Command Overview

O-SPS12

This briefing is UNCLASSIFIED / FOUO

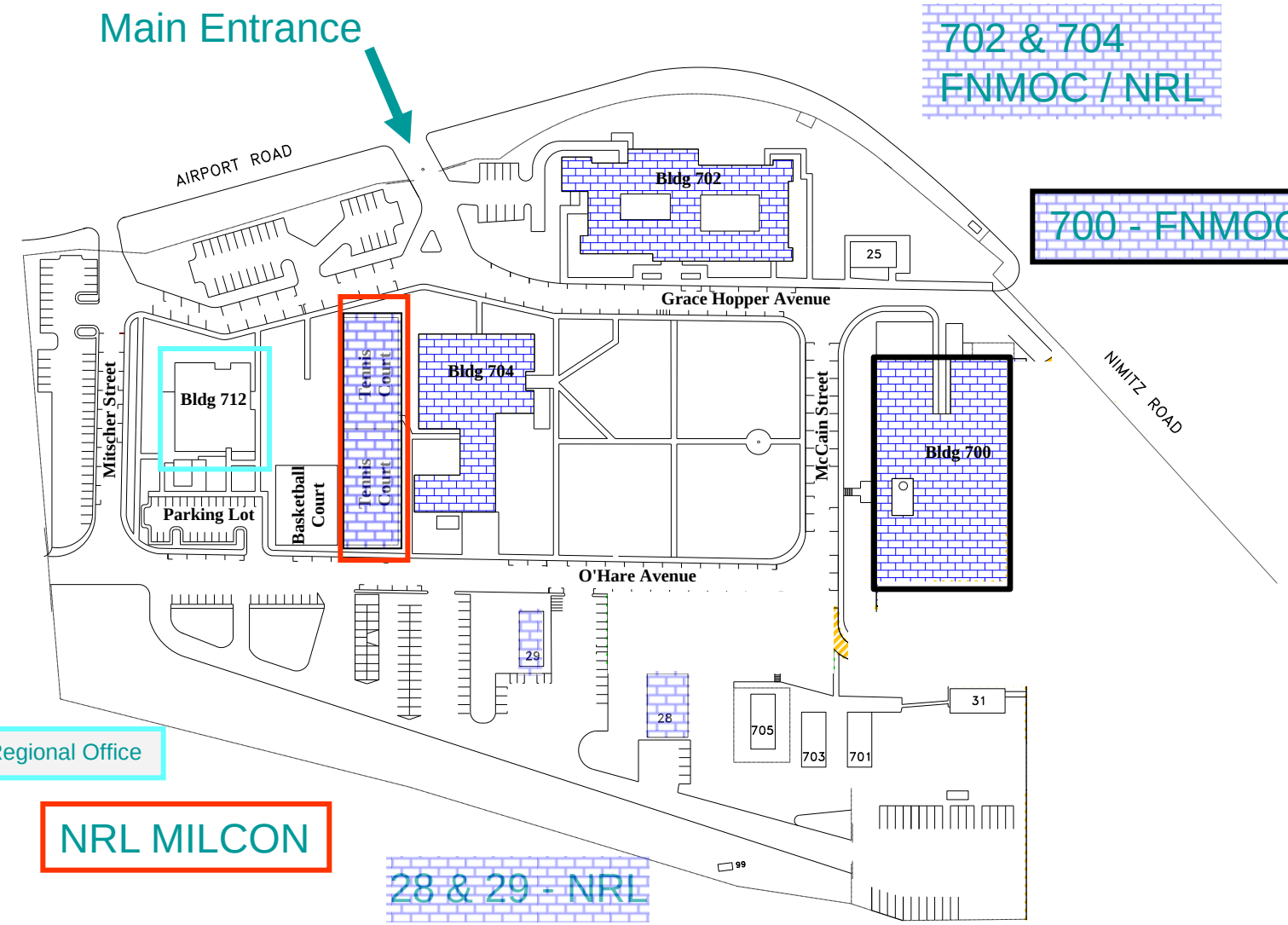
LT Stan Rogers
Fleet Liaison Officer

Fleet Numerical…

- A World recognized Numerical Weather Prediction (NWP) Center…
  - With High Performance Computing (HPC) at all levels of classification
  - Is the only HPC center modeling the Global Atmosphere to DoD Information Assurance (IA) Standards
  - Provides climatological support to Naval Operations
  - Executes Submarine Weather (SUBWEAX) support globally
  - Co-located with NRL and NWS and near NPS

…enabling fleet safety & decision superiority

FNMOC – NRL – NWS Annex



Providing the Foundation for Fleet Safety…

Maritime Forecasting

Safety of Ships at Sea

- *Two Fleet Weather Centers located in Norfolk, VA and San Diego, CA.*
- *Provide 100+ forecasts daily to ships underway.*
- *Over 1,000 ship diverts provided annually to avoid hazardous weather events.*

Aviation Forecasting

Forecasts for Naval Aviation Assets Worldwide

- *Automated Wide Area Alert Network - single focal point for hazardous weather impacts to Navy installations.*
- *37,000 aviation forecasts issued for activities at 22 airfields located in the U.S. 7 airfields overseas.*

… At Sea and Ashore

Sea

- *Global deployments in support of Operations in every theater*
- *Anti-piracy support in Horn of Africa*
- *Counter-drug interdiction efforts in Caribbean*

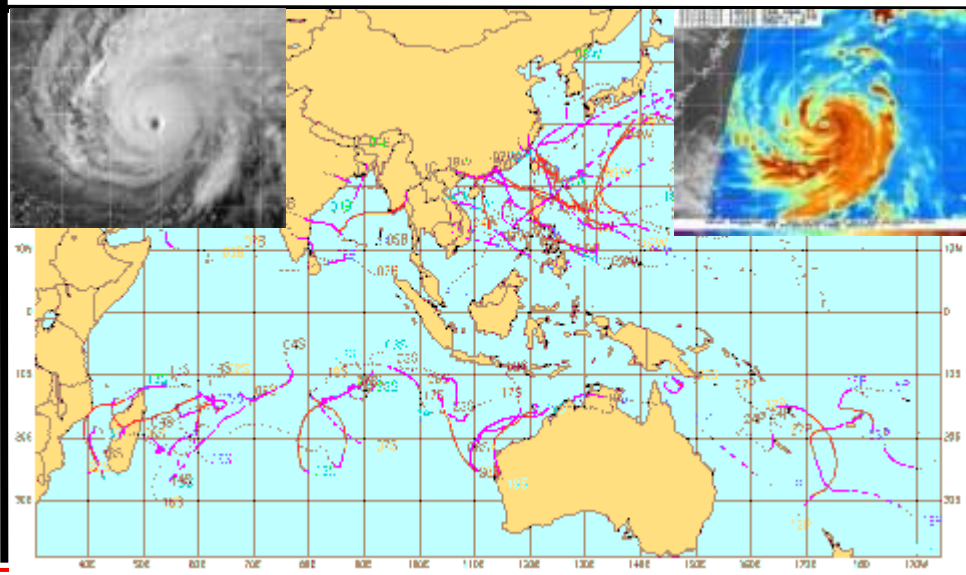
Ashore

- *Fleet Weather Centers provide resource protection role*

Joint Typhoon Warning Center (JTWC)

Tropical cyclone forecasts and warnings for DoD and US Gov't activities in Pacific and Indian Oceans

- *~90% of world's tropical cyclones fall under JTWC. The rest falls under NHC in Miami*
- *60 Tropical cyclone advisories per year*
- *Over 50 years of operational excellence*



Alignment

Chief of Naval Operations

Commander, U. S. Fleet Forces Command

Commander, Naval Meteorology and Oceanography Command

- **Naval Oceanographic Office (NAVOCEANO) Stennis Space Center, MS**
- **Fleet Numerical Meteorology and Oceanography Center (FNMOC) Monterey, CA**
- **U.S. Naval Observatory (NAVOBSY) Washington, D.C.**
- **Naval Oceanography Operations Command (NOOC) Stennis Space Center, MS**
- **Naval Meteorology and Oceanography Professional Development Center (NMOPDC) Gulfport, MS**

History

- 1958: Navy Numerical Weather Problems (NANWEP) Group established at Suitland, MD
- 1959: Moved from MD to NPS Monterey
- 1961: Fleet Numerical Weather Facility (FNWF) established
- 1974: The command moved from NPS to present site
- 1993: Adopted the present name of Fleet Numerical Meteorology & Oceanography Center (FNMOC)
- 2005: Naval Meteorology & Oceanography Realignment under CUSFFC
- 2008: Assigned mission of 24x7 Global Submarine Weather Support (SUBWEAX) for USN and Allied submarines
- 2009: Became a key member of the new Information Dominance Corps (IDC)
- 2010: MILCON – 14.3K sq ft new/upgraded Computer Operations Center and SCIF
- 2011: Celebrated the 50th Anniversary of Fleet Numerical and christened the new Computer Operations Center and SCIF

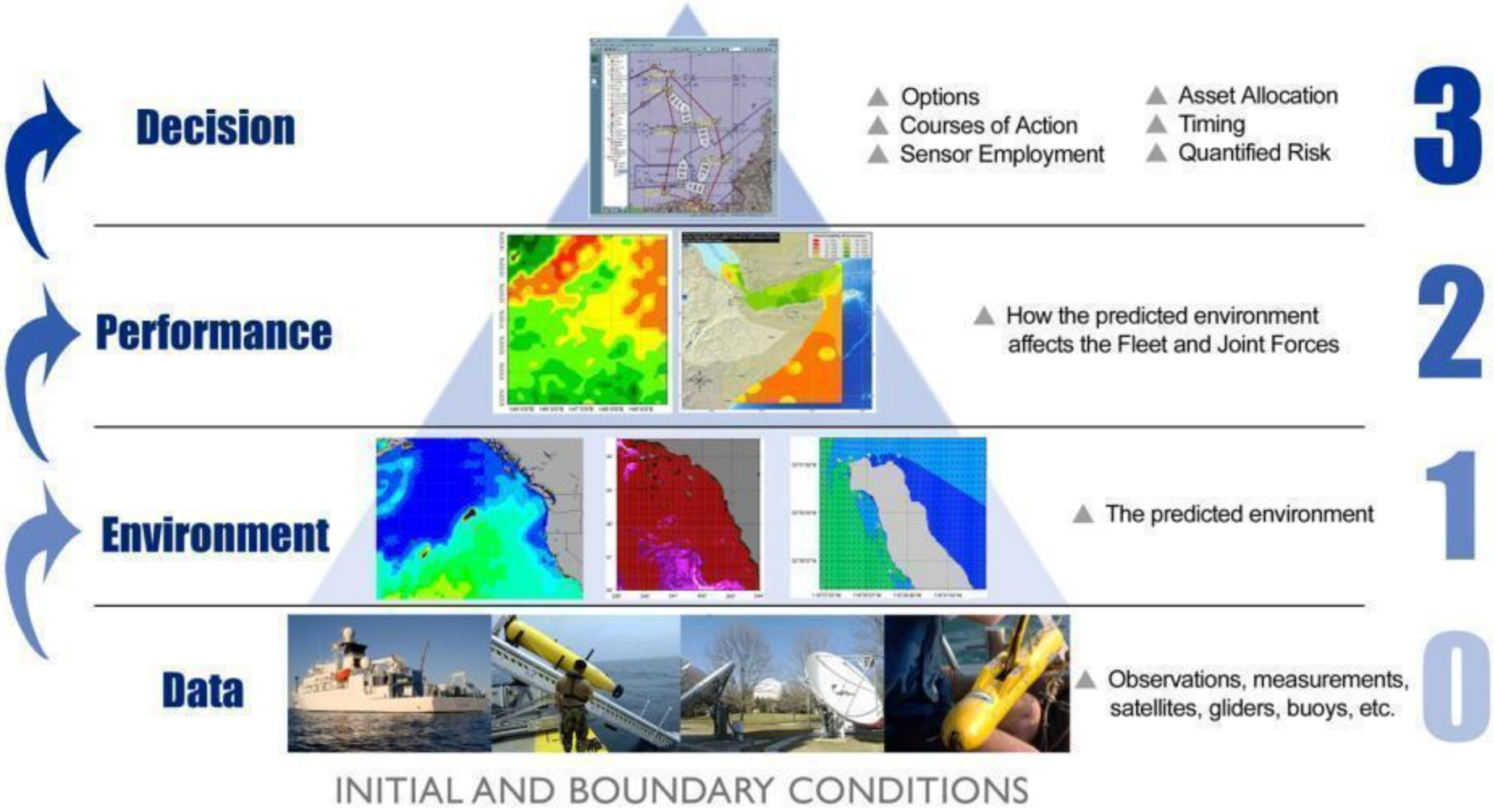
Organizational Profile

- Highly technical, educated, and warfare experienced workforce consisting of military, civilians, and contractors
  - 14 Officers
    - Designators: 1800, 1820, 1810 (Jul12), 1110
    - 6% PhD, 50% MS Degree
    - 100% of IDWO eligible are qualified
    - USAF Weather Officer (PEP)
  - 17 Enlisted
    - All Aerographer's Mates (AG)
    - 65% with Advanced Navy Specialty Training
    - 23% EIDWS, 77% Warfare qualified
  - 127 FTE & 40 Contractors:
    - Predominantly Physical Science and IT specialties (Meteorology, Oceanography, Computer Sciences)
    - 3% PhD, 23% MS Degree, 34% BS Degree
- TOA: ~$20M OMN, ~$4M OPN

Battlespace On Demand

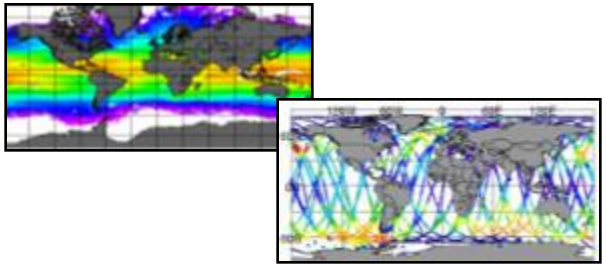
Linking Forecasts to Decisions

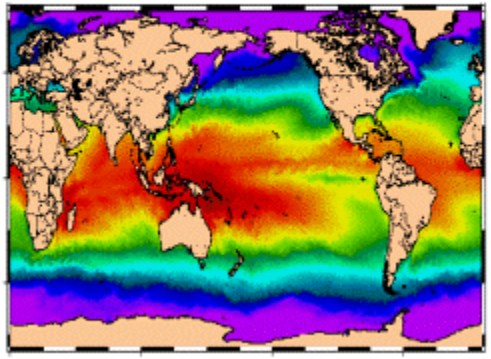
Decision Superiority: Making better decisions faster than the adversary

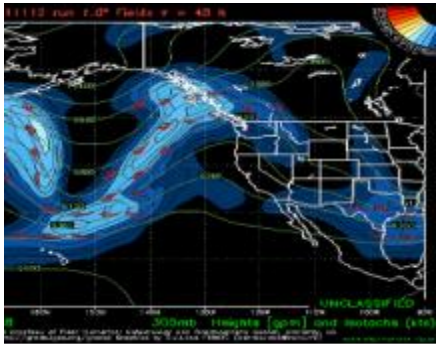


Ocean and Atmosphere Circulation Modeling

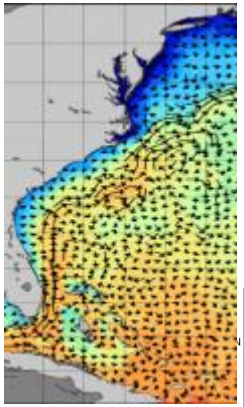
Global

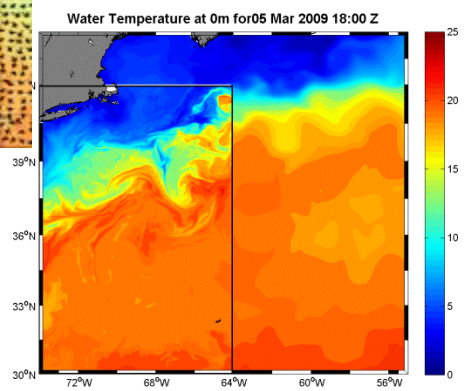


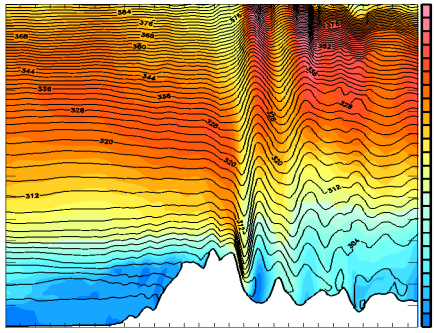




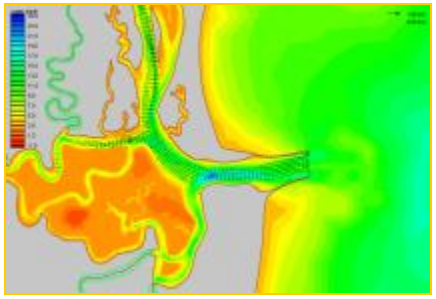
Regional

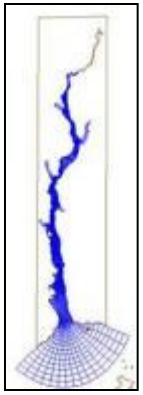


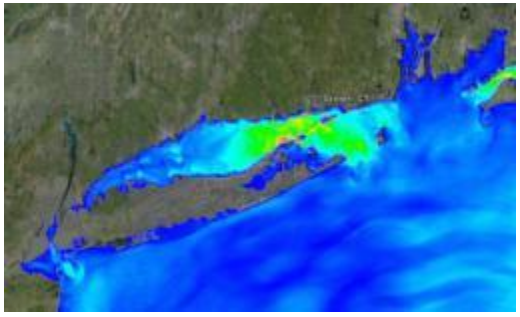




Local





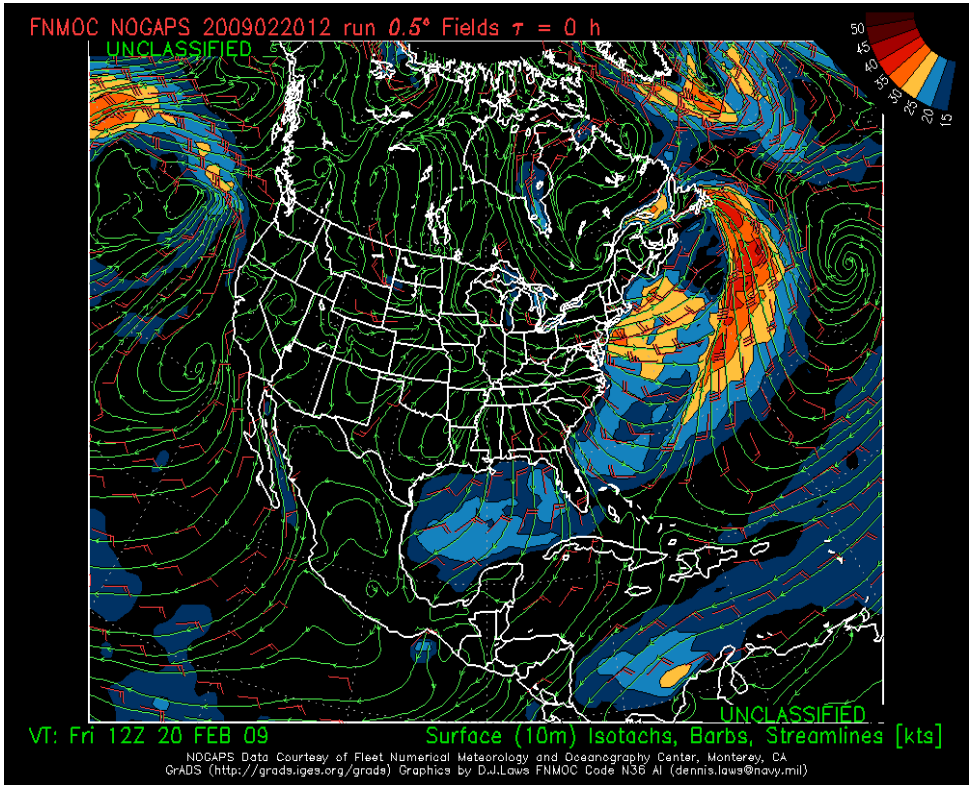


Models Overview

- **NOGAPS** – Navy Operational Global Atmospheric Prediction System; ~40 km resolution, 42 levels; global spectral model. At the center of FNMOC production.
- **COAMPS** – Coupled Ocean/Atmosphere Mesoscale Prediction System; regional mesoscale model, multi-nested to ~3 km resolution 45 levels. Driven by NOGAPS.
- **GFDN** – Navy implementation of the GFDL TC model; only moveable-nest TC model operational in all ocean basins (critical model for extended TC forecasts). Driven by NOGAPS.
- **WW3** – WaveWatch III spectral ocean wave model; global and regional implementations. Driven by NOGAPS and COAMPS.
- **EFS** – NOGAPS-based global 20-member 16-day Ensemble Forecast System; includes 20-member global WW3 ensemble.
- **NAAPS** – Navy Atmospheric Aerosol Prediction System; only operational global aerosol model. Atmospheric optical properties output feeds Target Acquisition Weapons Software (TAWS). Driven by NOGAPS.

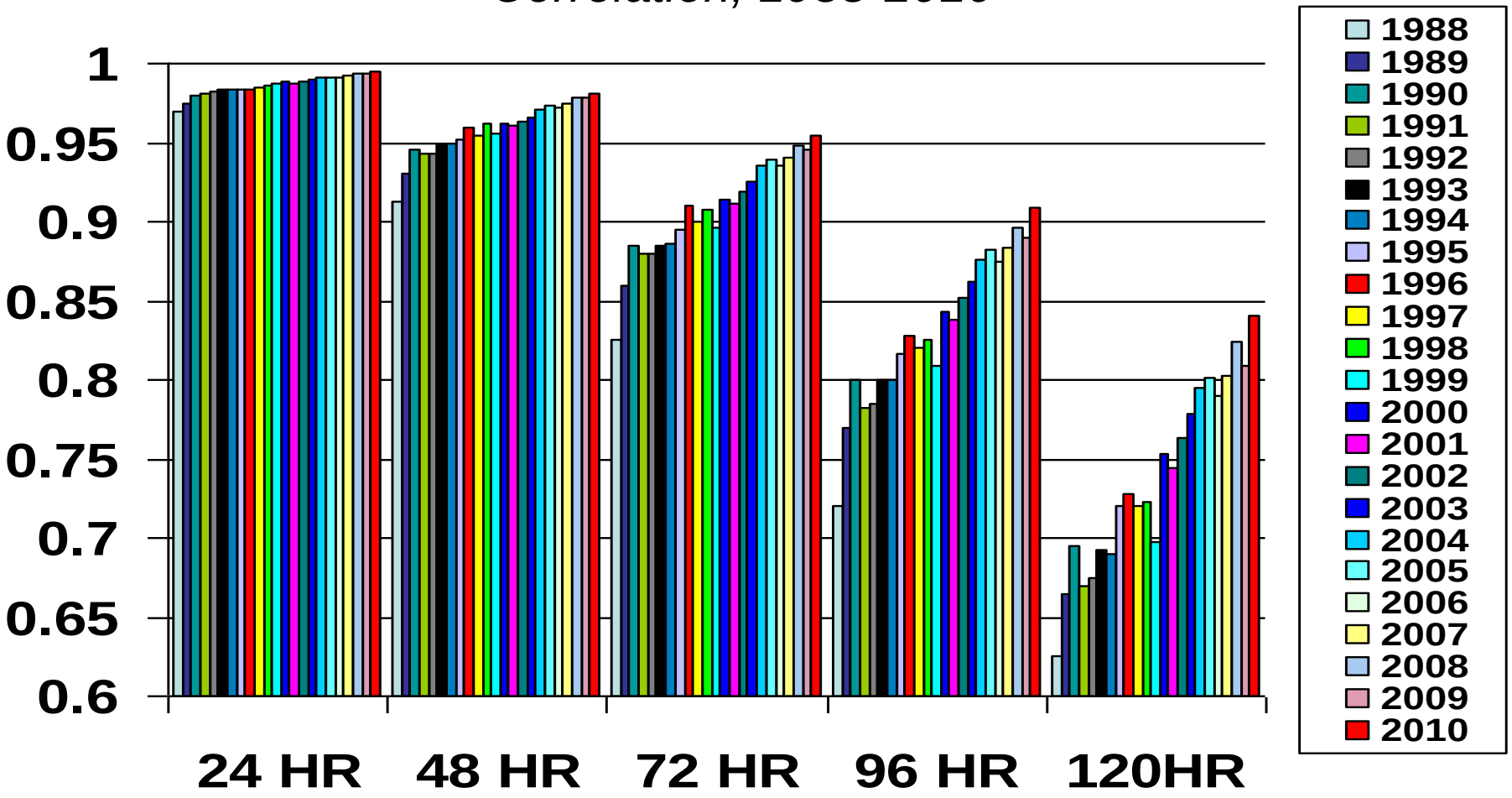
NOGAPS

- At the center of FNMOC production
- Provides lateral boundary conditions and/or surface forcing for every other forecast model
- Global hydrostatic spectral model
- Resolution: ~40km
- Runs 4 times per day with forecasts up to 180 hours



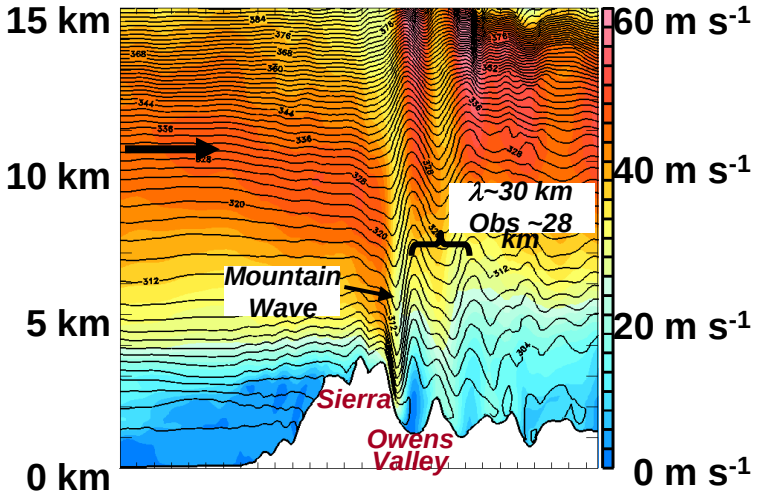
NOGAPS Skill Over Time

NOGAPS NHEM 500 mb Height Anomaly Correlation, 1988-2010



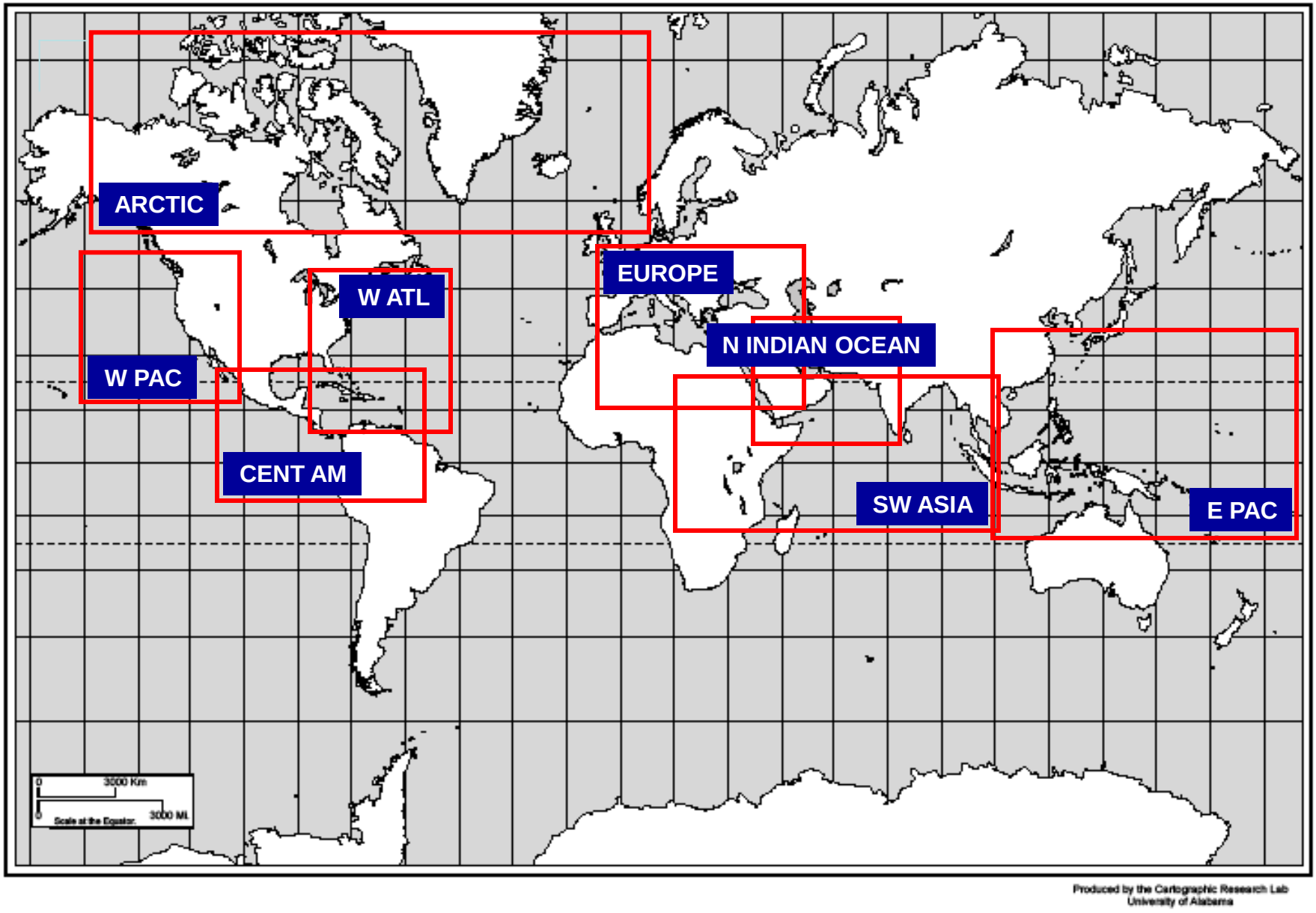
Regional Model

- Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS™)
  - High-resolution support to operations
  - Classification levels up to TS/SCI
  - Multi-nested model with resolutions down to ~1.5 km with 45 vertical levels
  - Run for many areas, multiple times per day
  - Forecasts typically to 72 hours
  - Optimized for coastal prediction through close coupling with ocean models
  - Coupled with littoral ocean models
  - Developed and supported by NRL
  - Re-locatable in *minutes* for on-demand operations support (COAMPS-OS)



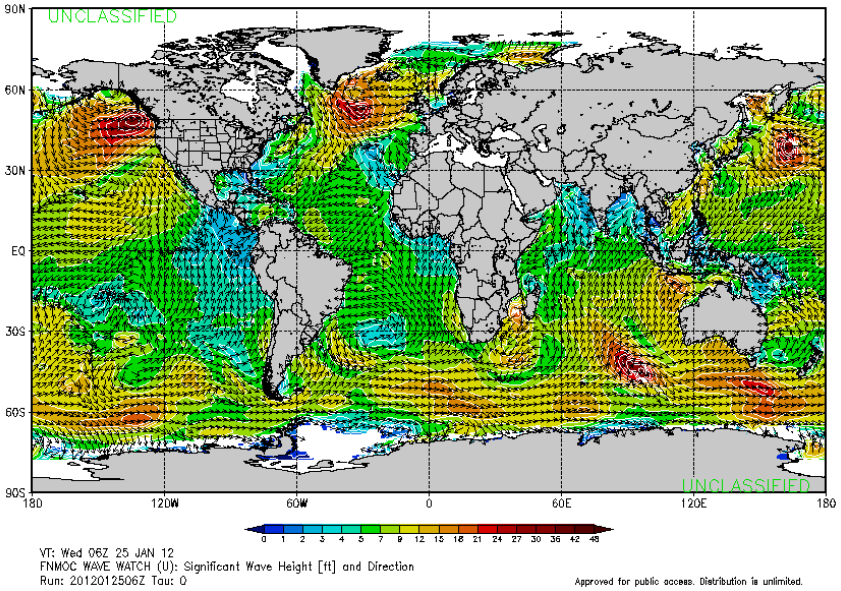
Cross section of temperature and wind speeds from COAMPS showing mountain waves over the Sierras

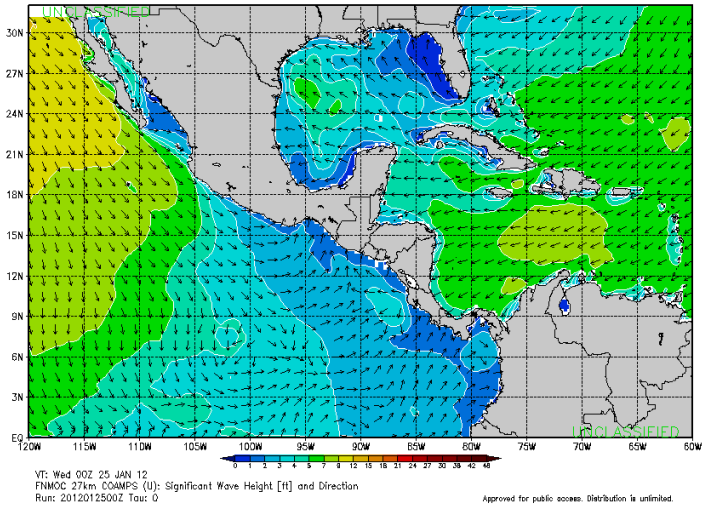
COAMPS Regions



Wave Watch 3

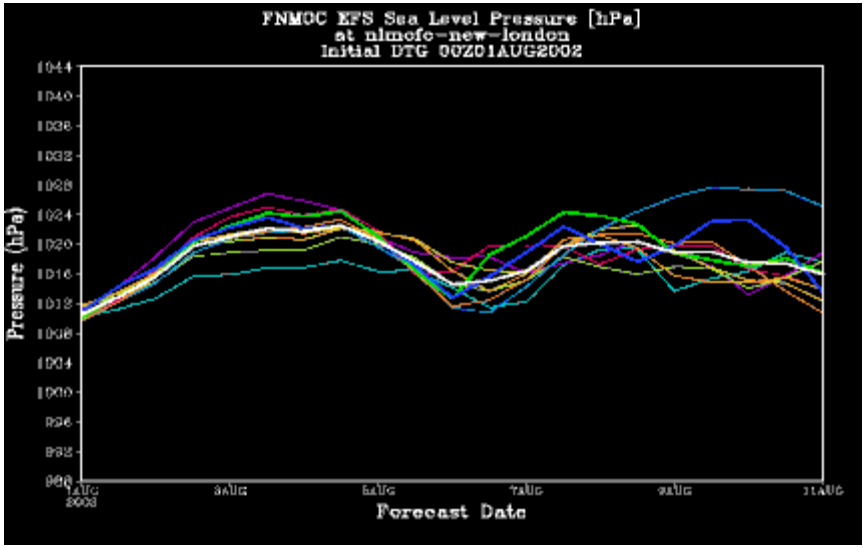
- Global model runs at ½ degree resolution
- Forced by NOGAPS out to 180 hours
- Regional WW3 forced by COAMPS ~22km
- 16 Member global EFS runs at 1 deg resolution
- Version 3.12 implemented in Oct. 2008
- Assimilation of altimetry data since May 2010
- Integration into COAMPS On Scene for rapid implementation.

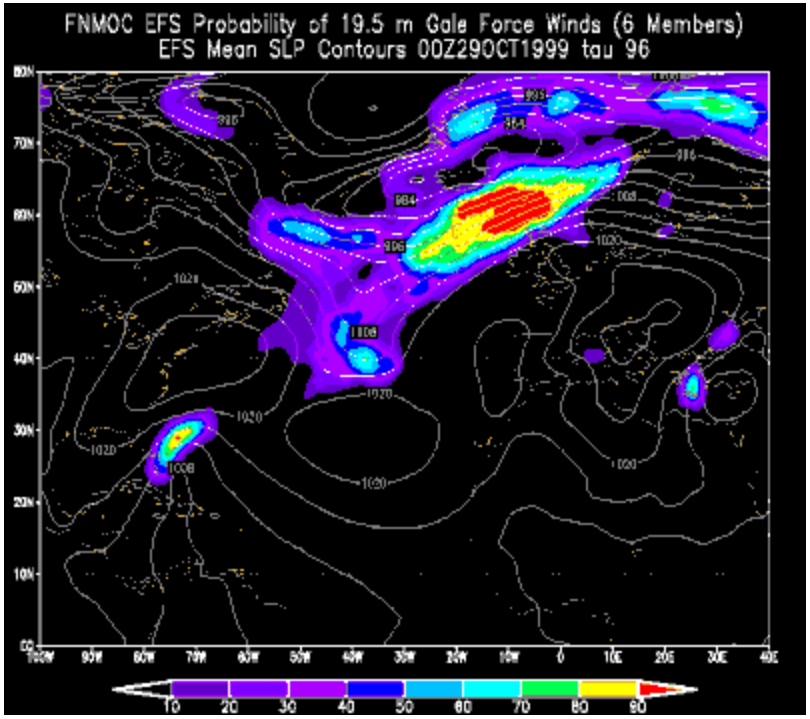




Ensemble Forecast System (EFS)

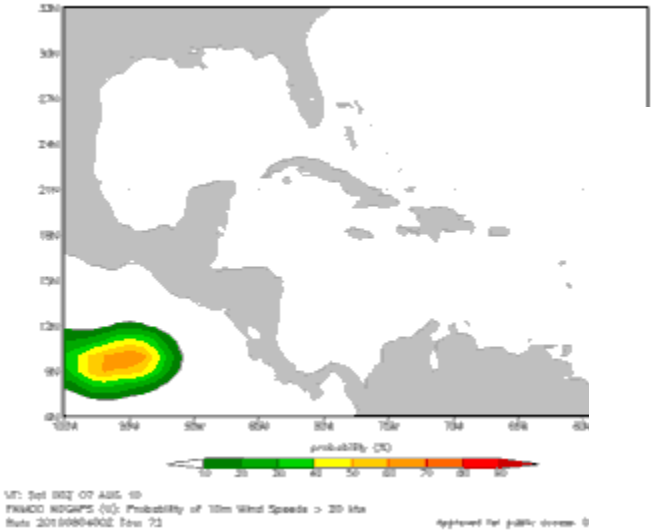
- Based on NOGAPS and WW3
- 20 Members; 16 day forecasts



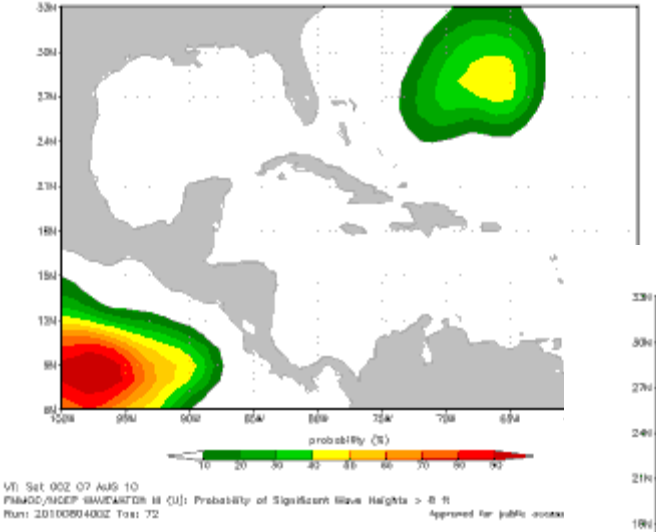


DEEPWATER HORIZON Support Example

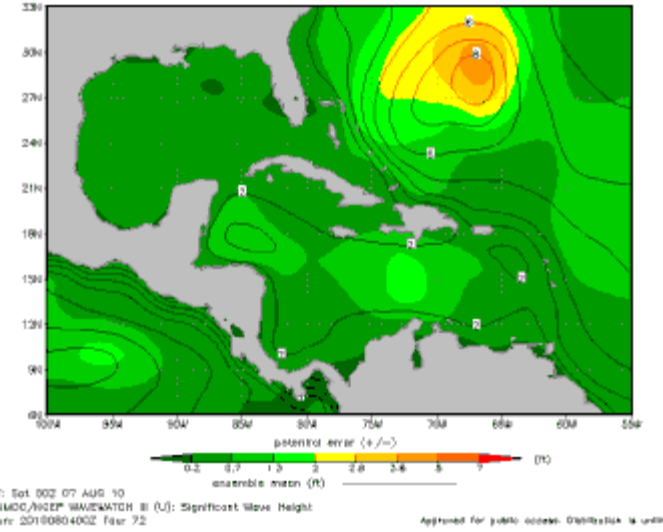
Probability of 10 m winds > 20 kt
72 hours



Probability of Sig Wave Height > 8 ft
72 hours



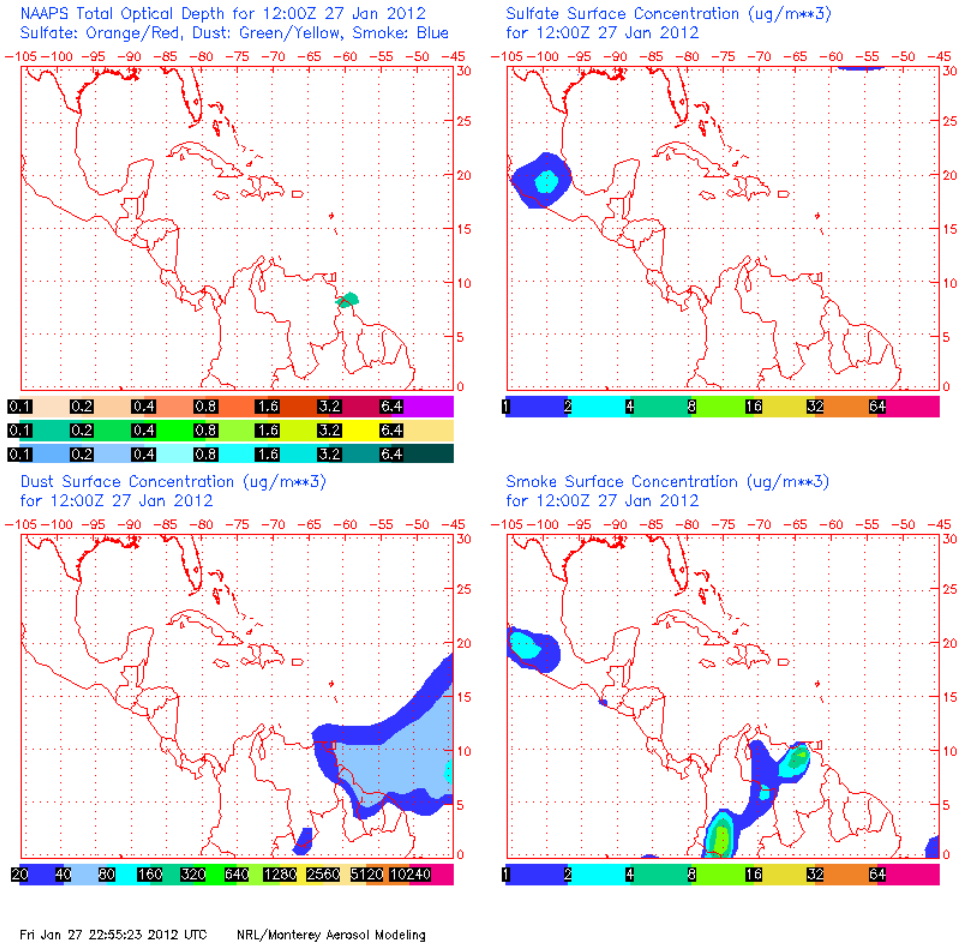
Ensemble Mean and
Uncertainty
72 hours



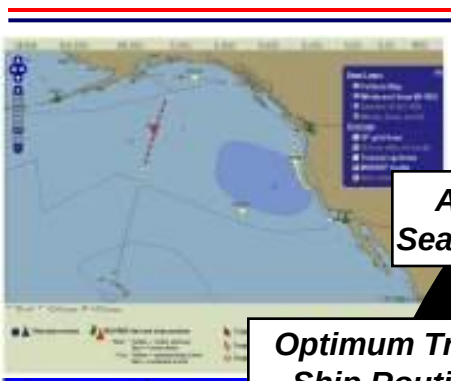
NAAPS

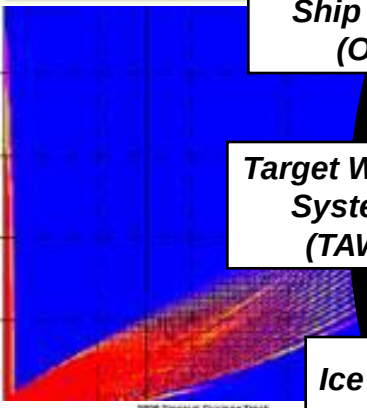
NAAPS (Navy Atmospheric Aerosol Prediction System)

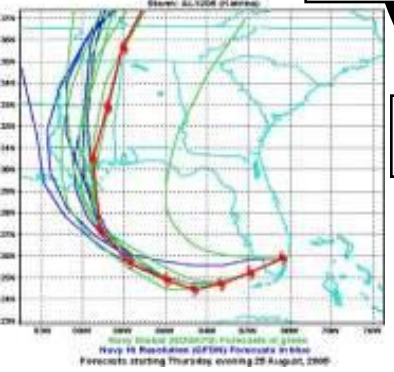
- A global atmospheric aerosol prediction system driven by NOGAPS that includes smoke and dust from source region
- Provides direct feed of dust and smoke concentration to the Forecast of Atmospheric and Optical Radiative Properties (FAROP)

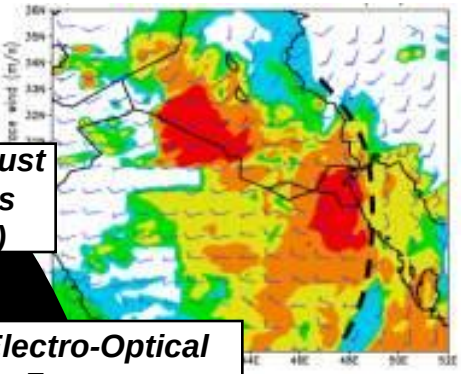


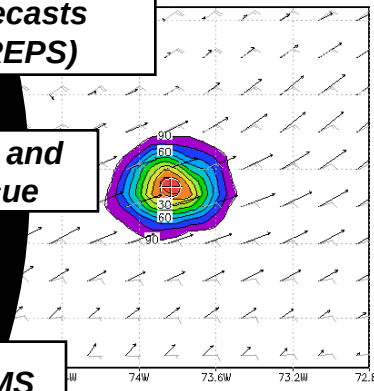
Models and Applications

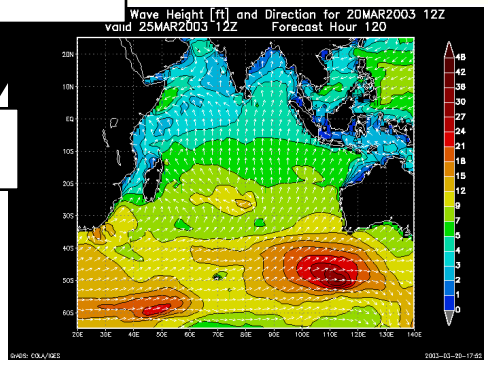












Ocean Acoustic Forecasting

Aircraft Routing (OPARS)

Automated High Seas / Wind Warnings

Visibility/Dust Forecasts (NAAPS)

Optimum Track Ship Routing (OTSR)

Aerosol Modeling

Electro-Optical Forecasts (AREPS)

Target Weapon Systems (TAWS)

Global Models

NWP

Regional Models

Search and Rescue

Ice Forecasts

CEEMS

Ensemble Models

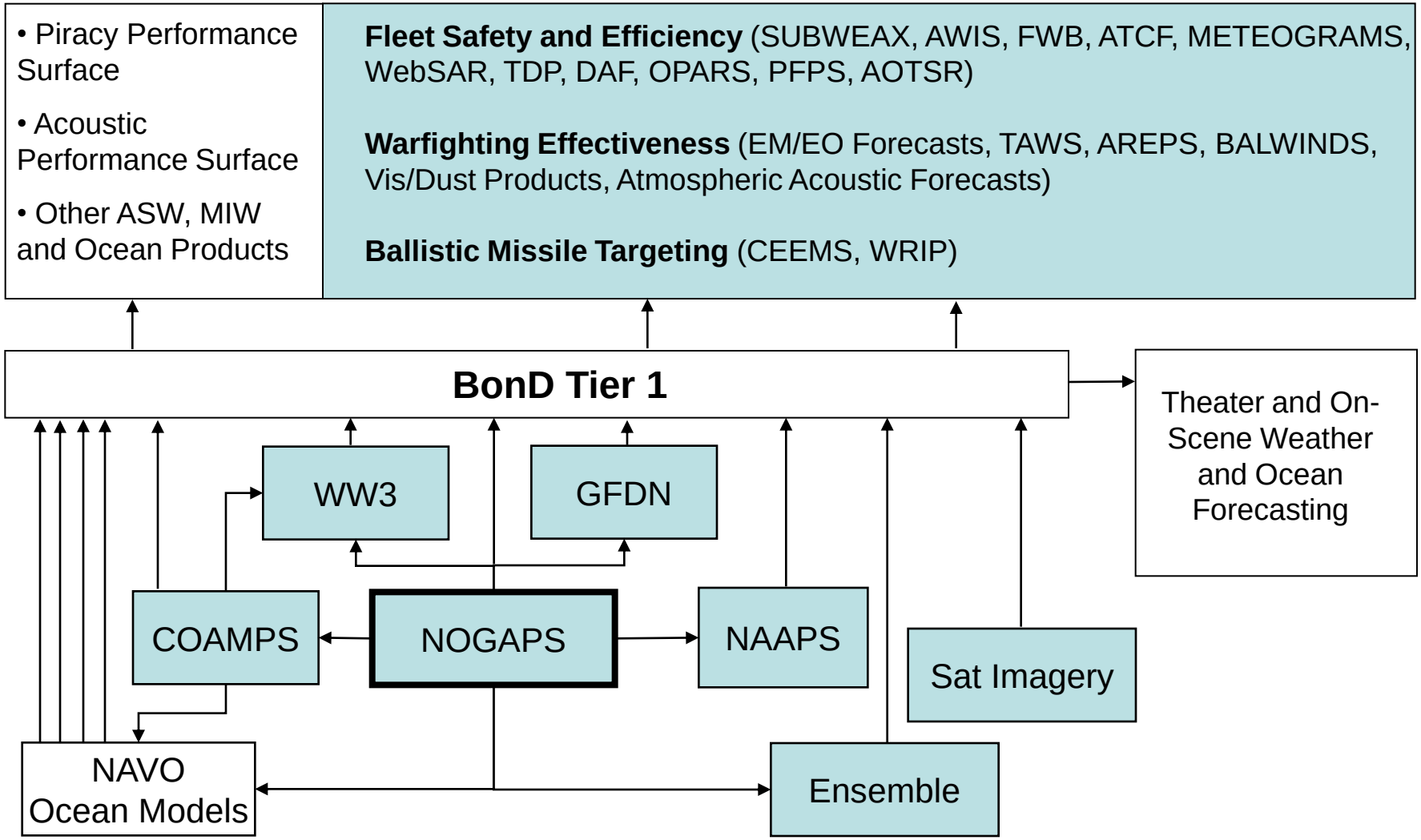
Tropical Cyclone Forecasts

Long-Range Planning

Ballistic Wind Computations

WRIP

NWP Model Interactions



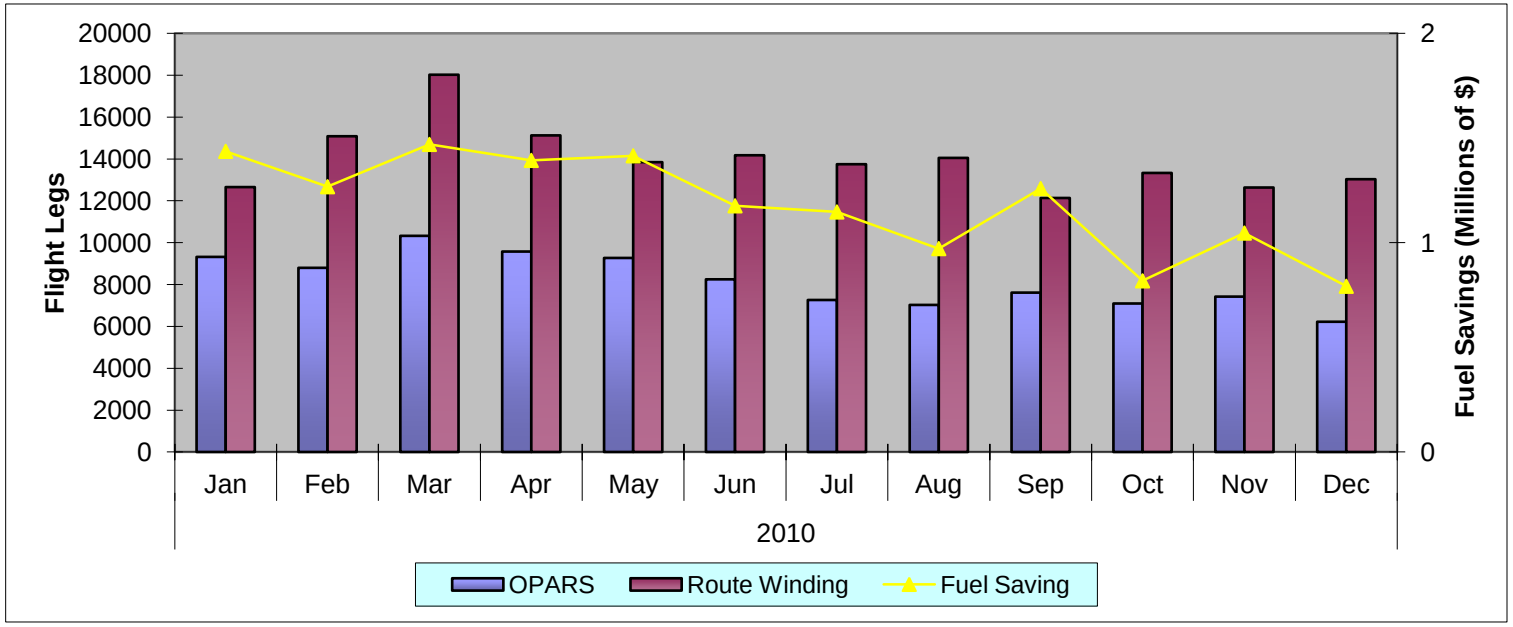
Way Ahead for Navy NWP

- National Unified Operational Prediction Capability (NUOPC)
- Transition to Navy Global Environmental Model (NAVGEM)
- Fully exploit satellite data assimilation
  - Ready for next Polar-orbiting systems (JPSS)
- Continue development of executing remote operational model runs (DSRC)
- Seek partnerships for development of a next-generation global NWP model for operational implementation (~2020)
  - Link next-generation global model to growing Navy interest in support of the arctic, climate change, and energy conservation

Optimum Path Aircraft Routing System (OPARS)

Estimated Fuel Cost Avoidance for 2010: $14,222,267

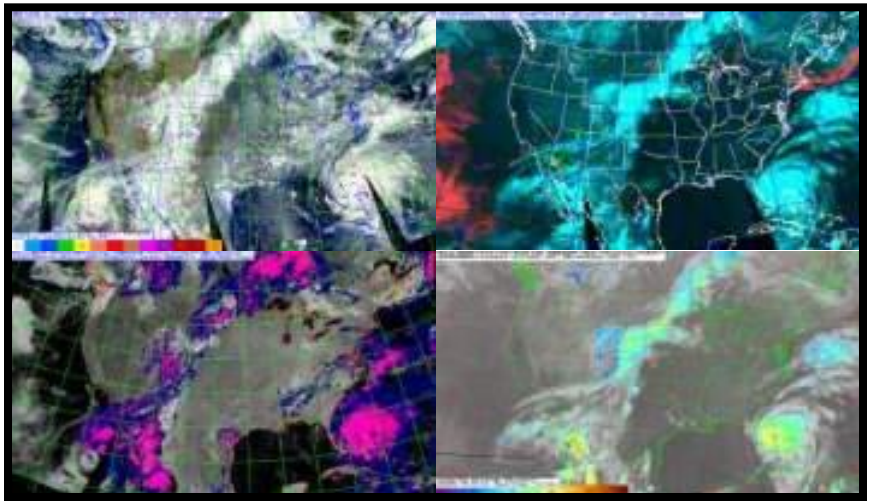
Based on Customer Supplied Cost Avoidance Percentage and Navy contract price of fuel per gallon



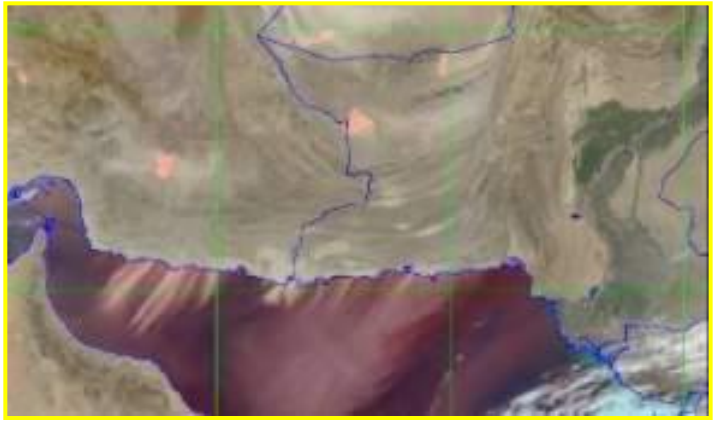
Warfighters supported	4,214
** By Command/Unit/Squadron/Individual*	
Number of aircraft types supported	131
** top 5 aircraft types: UC35, C130, C12, P3C, C9*	
Total OPARS flight legs requested	98,168
Total Route Winding requests	167,825

Satellite Applications

- FNMOC produces a wide variety of on-demand satellite imagery products from meteorological satellites (including NASA platforms)
- Complements the COAMPS modeling capability
- Includes unique capability to pull out dust plumes from imagery
- Developed and supported by NRL

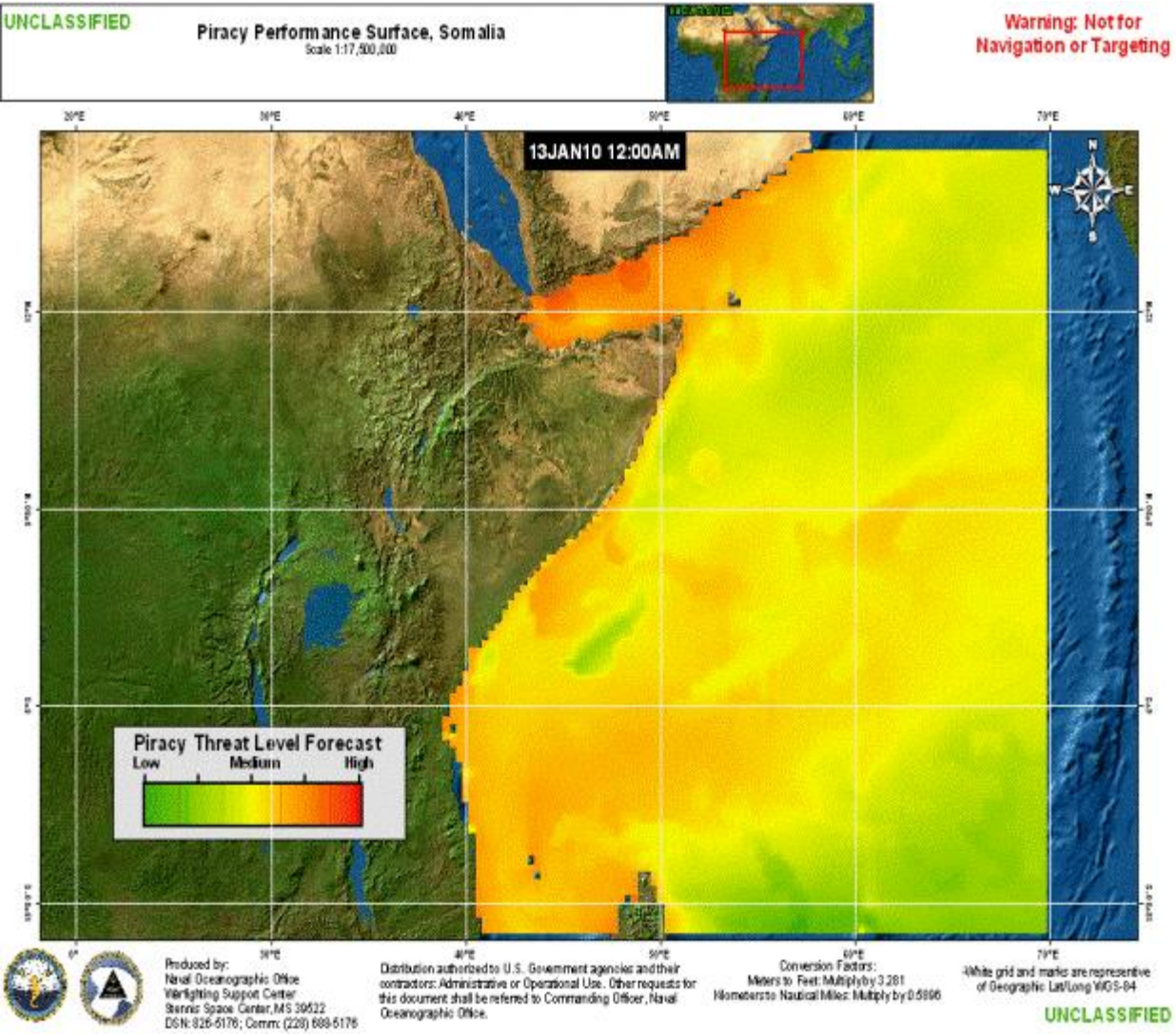


Example SATFOCUS Products



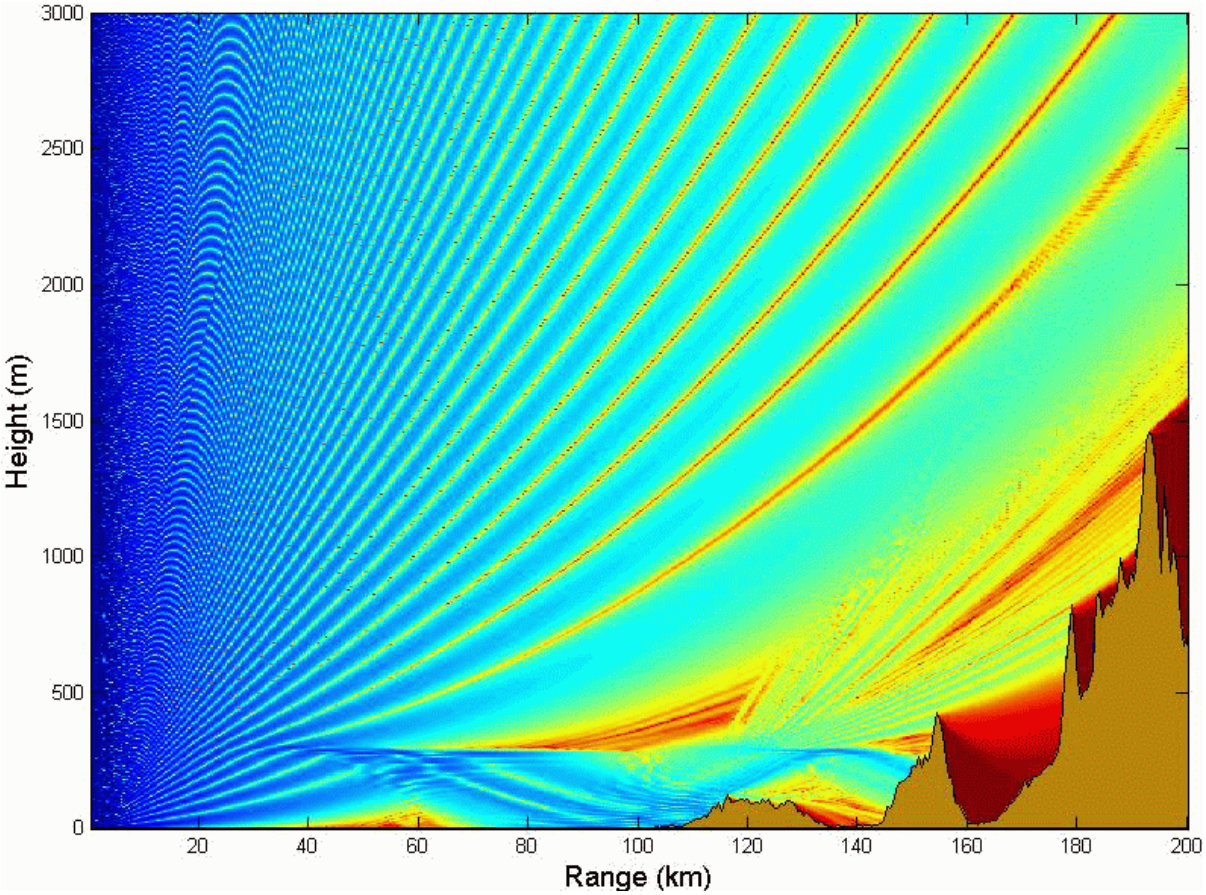
SATFOCUS Dust Enhancement Product

Piracy Performance Surface



- ***Predictive surface (72 hours) of high probability of areas of pirate activity***
- ***Created by fusing atmospheric models and intelligence information***
- ***Significantly reduces operating areas to a more manageable size***
- ***Enables decision makers to smartly focus assets toward high probability areas***

Refractivity Support



- Support Available 24/7 for SUBFOR
- FWC's provide support for all others

TC-Web

FNMOC Satellite Data Tropical Cyclone Page

2012 Storms

All | Active | Year

Atlantic

East Pacific

Central Pacific

West Pacific

Indian Ocean

Southern Hemisphere

- 98S.INVEST
- 90S.INVEST
- 09S.IGGY
- 08S.FUNSO

Display: Latest | Prev. | Track&Image | Pass_Mosaic

Warn: Text | Track

Info: General | Tutorial | Disclaimer

Environment: TPW | TPW&NOGAPS_TPW. | TPW&NOGAPS_850_Winds

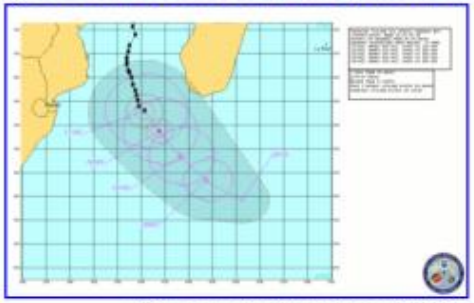
SSMI | SSMIS | TRMM | AMSU | QuikScat | AMSR | WindSat | ASCAT | MODIS | VIS | IR | OLS

Age <= 6hrs old | Age <= 12hrs old | Age >12hrs old | 00:54:19 UTC(Z)

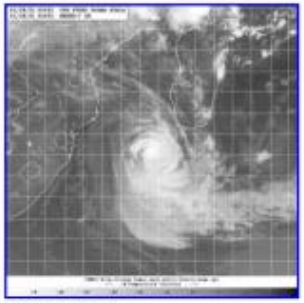
08S.FUNSO

Forecast by Joint Typhoon Warning Center/Naval Maritime Forecast Center

Graphic by Naval Maritime Forecast Center/Joint Typhoon Warning Center



Latest Image



(Click product for full sized image 47346 Bytes and 232067 Bytes.)

	Latest		Upcoming Passes (more)		
SSMI:	01/27 1334Z	164	01/28 00:53	F-15	377
SSMIS:	01/27 1802Z	0	01/28 03:04	F-16	64
TMI:	01/27 1919Z	83	01/28 13:28	TRMM	167
AMSU:	01/27 2304Z	786	01/27 23:04	N-19	786
QScat:	/ Z	0	01/28 03:11	QUIK	845
WSat:	01/27 1528Z	125	01/28 02:46	WSAT	344
ASCAT:	/ Z	0	01/28 06:44	MetOp-A	405
AMSR:	/ Z	0	01/28 10:55	AQUA	378
MODIS:	01/27 1935Z	0	01/28 20:20	TERRA	369

SATFOCUS

FNMOC Satellite Products

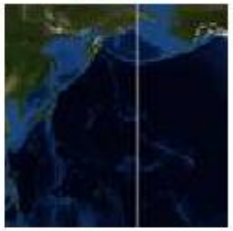
AFRICOM

CENTCOM

EUCOM

NORTHCOM

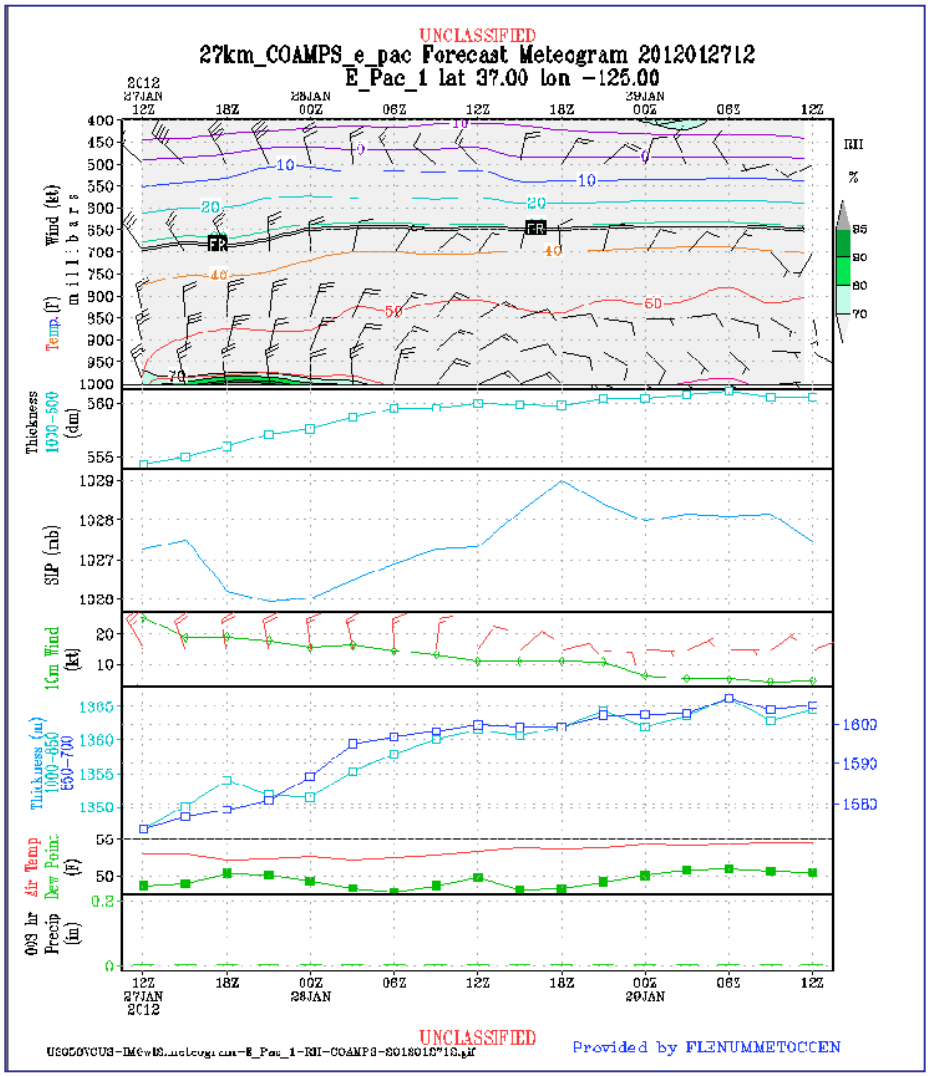
PACOM



SOUTHCOM

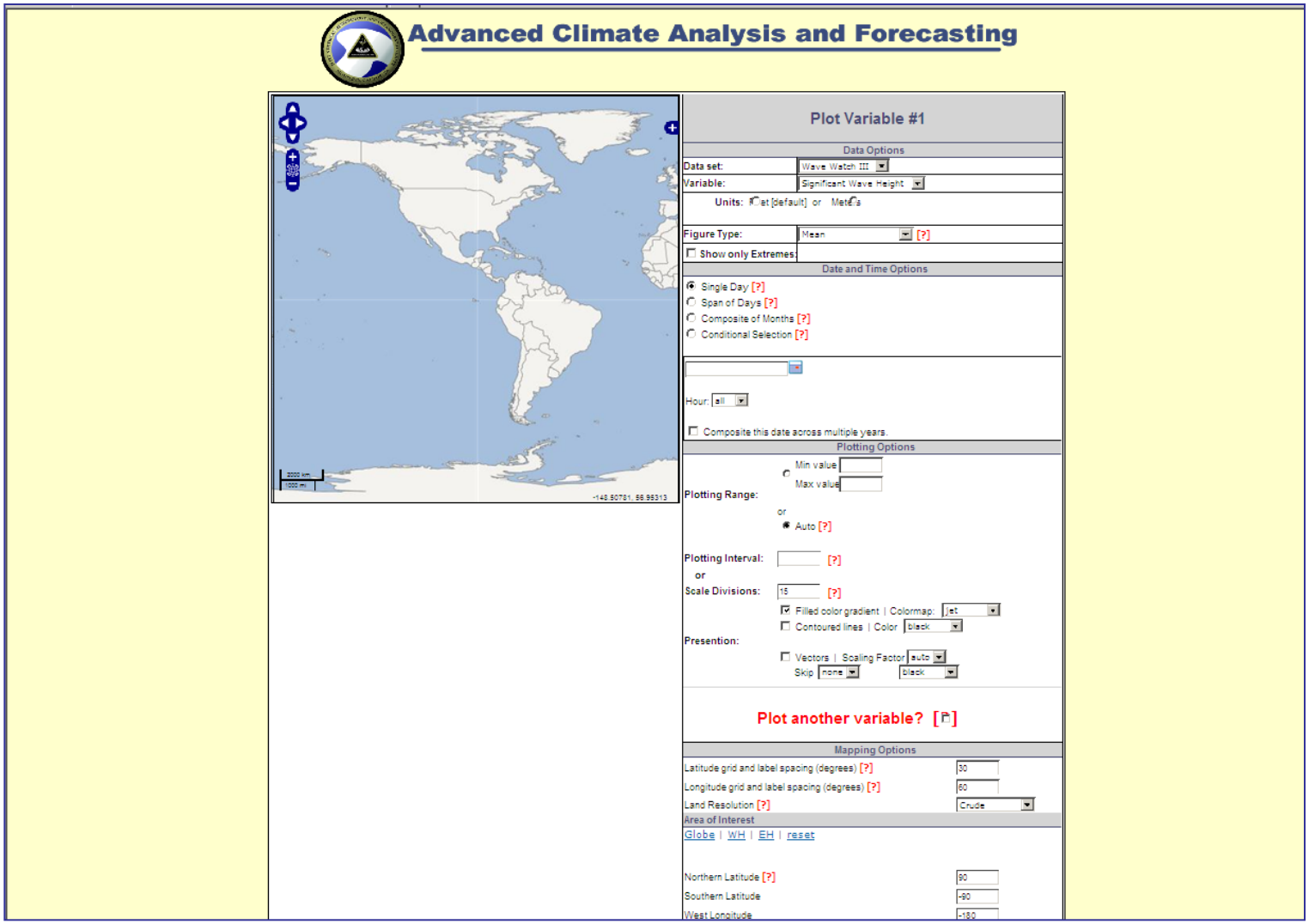
GLOBAL

METEOGRAMS

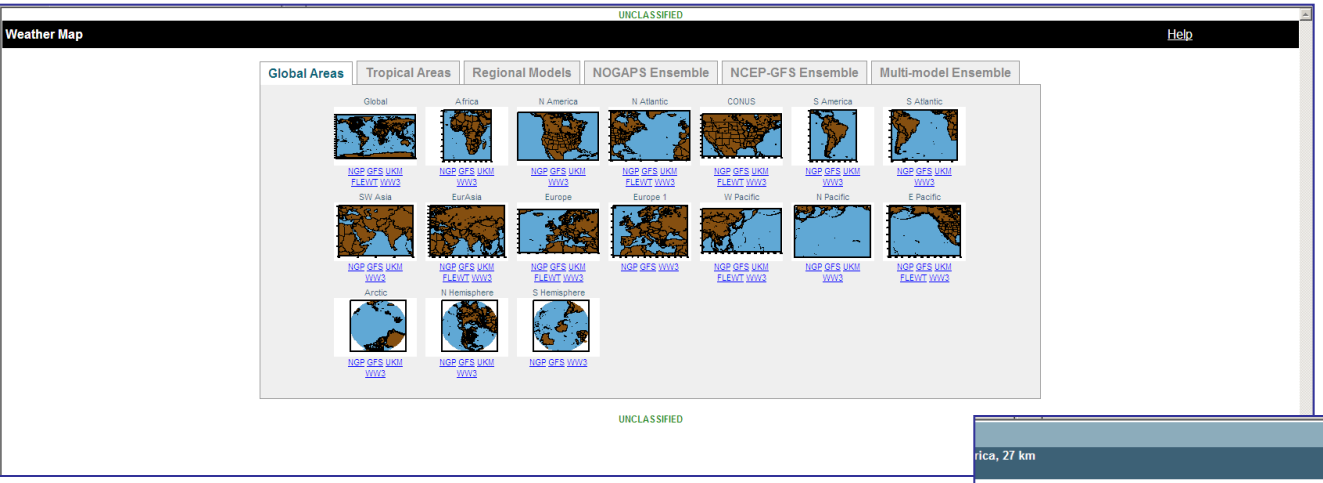


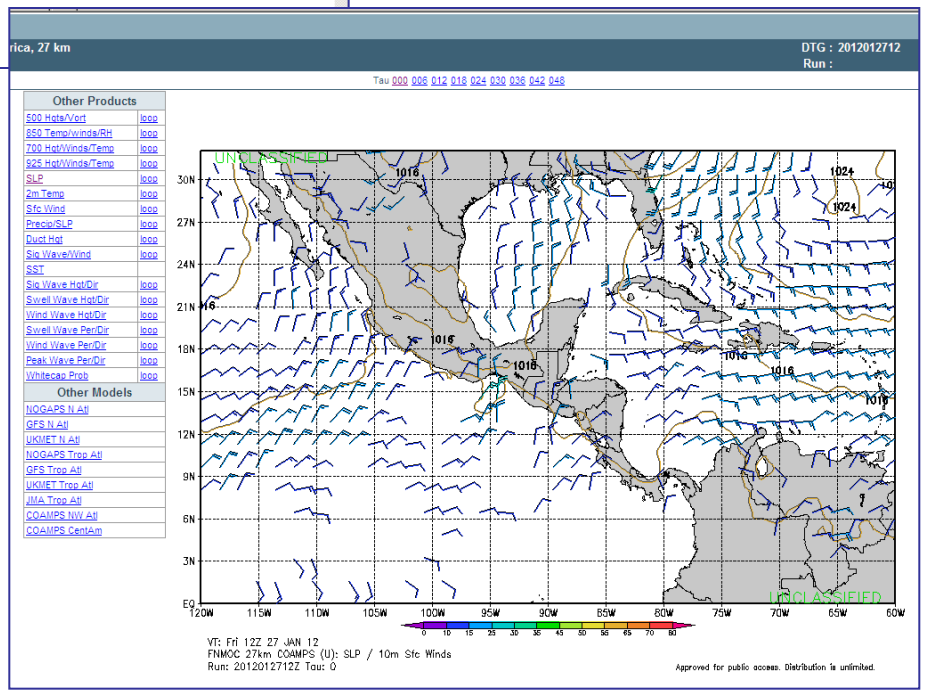
Unclassified FOUO

Climatology



WXMAP





Unclassified FOUO

FNMOC Numerical Weather Prediction Details

Basic Equations For NOGAPS

Vertical coordinate

$$\eta = \eta(p, p_s, p_{top})$$

$$p = A(\eta) + B(\eta)\pi$$

$$\pi = p_s - p_{top}$$

Continuity Eqn

$$\frac{\partial}{\partial t}\left(\frac{\partial p}{\partial \eta}\right) + \vec{\nabla}\cdot\left(\vec{V}\frac{\partial p}{\partial \eta}\right) + \frac{\partial}{\partial \eta}\left(\dot{\eta}\frac{\partial p}{\partial \eta}\right) = 0$$

Surface Pressure Eqn

$$\frac{\partial \pi}{\partial t} + \int_{\eta_t}^{\eta_b} \vec{\nabla}\cdot\left(\vec{V}\frac{\partial p}{\partial \eta}\right) d\eta = 0$$

Vertical Motion Eqn

$$\left(\dot{\eta}\frac{\partial p}{\partial \eta}\right)_{\eta_t} = \left(\dot{\eta}\frac{\partial p}{\partial \eta}\right)_{\eta_b} = 0$$

$$\dot{\eta}\frac{\partial p}{\partial \eta} = -\int_{\eta_t}^{\eta}\left[\frac{\partial}{\partial t}\left(\frac{\partial p}{\partial \eta}\right) + \vec{\nabla}\cdot\left(\vec{V}\frac{\partial p}{\partial \eta}\right)\right] d\eta$$

Constituent Eqn

$$\frac{\partial q}{\partial t} + \vec{V}\cdot\vec{\nabla}q + \dot{\eta}\frac{\partial q}{\partial \eta} = F_q$$

... and a few more...

...utilizing a Horizontal spectral differencing, second-order finite difference in the vertical, and central time differencing with semi- implicit corrections... (Robert et al., 1972)

~5 million grid points...

~9 million observations…

requiring about 11 million lines of code

HPC Systems

NAME	TYPE	CORES	MEMORY (TB)	PEAK (TFLOPS)	DISK (TB)	OS
A2 EMERALD	Dell Linux Cluster System	2,372	4.8	27.3	605	Linux
A2 ALPHA	Dell Linux Cluster System	842	1.9	8.4	605	Linux
A2 BETA	Dell Linux Cluster System	672	1.3	6.9	605	Linux
A2 BERYL*	Dell Linux Cluster System	1,252	1.8	13.3	43	Linux
A2 ZIRCON	Dell Linux Cluster System	232	0.3	2.0	605	Linux
A2 RUBY	Dell Linux Cluster System	1,168	1.2	12.0	275	Linux
A2 BETA	Dell Linux Cluster System	184	0.8	1.9	275	Linux
A2 TOPAZ	Dell Linux Cluster System	256	1.2	2.3	16	Linux
FS1	SGI ORIGIN 3900	256	0.3	0.7	30	TRIX
FS2	SGI ORIGIN 3900	256	0.3	0.7	30	TRIX
	TOTALS	7,490	14	76	3,090	

FNMOC HPC Systems are linked directly to ~2,000 TB of tape archive space.

FS = File Server / Cross Domain
AMS = Analysis and Modeling Subsystem
ATOS = Applications, Transactions, and Observations Subsystem
A2 = Combined AMS / ATOS System
* = NPP test system

UNCLAS
SECRET
TS/SCI
UNCLAS & SECRET

Fleet Numerical…

- A World recognized Numerical Weather Prediction (NWP) Center…
  - With High Performance Computing (HPC) at all levels of classification
  - Is the only HPC center modeling the Global Atmosphere to DoD Information Assurance (IA) Standards
  - Provides climatological support to Naval Operations
  - Executes Submarine Weather (SUBWEAX) support globally
  - Co-located with NRL and NWS and near NPS

…enabling fleet safety & decision superiority


Questions?