Thoughts on Operational Regional Climate Modeling to Support ISI Time Scales and Beyond

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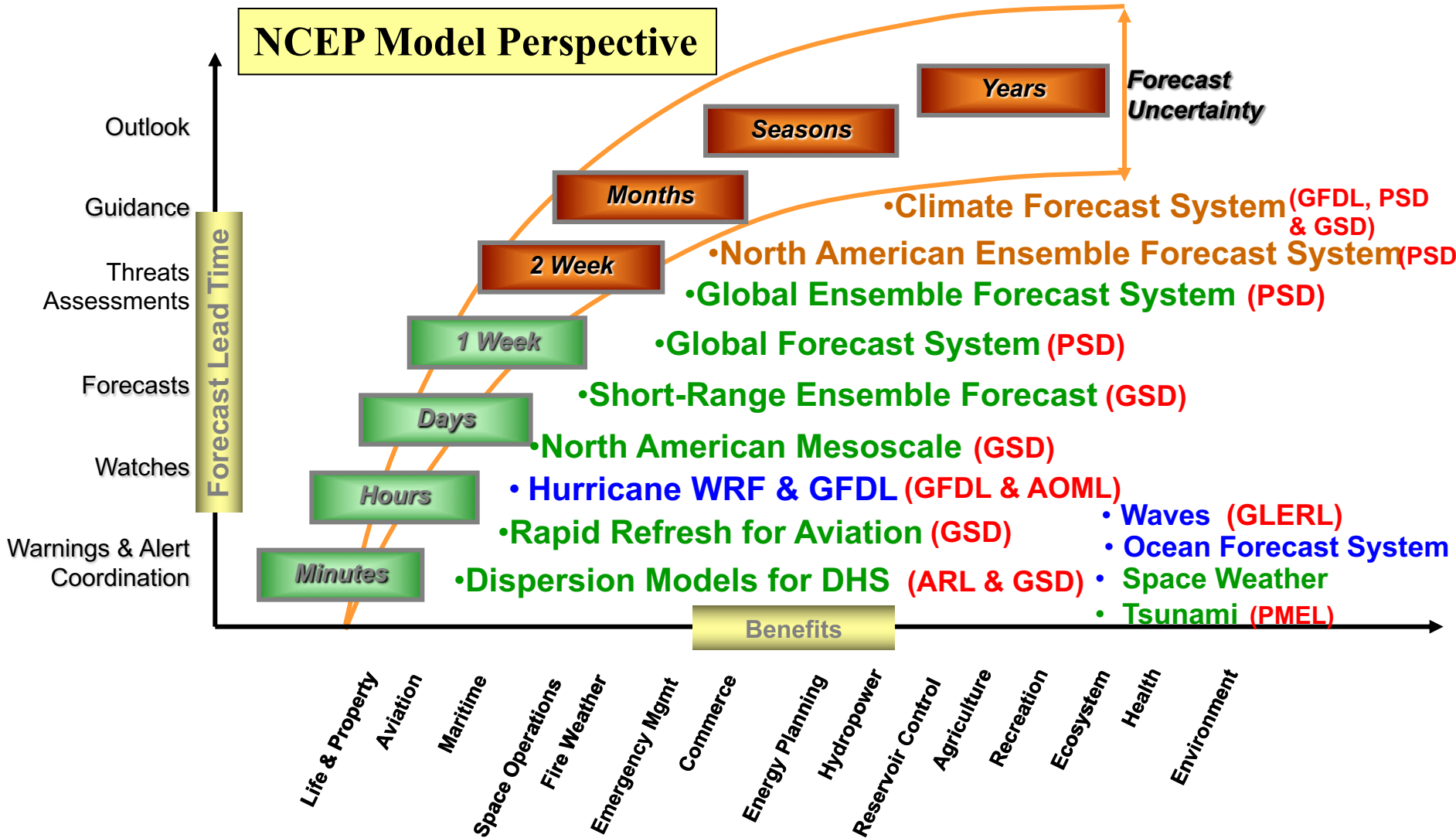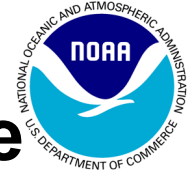**E**
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With contributions from EMC Staff……

Seamless Suite of Numerical Guidance Systems Spanning Weather and Climate

NCEP Model Perspective

Forecast Uncertainty

Forecast Lead Time (vertical axis): Outlook, Guidance, Threats Assessments, Forecasts, Watches, Warnings & Alert Coordination

Time scale boxes: Years, Seasons, Months, 2 Week, 1 Week, Days, Hours, Minutes

- **Climate Forecast System** (GFDL, PSD & GSD)
- **North American Ensemble Forecast System** (PSD)
- **Global Ensemble Forecast System** (PSD)
- **Global Forecast System** (PSD)
- **Short-Range Ensemble Forecast** (GSD)
- **North American Mesoscale** (GSD)
- **Hurricane WRF & GFDL** (GFDL & AOML)
- **Rapid Refresh for Aviation** (GSD)
- **Dispersion Models for DHS** (ARL & GSD)

- **Waves** (GLERL)
- **Ocean Forecast System**
- **Space Weather**
- **Tsunami** (PMEL)

Benefits (horizontal axis): Life & Property, Aviation, Maritime, Space Operations, Fire Weather, Emergency Mgmt, Commerce, Energy Planning, Hydropower, Reservoir Control, Agriculture, Recreation, Ecosystem, Health, Environment

NCEP Production Suite Supports NOAA/NWS Operational Requirements

NWS Government Performance and Results Act Goals

Boxes marked with a "X" indicate where a Data Assimilation and Modeling numerical guidance system directly supports a NWS GRPA Goal

Existing GPRA
Planned GPRA

NWS GPRA Goals	NCEP Production Suite Numerical Guidance Systems														
	HYSPLIT	RAP	NAM	SREF	GFS	GEFS	NAEFS	CFS	HYCOM	WW3	Wave Ensemble	Tsunami	HWRF	GFDL	ENLIL
Flash Flood Warnings Lead Time		X	X	X	X	X	X								
Flash Flood Warnings Accuracy		X	X	X	X	X	X								
Marine Wind Speed Forecast Accuracy			X	X	X	X	X		X						
Marine Wave Height Forecast Accuracy					X	X			X	X	X				
Aviation Forecast IFR Accuracy	X	X	X												
Aviation Forecast IFR False Alarm Ratio		X	X												
Winter Storm Warnings Lead Time		X	X	X	X	X	X								
Winter Storm Warnings Accuracy		X	X	X	X	X	X								
IMET Fire Response Time			X												
Precip Forecast Day 1 Threat Score			X	X	X	X	X								
US Seasonal Temp Forecast Skill								X							
Hurricane Forecasts Track - 48 hr Error					X	X							X	X	
Hurricane Forecasts Intensity - 48 hr Error													X	X	
Tsunami Message Response Time												X			
Geomagnetic Storm Forecast Accuracy															X
Geomagnetic Storm Forecast False Alarm Ratio															X

Requirements for the NOAA Climate Forecast System

➢ **Service and Societal:**

- ■ **Directly supports the US Seasonal Temperature GPRA Goal**

- ■ **Supports climate monitoring, predictions and projections globally and regionally**

- ■ **Inform adaptation planning and decision making**

➢ **Scientific Understanding:**

- ■ **Advance understanding of climate variability and change and their impact on the Earth system**

- ■ **Facilitate research on the interplay between climate and weather (including high-impact weather events)**

- ■ **Develop process-level understanding of climate forcing mechanisms and interactions in a variable and changing climate system**

Improved WH MJO Signal in CFSv2

CFS Forecast Skill (%) of WH-MJO Index 1999-2009

CFSv1

50%

8-day lead
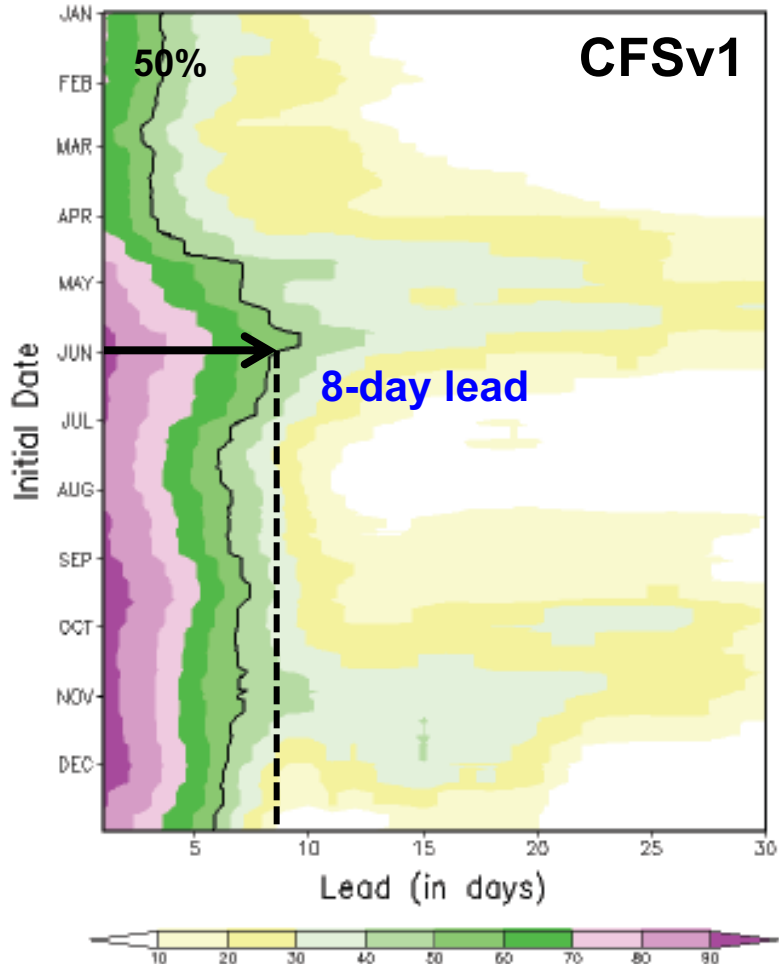
CFSv2 Forecast Skill (%) of WH-MJO Index 1999-2009

CFSv2

50%

18-day lead
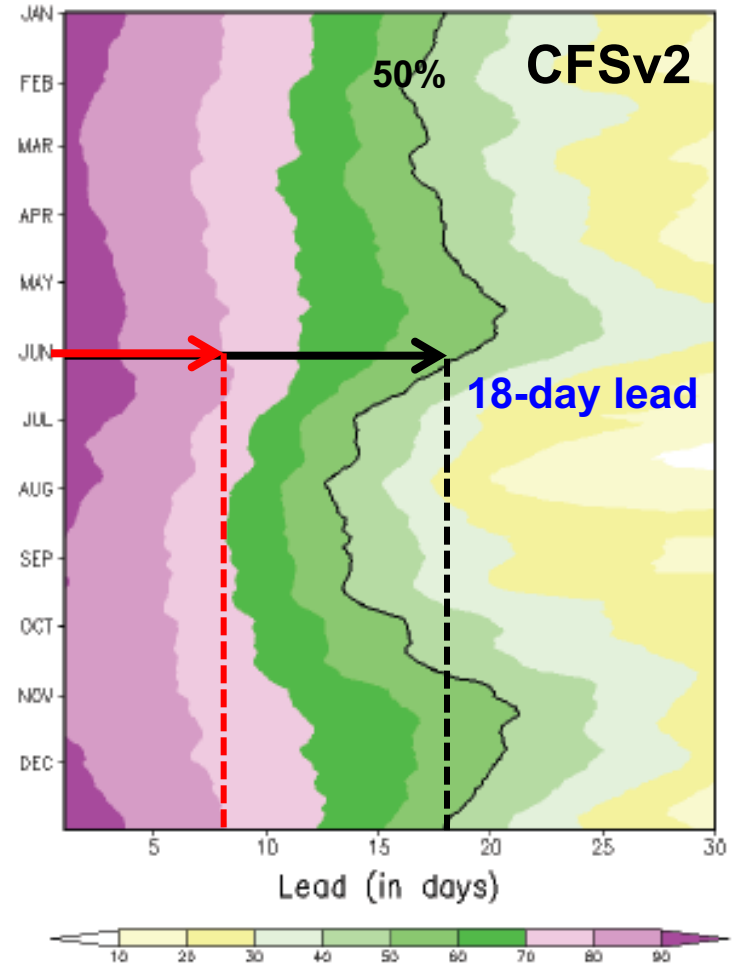
National Multi-Model Ensemble (NMME) Project

- **Facilitated by the NOAA Climate Test Bed**

- **Intellectual and programmatic interactions between NCEP and CPO**

- **NMME as a Modeling Test-Bed**
  - **Seasonal to Interannual Time Scales**
  - **Predictability Research: e.g., South East US Drought**
  - **Model Evaluation and Development**
  - **Initialization Strategies: e.g., Land, Ocean**
  - **Fosters interaction between research and operations**
  - **Provides experimental guidance products to Climate Prediction Center**

- **Participating Organizations:**
  - **University of Miami - RSMAS**
  - **National Center for Atmospheric Research (NCAR)**
  - **Center for Ocean---Land---Atmosphere Studies (COLA)**
  - **International Research Ins7tute for Climate and Society (IRI)**
  - **Canadian Meteorological Centre (Soon)**
  - **NASA – GMAO**
  - **NOAA/NCEP/EMC/CPC**
  - **NOAA/GFDL**
  - **Princeton University**
  - **University of Colorado (CIRES)**

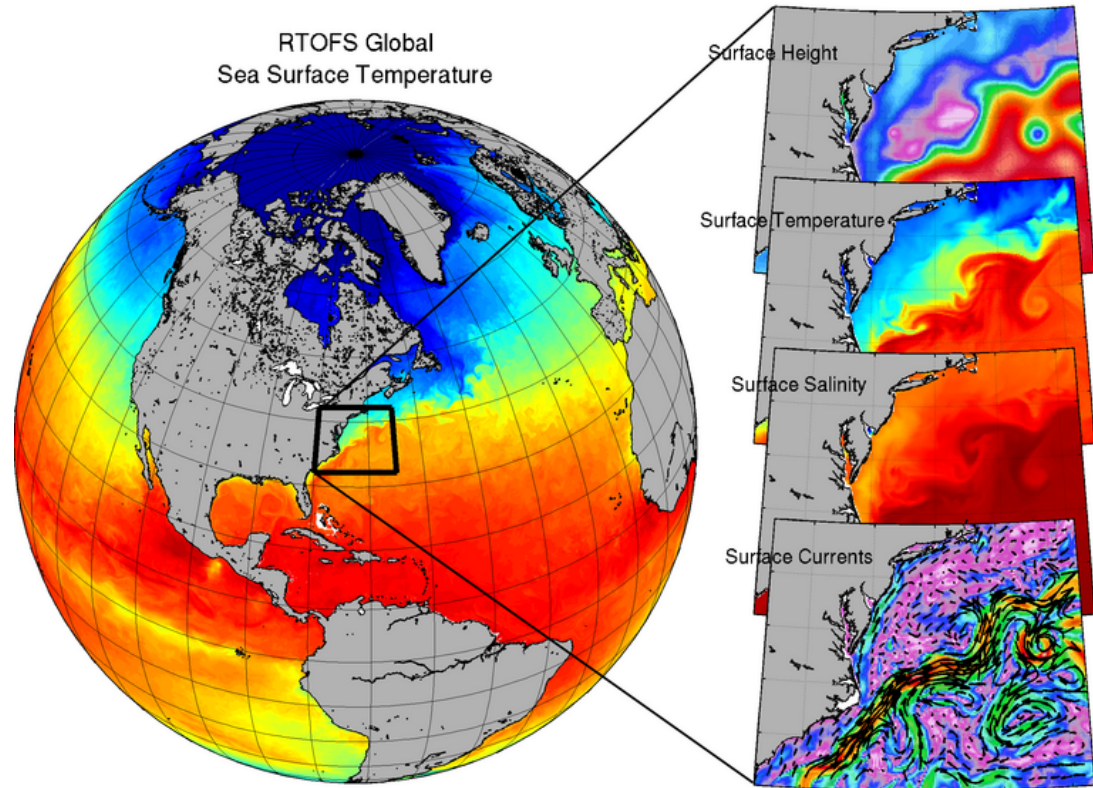**Data are available at: http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/**

Real Time Ocean Forecast System

Implemented 24 October 2011

- RTOFS Global is the first global eddy-resolving ocean forecast system at NOAA/NCEP

- 1/12 degree HYCOM (HYbrid Coordinate Ocean Model)

- 6-day forecasts initialized at 00 UTC

- 32 vertical hybrid layers (isopycnal in the deep, isolevel in the mixed layer and sigma in shallow waters)

- Initialization: MVOI scheme (NCODA) developed by the US Navy

- Forced with the GFS surface fluxes of radiation, precipitation and momentum.

RTOFS Global
Sea Surface Temperature

Surface Height

Surface Temperature

Surface Salinity

Surface Currents

Thanks to the NAVY for partnering with NOAA and making HYCOM available

NEMS GFS/GOCART Aerosol
Scheduled Implementation Q4FY12

Experimental (non-operational)

- Executable compiled from NEMS trunk code repository

- 120-hr dust-only forecast

- Once per day (00Z)

- 3-hourly products: 3d distribution of dust aerosols (5 bins from 0.1 – 10 μm)

- Automatic output archive, post processing and web update since June 11, 2011

- Same physics and dynamics as operational GFS with the following exceptions:

  – Lower resolution (T126 L64)

  – Use RAS with convective transport and tracer scavenging

  – Aerosol-radiation feedback is turned off

2011061700 00hr Fcst ctrl Column AOD at 550nm
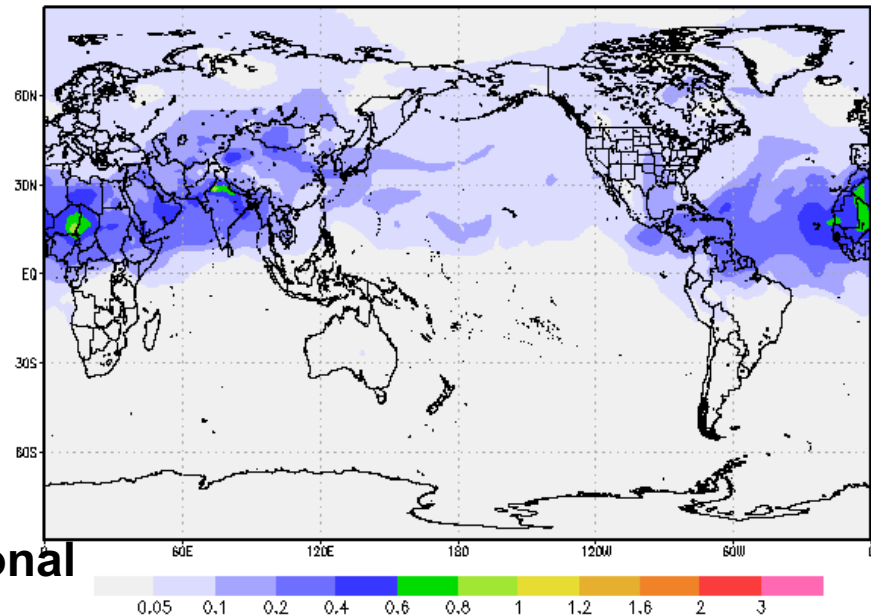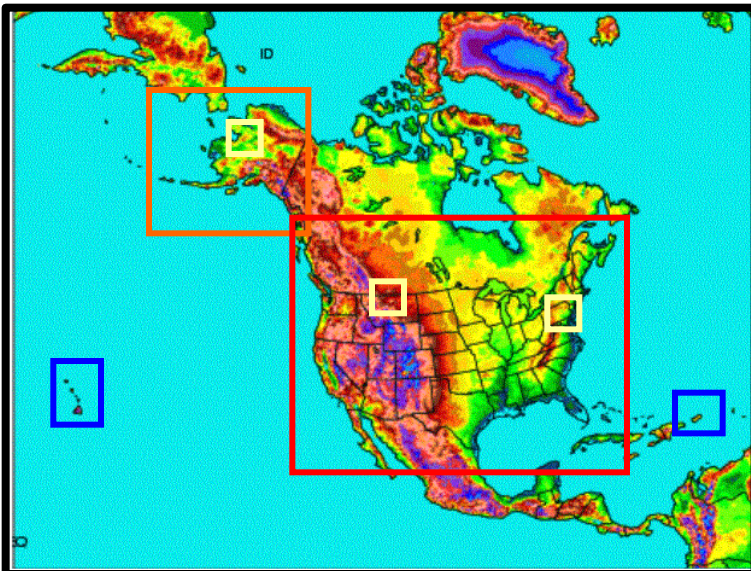
Column AOD @ 550nm

Operational Mesoscale Modeling for CONUS:

North America Model (NAM)

- *Implemented 18 October 2011*
- **NEMS based NMM**
- **Outer grid at 12 km to 84hr**
- **Multiple Nests Run to ~48hr**
  - **4 km CONUS nest**
  - **6 km Alaska nest**
  - **3 km HI & PR nests**
 - **1.3km DHS/FireWeather/IMET**

Rapid Refresh (RAP)

- *Implemented 1 May 2012*
- **WRF-based ARW**
- **Use of GSI analysis**
- **Expanded 13 km Domain to include Alaska**
- **Experimental 3 km HRRR**

WRF-Rapid Refresh domain – 2010

Original CONUS domain

Experimental 3 km HRRR
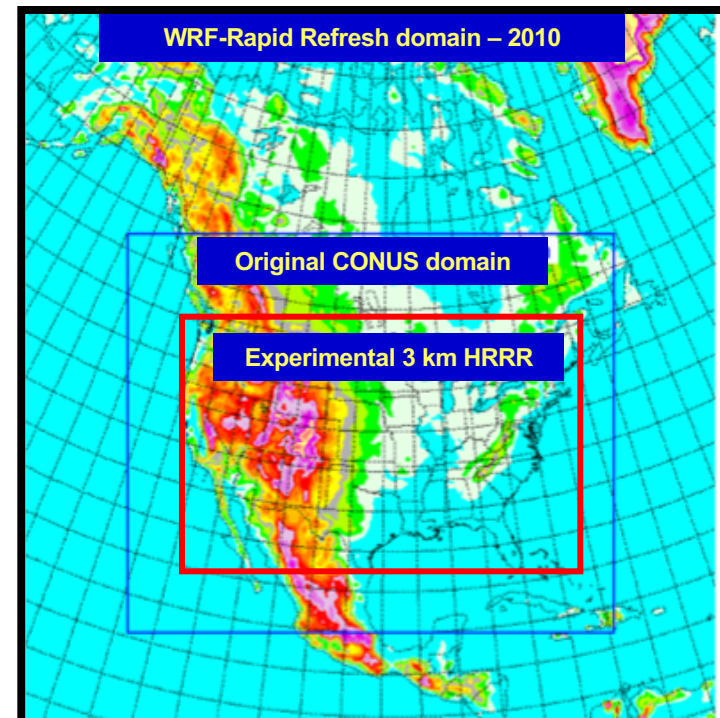
Is a Unified Modeling Approach Possible at NOAA?
Global, CONUS & Hurricane

84-hour forecasts from 12Z 17 Sep 2010
Lowest model layer winds (m/s).
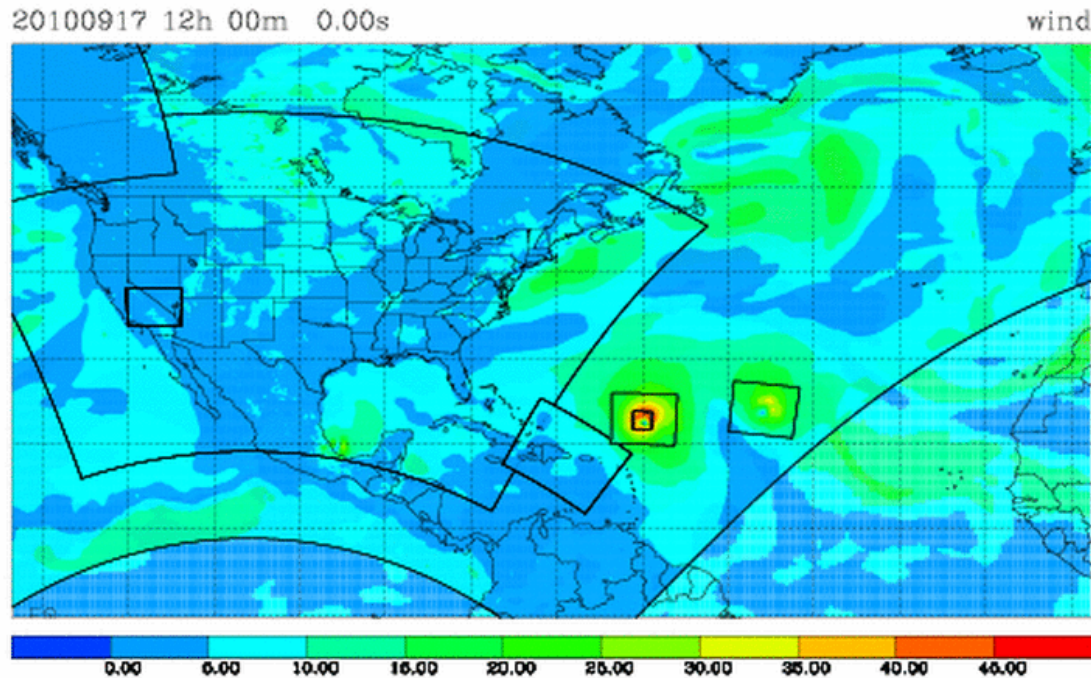
> **Global NMM-B in the outermost domain**
> **NAM/NMM-B inside the global domain**
> **CONUS nest inside the NAM**
> **Moving nests of Hurricanes Igor and Julia**
> **Configuration within a single executable**

Looking Forward....

➢ **Identify and document customer expectations for next generation CFS**

➢ **NOAA must build plan to meet current and emerging customer requirements—science based approach**

➢ **Must include reanalysis and reforecast components**
- **Model—land, atmosphere, ocean, ice**
- **Analysis—observations, assimilation, models**
- **Monitoring**

➢ **Community requests inclusion in the development process**
- **Intellectual**
- **Access to information (data)**
- **Accountability**

NOAA Center for Weather and Climate Prediction (NCWCP) Status
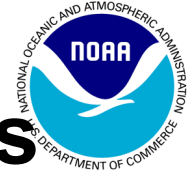
A.K.A.—the new building….

- **Four-story, 268,762 square foot building in Riverdale, MD will house 800+ Federal employees, and contractors**
  - **5 NCEP Centers (NCO, EMC, HPC, OPC, CPC)**
  - **NESDIS Center for Satellite Applications and Research (STAR)**
  - **NESDIS Satellite Analysis Branch (SAB)**
  - **OAR Air Resources Laboratory**

- **Includes 40 spaces for visiting scientists**

- **Includes 465 seat auditorium & conference center, library, deli, fitness center and health unit**
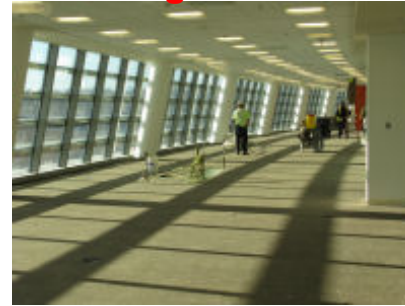
Questions Welcome

Advancement of Climate Forecast System
Implemented 30 March 2011

Attribute	CFSv1 (2004-2011)	CFSv2: March 2011
Analysis Resolution	200 km	27 km
Atmosphere model	200 km/28 levels Humidity based clouds	100 km/64 levels Variable CO_2 AER SW & LW radiation Prognostic clouds & liquid water Retuned mountain blocking Convective gravity wave drag
Ocean model	MOM-3: 60N-65S 1/3 x 1 deg. Assim depth 750 m	MOM-4 fully global ¼ x ½ deg. Assim depth 4737 m
Land surface model (LSM) and assimilation	2-level LSM No separate land data assim	4 level Noah model GLDAS driven by obs precip
Sea ice	Climatology	Daily analysis and Prognostic sea ice
Coupling	Daily	30 minutes
Data assimilation	Retrieved soundings, 1995 analysis, uncoupled background	Radiances assimilated, 2008 GSI, coupled background
Reforecasts	15/month seasonal output	25/month (seasonal) 124/month (week 3-6)

Dealing with Interoperability in a Operational Environment

➢ **The NOAA Environmental Modeling System (NEMS)**
  - **Supported by NOAA OCIO HPCC and CPO Global Interoperabilty Program**

➢ **NOAA contribution to the National Unified Operational Prediction Capability (NUOPC) with Navy and Air Force**

➢ **Provides a common superstructure for NCEP Production Suite components**

➢ **Reduce overhead costs and provide a flexible infrastructure in the operational environment**
  - **Concurrent nests**
  - **NAM executed concurrent with GFS**
  - **Stochastic ensemble generation**
  - **Coupled atmosphere/ocean/land/ice systems becoming a NOAA requirement**

➢ **Modularize large pieces of the systems with ESMF components and interfaces—concurrent execution**