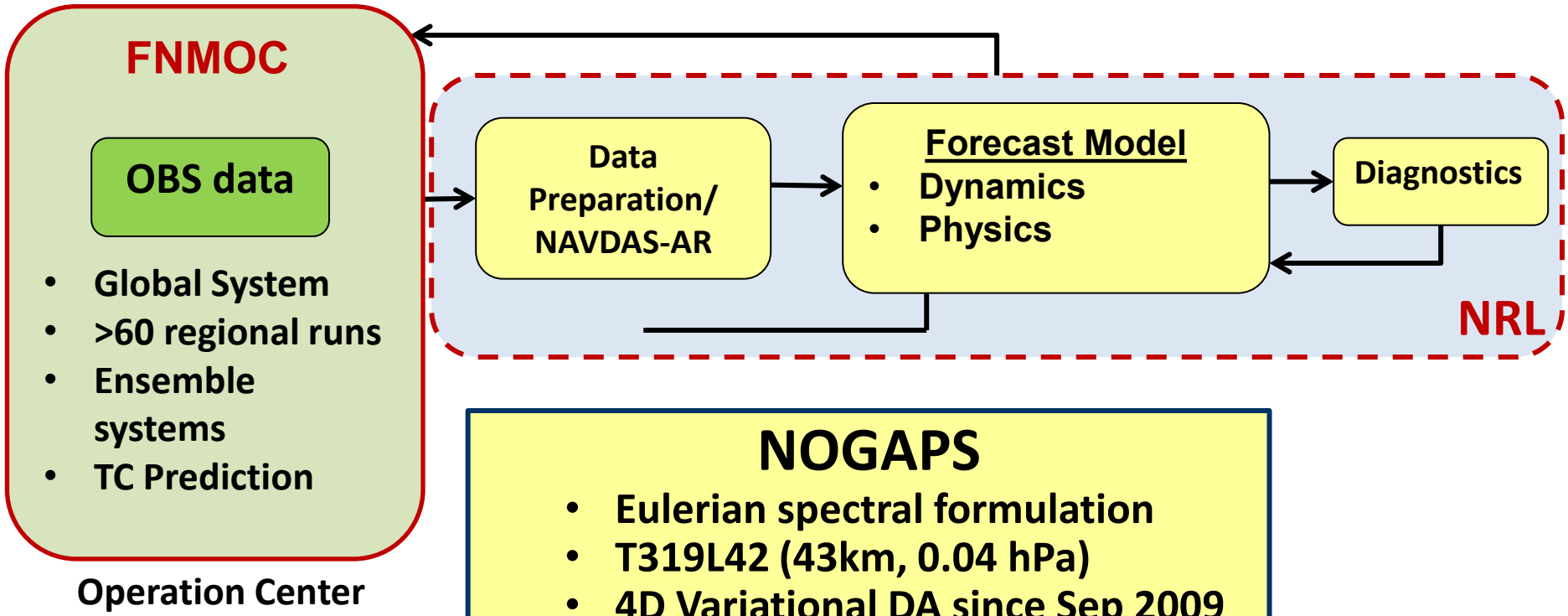


MMD is responsible of developing and transition to operations the full suite of NWP systems

Global Prediction System



US Navy Global Prediction Systems



NOGAPS

- Eulerian spectral formulation
- T319L42 (43km, 0.04 hPa)
- 4D Variational DA since Sep 2009
- 3.5 mins/day with 180 processors
- 20-member Ensemble System

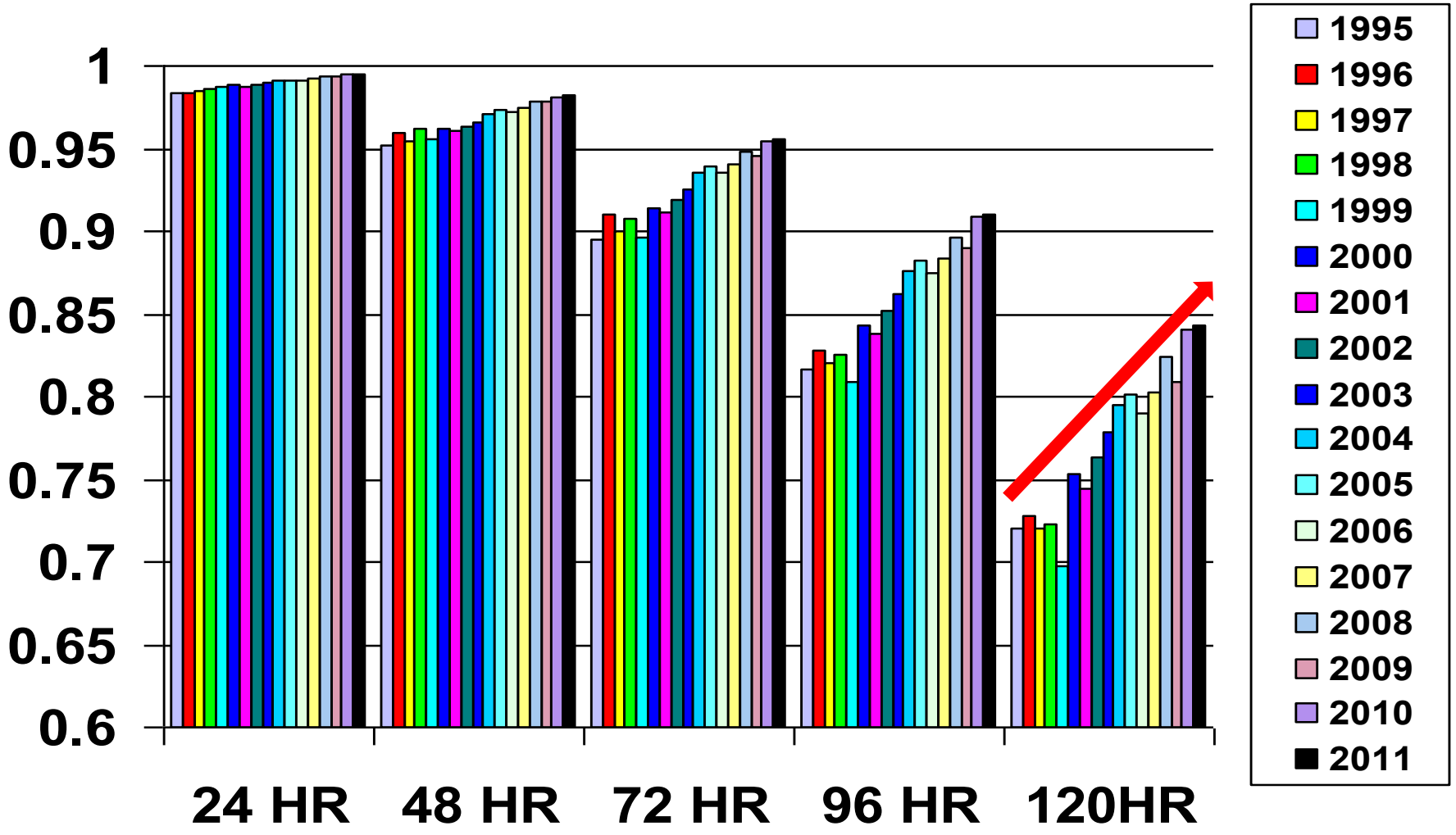
NAVGEM (2014)

- Semi-Lagrangian/Semi-Implicit
- T681L80 (19km, 0.04mb)
- Advanced physics

NUMA (~2020-2025)

- Under ESPC development
- 10km, 100 levels
- Advanced physics

NOGAPS Annual Mean Forecast Statistics
N. Hemisphere 500 mb Heights
Anomaly Correlation



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

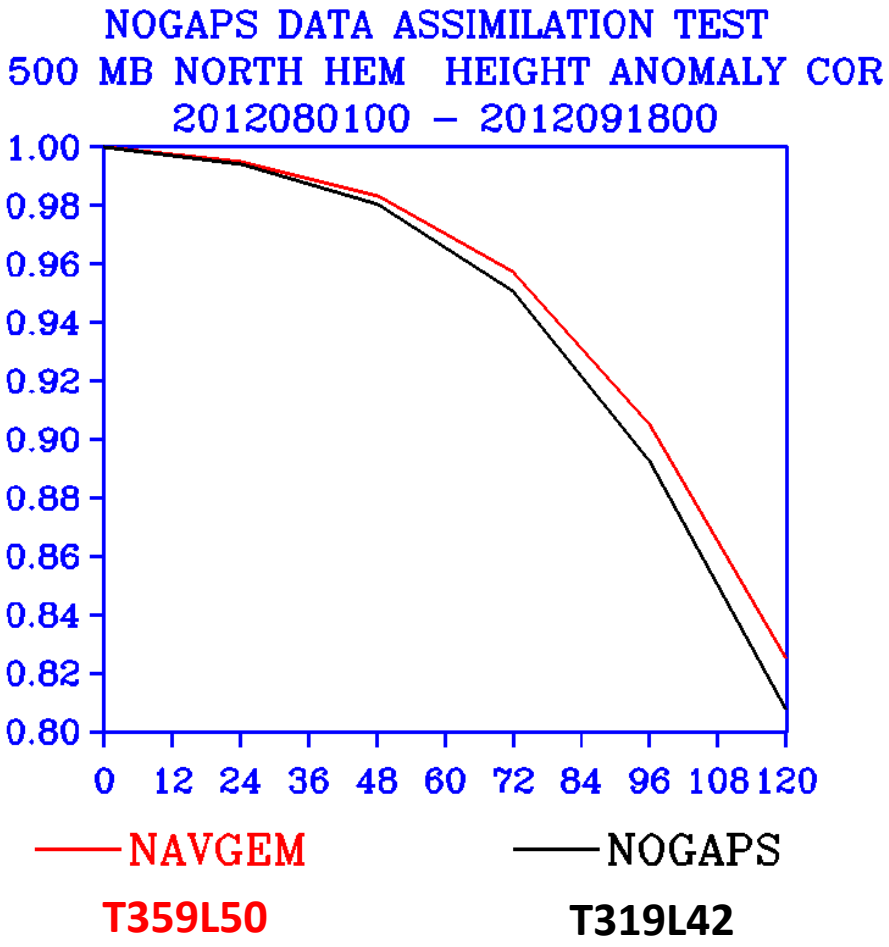
New Physics

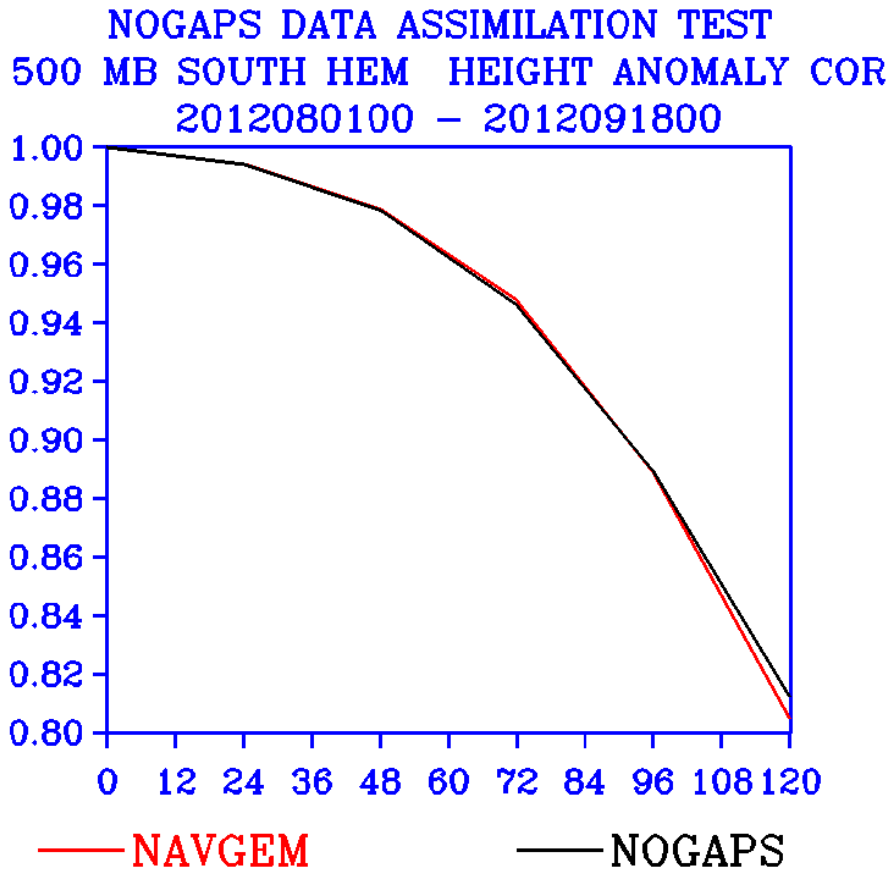
- Simplified Arakawa-Schubert scheme
- Shallow convection
- 2-specy prognostic cloud scheme
- RRTMG 4-stream radiation
- Modified cloud fraction scheme
- Modified boundary layer scheme

NAVGEM transitioned to FNMOC for OPTEST in September 2012

500 hPa Height Anomaly Correlations

August 1, 2012 – September 18, 2012





NAVGEM has better anomaly corrections at 500 hPa

NAVGEM Roadmap

FY13

- NAVDAS-AR (4D VAR with weak constraint, 2nd outer loop)
- Assimilation of NPP data
- Increased resolution
- Reduced grids
- Two-time-level integration
- Test on NAVO computer systems
- 4-specy cloud scheme
- Downstream impacts

FY14

- NAVDAS-AR (Hybrid 4D-Var)
- Aerosol assimilation
- T681L80 (19km) on NAVO
- New land surface model
- 1 ½ order PBL scheme
- 4 aerosol constituents prediction
- Coupled with ocean (HYCOM)
- Seasonal predictions
- High-resolution Ensemble

Earth System Prediction Capability (ESPC)

October 2012

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.

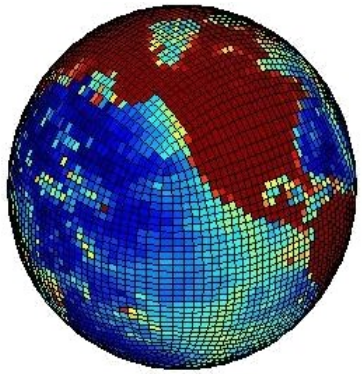
Approach

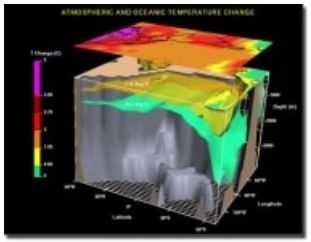
Improved Model Physics
- Coupled global modeling
- Improved resolution & parameterization

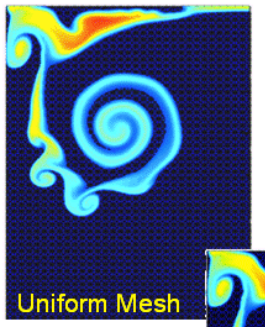
Improve Initial Value Problem through
- Joint observational retrievals
- New hybrid DA approaches

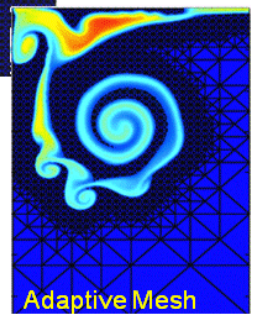
Increase Forecast Information through
- Stochastic prediction and post-model processing
- National Multi-model ensembles
- Seamless prediction

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







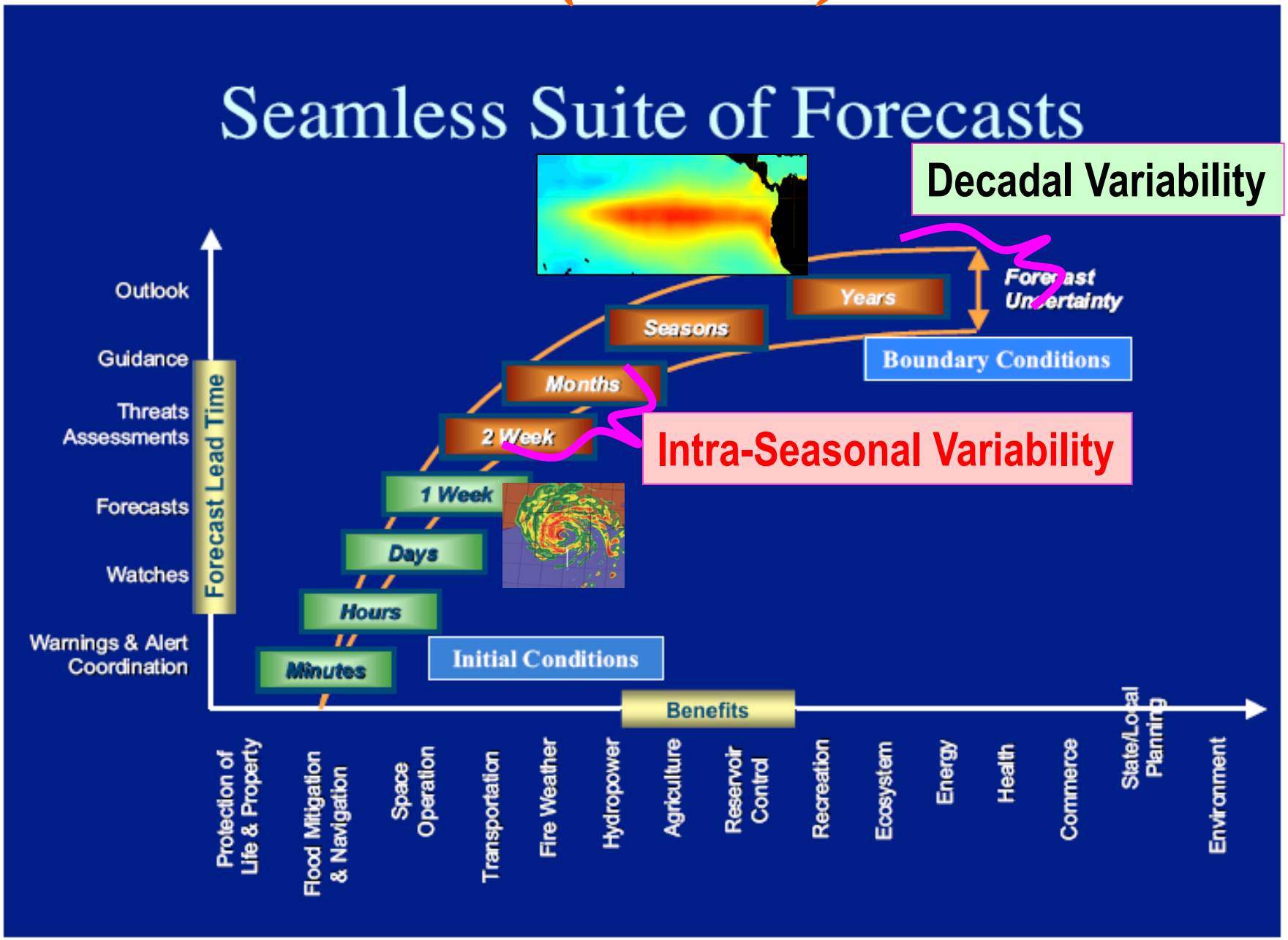


Phase I: ESPC Demonstrations

Interim Science Steering Group (ISSG) Workshop 21-23 March, 2012

- The ***most needed and most scientifically feasible forecast timescales are in the 10-day to 1-2 year range based on our current and near term understanding and capability***
- Linkages between climate research (USGCRP, CLIVAR, WCRP, etc.), weather research (US THORPEX, WWRP, etc.) and ESPC development and transition to operations were identified for coordination within the Demonstration Science Teams.

WCRP (2005-2015)



Phase I: ESPC Demonstrations

- Extreme Weather Events: Predictability of blocking events and high impact weather at lead times of 1-6 weeks (**Stan Benjamin***, NOAA/ESRL)
- Seasonal Tropical Cyclone Threat: Predictability of tropical cyclone likelihood, mean track, and intensity from weekly to seasonal timescales (**Melinda Peng***, NRL MRY)
- Coastal Sea: Prediction of sea circulation, hypoxia, and algal blooms at 1-6 weeks time scale (**Gregg Jacobs***, NRL SSC)
- Arctic Sea Ice Extent and Seasonal Ice Free Dates: weekly to seasonal timescales (**Phil Jones***, LANL)
- Open Ocean: Predictability of the Atlantic Meridional Overturning Circulation (AMOC) from monthly to decadal timescales (**Jim Richman***, NRL SSC)

* Demonstration Coordinator/ Contact

Extreme Weather Events: Predictability of Blocking Events and High Impact Weather at Lead Times of 1-6 Weeks

ESPC Demonstration #1 – Improved guidance for extreme weather events related to atmospheric blocking flow (flooding, drought, persistent anomalously cold/warm conditions).

Objective:

•Apply our current understanding of the blocking process to develop and assess utility of model diagnostics to current state and forecast.

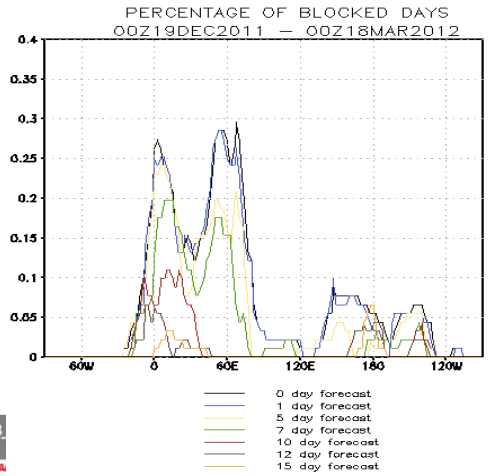
Thrusts:

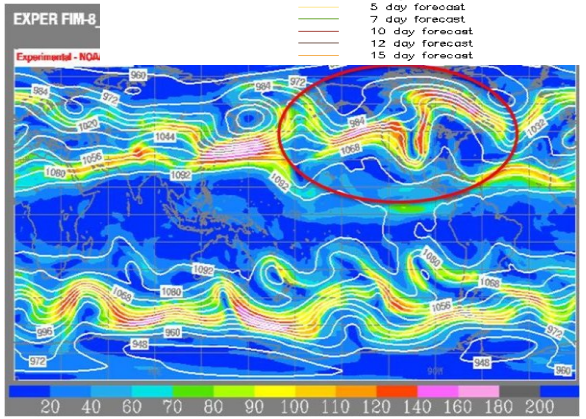
• Diagnose longer-term weather anomalies from atmospheric blocking (quasi-stationary events with duration of at least 4 days to 2+ months)

• Predict seasonal statistics (below/normal/above average conditions) at various lead times up to six months.

• Predict individual events (onset/ persistence/ cessation)

• Predict outcomes (floods, droughts, fires, extreme temps, snow).





Challenges:

•Several possible causes are postulated each with unique sources of predictability and technical approach. These include MJO interaction, TCs/extratropical transition, SSW events, and early season snow cover or melting.

Seasonal Tropical Cyclone Threat

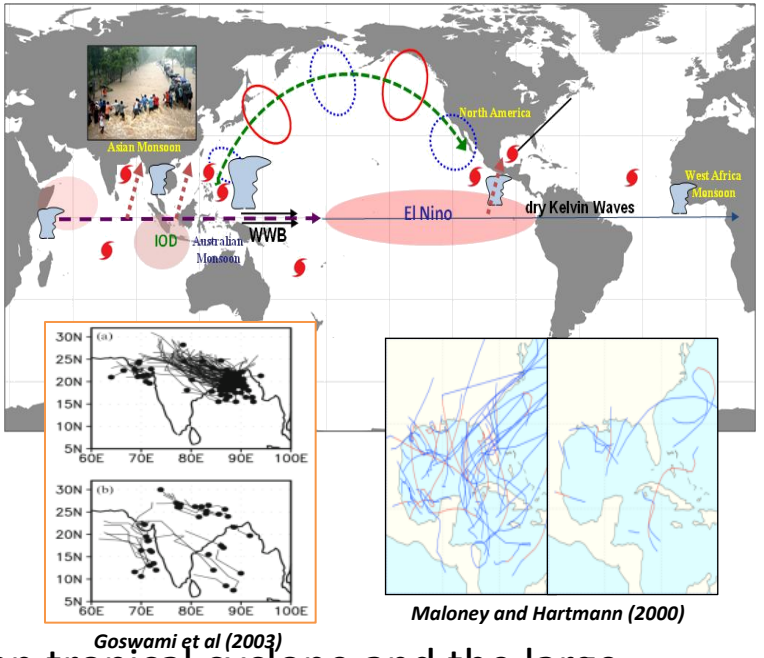
ESPC Demonstration #2 – Improved pre-season guidance of tropical cyclone seasonal track and frequency statistics as well as sub-seasonal outlooks for civil and military planning.

Objectives:

- Prediction of seasonal basin scale tropical cyclone genesis and track distributions and potential intensity.

Thrusts:

- Initial value, short range prediction improvements for track and structure.
- Boundary value, longer range probabilistic forecasts of maximum likelihood genesis, track, intensity.
- Landfall probability with the accompanying potential intensity and precipitation to support resource management, evacuation plans, ship routing, etc.



Goswami et al (2003)

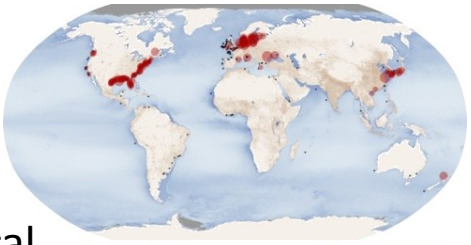
Maloney and Hartmann (2000)

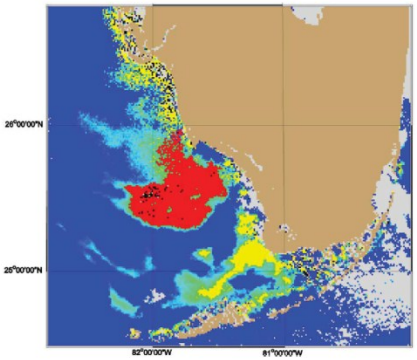
Challenges:

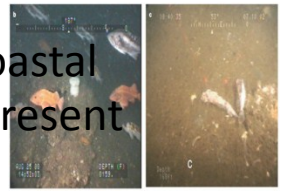
- Multi-scale convective processes and interaction between tropical cyclone and the large scale environment, and our understanding and ability to predict them vary widely from basin to basin.

Predictability of Circulation, Hypoxia, and Harmful Algal Blooms in Coastal Seas

ESPC Demonstration #4 – Establish, at a range of lead times beyond the present weather prediction scales, the forecast skill for Harmful Algal Blooms (HABs) and coastal sea hypoxia.







Objectives:

- Identify effects in global forecasts of the physical earth system that lead to conditions conducive to HABS and hypoxia.
- Communicate the global forecasts, uncertainty, and variability to physical predictions for specific regionally affected areas (downscaling).
- Predict impact of globally forecasts on local area biology/chemistry.

Thrusts:

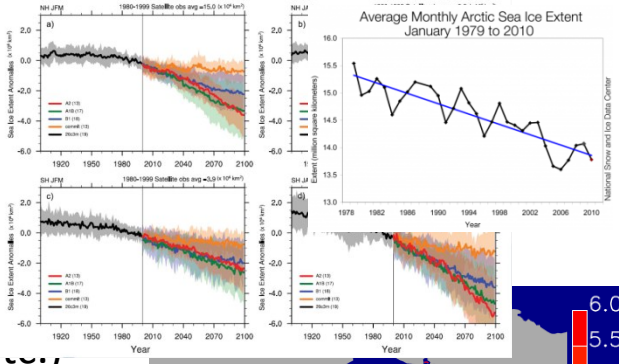
- Relevant physical earth system observations and coupled predictions.
- Local physical conditions in under-observed , high resolution regions particular to areas in which HABS and hypoxia are significant concerns.

Challenges:

- Precipitation residence times and nutrient loading changes from watershed to coastal waters is not well characterized in forecast models and difficult to efficiently represent numerically in a unified vertical coordinate system.
- Upwelling, driven by 3-dimensional air and ocean circulations, and modified by waves, bathymetry, and topography, also a major cause of HABs and hypoxia.

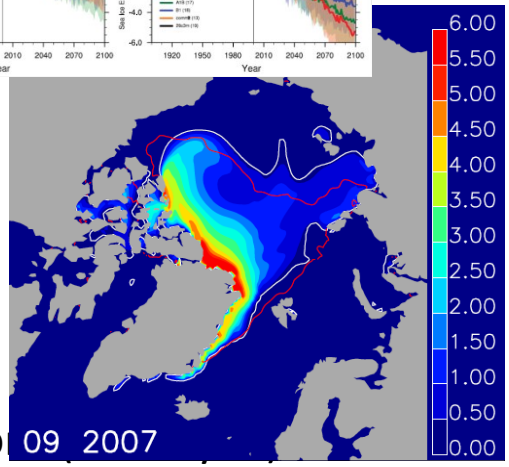
Arctic Sea Ice Extent and Seasonal Ice Free Dates

ESPC Demonstration #3 – Improved pre-season guidance of arctic sea ice changes, navigability of Arctic passages, and sub-seasonal forecasts of ice conditions for civil and military planning.



Objectives:

- Further explore limits of predictability of sea ice extent and volume, and freeze and melt onset dates, at 3-12 month leads.
- Extend prediction to regional scale areas of interest (e.g. Northern and Northwest passages).
- Extend forecast variables to other ice and atmosphere properties (ice thickness/movement, marginal ice , snow, fog, etc.)



Thrusts:

- Assessing adequacy of current sea ice models (that produce accurate hindcasts) for use as forecast models when conditions are changing.
- Predictability and suitability of different approaches at different forecast timescales as ice thins and system persistence is reduced.

Challenges:

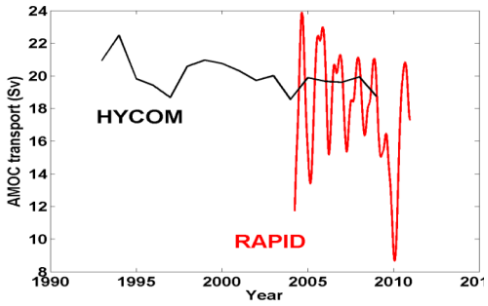
- Models reproduce historical records well when forced with observatio… sense, but the fidelity needed for Arctic shipping and other operations is poorly characterized. Predictability of thinning/single year ice and seasonal/annual conditions is uncertain.

Predictability of the Atlantic Meridional Overturning Circulation (AMOC)

ESPC Demonstration #5 – Improved representation of basin scale three dimensional ocean circulation from months to years for use in coupled climate and weather models.

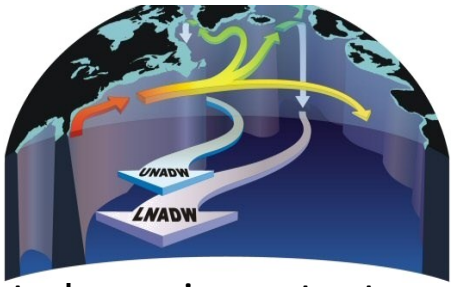
Objectives:

- Assess model representation and predictability of ocean circulation from monthly to decadal timescales using RAPID and other long duration multi-level ocean observational datasets.



Thrusts:

- Build upon the existing IPCC, ECCO, and USGCRP/CLIVAR efforts to assess basic predictability of the net transport and sensitivity to forcing in order to identify knowledge gaps and design new studies.
- Conduct high resolution coupled model simulations to look at detailed structure and air-ocean feedback.



Challenges:

- It is not clear what is predictable about the AMOC. The AMOC is thought to be an important driver for the oceanic meridional heat flux and sea surface temperature, although the link between the AMOC and climate is not clear.
- Recent climate model studies have shown a slowdown in the AMOC with possible impacts on European regional seasonal climate, ENSO and hurricanes in the Atlantic Ocean.

Participating agencies/Institutes for the demonstration systems

Participants:

- NRL
- NCEP/EMC
- NCEP/CPC
- NOAA/ESRL
- NOAA/GFDL
- NCAR
- LANL
- NASA
- Universities

Demo Workshop
13-15 Nov
ESRL, Boulder

Models:

- NOAA Weather and Climate Forecast System (GFS/CFS)
- Navy Global Environment Model (NAVGEM)
- GFDL High-resolution Atmospheric Model (HiRAM)
- NCEP NMMB
- Flow-following finite-volume Icosahedral Model (FIM/NIM)
- Model for Prediction Across Scales (MPAS)
- Community Earth System Model (CESM)
- HYCOM
- Arctic Cap Nowcast/Forecast System (ACNFS)
- Regional Arctic System Model (RASM)

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