# NGGPS Ocean Planning at NCEP/EMC

— Avichal Mehra, Robert Grumbine, Arun Chawla and Hendrik Tolman

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# OUTLINE

- Current Status and upgrades
  - Oceans
  - Waves
- Planned projects
  - Oceans
  - Waves
  - Arctic
- Performance Metrics
  - Oceans
  - Waves
  - Sea Ice
  - Coupled Systems

# CURRENT STATUS

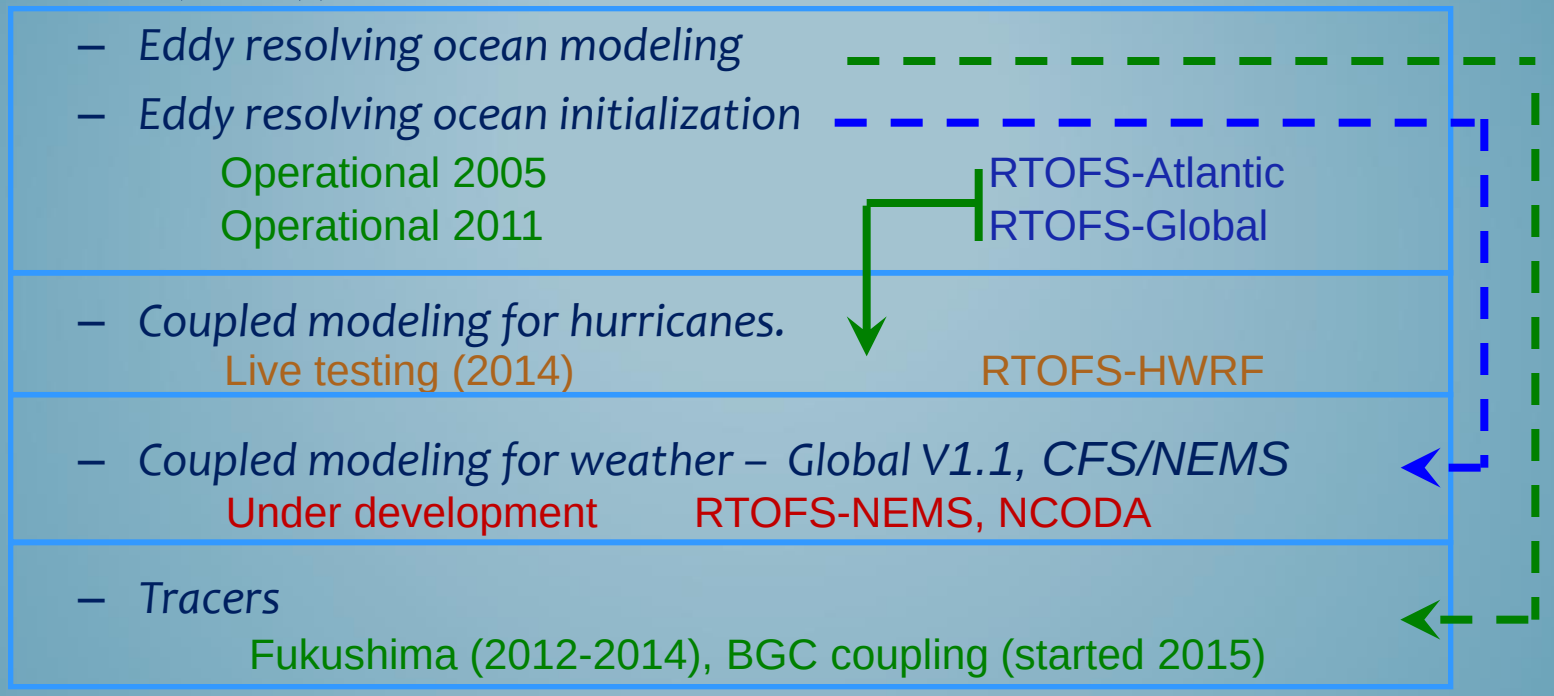
# Two Ocean Modeling Systems

- Modular Ocean Model (MOM) with Global Ocean Data Assimilation System (GODAS)
  - Seasonal scales
  - GFDL support
  - Integral part of CFSv2
  - Continued support for CFSv3 development

- Hybrid Coordinate Ocean Model (HYCOM) with Navy Coupled Ocean Data Assimilation (NCODA)
  - Weather time scales
  - NRL and academia support
  - Integral part of RTOFS systems
  - Expected R2O support for gaps

# RTOFS OVERVIEW

*Five major efforts:*




– *All RTOFS models presently based on HYCOM*

- *RTOFS represent line of products*
- *HYCOM is underlying ocean model*

***Strong collaboration with US Navy, leveraging core HYCOM and data assimilation developments at NRL.***

# RTOFS Global Current Status

- NCEP implemented RTOFS-Global v1.0 in operations on 10/25/11 using Global HYCOM developed by US Navy
- NAVO is delivering initialization data daily (NCODA-3DVar)
- MMAB/EMC has converted Navy model to be forced with GFS/GDAS fluxes.
- More details (and links to pubs) available at:
  http://polar.ncep.noaa.gov/global/
- Planned major upgrade for August/September 2015 on phase II

# RTOFS Global FY15 Upgrade

**Primary upgrades (developed by NRL):**

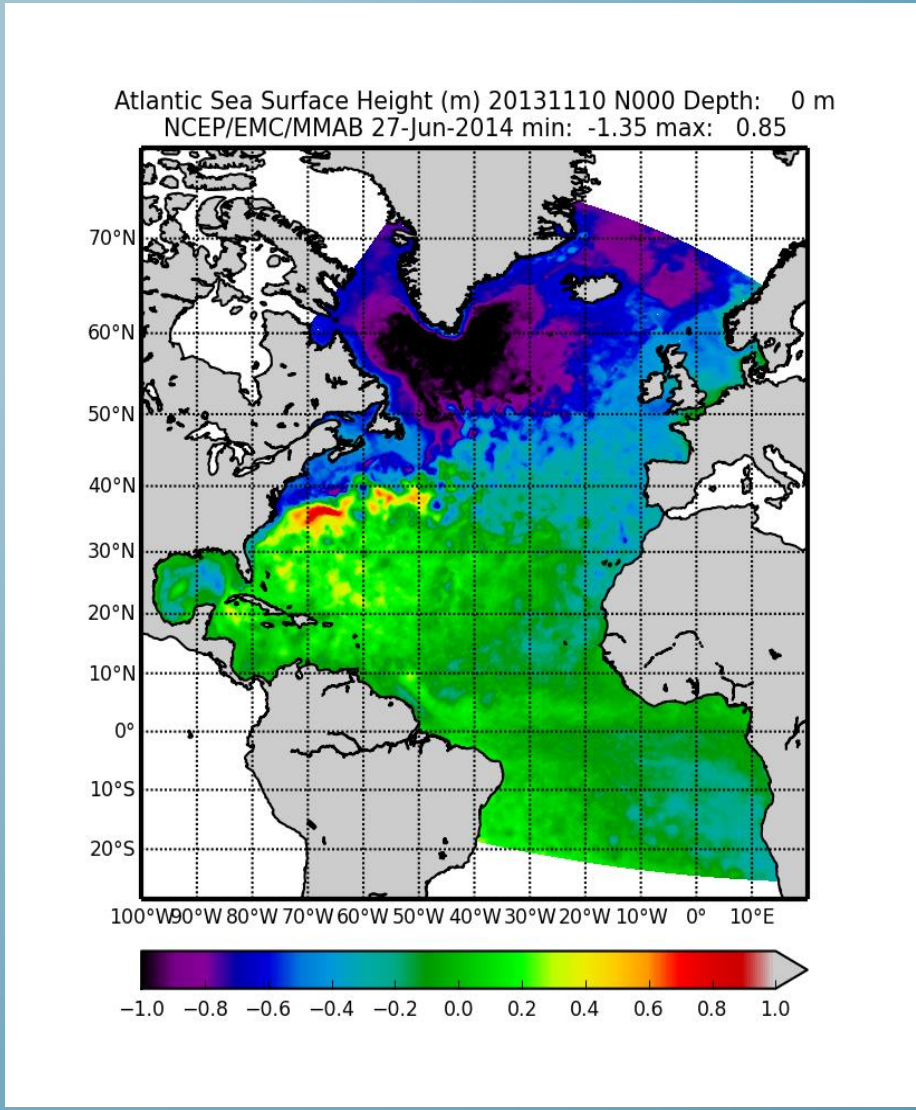
- 41 hybrid layers (increased from 32 layers)
  - Air-Sea boundary flux improvements for coupled applications (including Hurricanes)
  - Finer resolution for mixed layer (9 additional near surface layers)
  - Improved vertical coastal resolution for downstream applications (NOS OFS, IOOS RA's)

- Two-way coupled HYCOM with Los Alamos CICE (Community ICE code) (which replaces Energy-Loan Sea-Ice model)
  - 1 hour coupling frequency
  - Using ESMF v4.0 (non-NUOPC)
  - Additional forecasts (ice thickness, ice concentration, ice drift and stress)

- Improved climatology/bathymetry

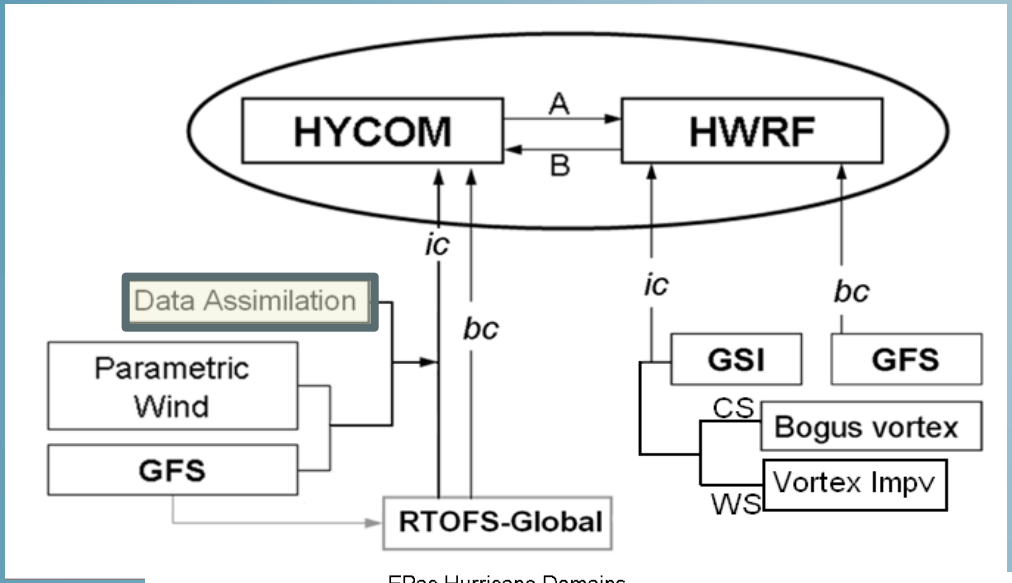
# RTOFS Atlantic FY16 Upgrade

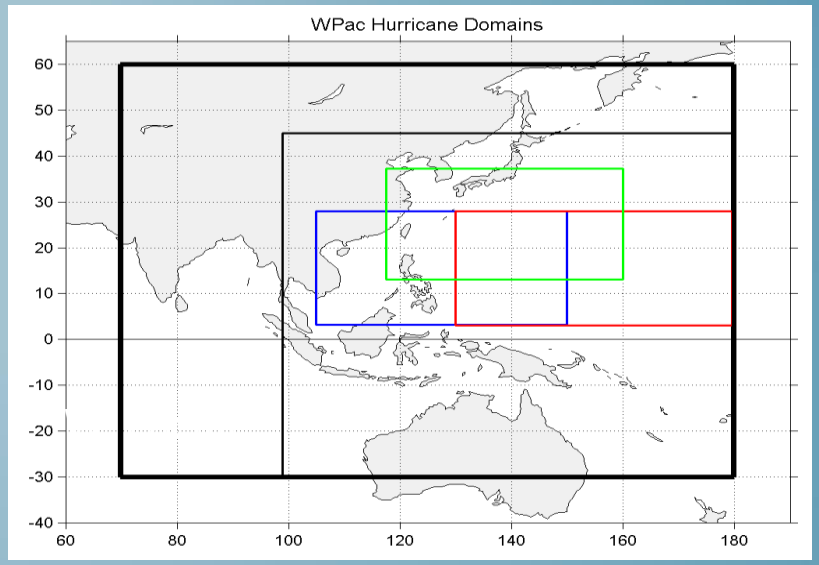
- Update codes to unify with RTOFS Global.
- Improve representation of basin geometry.
- Updates to data assimilation algorithm with new data sets for surface (SST, SSH, SSS).
- Updates to open boundary conditions to prevent drift.
- Ready to receive boundary data from RTOFS-Global (one-way nest)

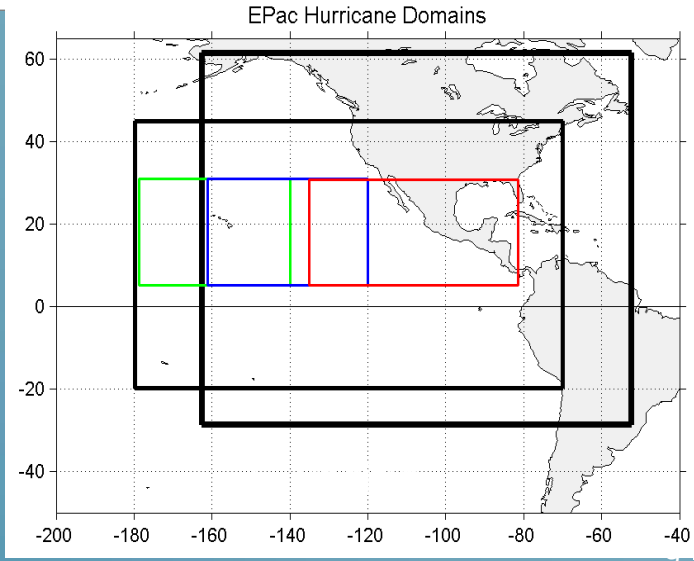


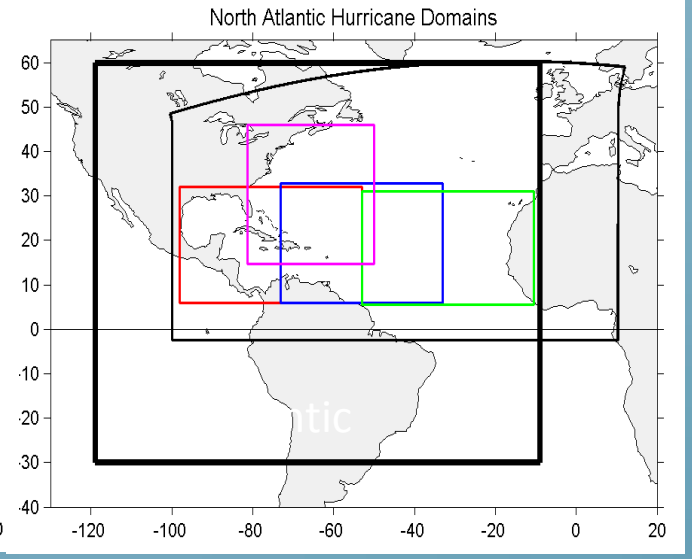
# Coupled HWRF-HYCOM System

Coupled hurricane modeling with regional ocean components




Current:

Future - basin

HWRF parent

# Wave Model Suites at NCEP

- A global wave model
  - Driven by GFS winds
  - Consists of 9 grids (two – way nested)
- A hurricane wave model
  - Driven by GFS + HWRF winds
  - Consists of 10 grids (global domain)
- An ensemble wave model
  - Driven by GEFS winds
  - Single global grid
- Great Lakes model
- Near Shore Wave Prediction System (NWPS)
  - On demand local wave modeling systems

WAVEWATCH III

SWAN (WAVEWATCH III to be added later)

# PLANNED PROJECTS

# RTOFS NEMS

- HYCOM coupled to GSM/GFS using ESMF NUOPC layer within NEMS
- Mediators/connectors also being built for Sea Ice, Waves and Land components
- ¼ degree Global, 50-60 layers, ensembles of 4 members per day (120 per month)
- 1/12 degree regional or basin-scale, 50-60 layers, 10-20 member ensembles (leverage Arctic-coupling)
- Unified Data Assimilation (LETKF/Hybrid)

# Wave model coupling

- NEMS capability being developed for WAVEWATCH III
- In the next one year develop a wave – atmosphere – ocean coupled modeling system for the Climate Forecast System
  - Coupling to be developed for a single grid
  - Study the impact of coupled systems in skill scores for both atmospheric and ocean systems
- Develop a wave – ocean coupled system for HYCOM to incorporate Langmuir mixing due to Stokes drift.
- In year 2 expand NEMS coupling of wave model and atmospheric model using multiple grids (for the wave model)
- A prototype wave – ocean – hurricane coupled system being developed
  - Will transition to NEMS once HWRF is NEMS compatible

# Wave model coupling (cont.)

- After year 2, the regular coastal grids in global model will be replaced by unstructured grids
  - Coastal unstructured domains to be coupled with surge models (ADCIRC)
- Local models
  - Coupled wave – atmosphere – circulation system for the Great Lakes
    - Coupling with FVCOM and atmospheric model
    - Currently developing wave model on FVCOM unstructured grid
  - Coupled Arctic modeling system
    - Curvilinear Arctic grid to model waves to the North Pole (currently being added to Global wave model)
    - Advanced wave – ice interaction processes (physics packages under development at collaborative institutes
  - Wave – surge – current coupling for the local NWPS systems

# Ocean Data Assimilation Plans

- Signed MOU with Navy to implement NCODA at NCEP for operational use.
  - Initially for RTOFS Global
  - 3DVAR, seven overlapping regions
  - Configure to use NCEP data tanks and data streams.
  - Tentative implementation FY 2016/2017.
  - Add new observations in the future (e.g. SSS, HF Radar)
  - Extend to all RTOFS applications (3DVar and Hybrid)
  - To be funded by NGGPS

## Ocean Data Assimilation Plans

- Transition Hybrid 3DVar/LETKF global ocean data assimilation to operations
  - NGGPS funded project at Univ. of Md
  - Target CFSv3
  - Build new ensemble-based ocean data assimilation systems
  - Unified DA applications
  - MOM tests underway
  - HYCOM tests under development

# Data assimilation in wave models

- Wave data assimilation developing along two tracks
  - A GSI based data assimilation approach
  - An LETKF based data assimilation approach
- Develop a hybrid approach to improve wave model skill
- Once models are coupled, develop a coupled data assimilation for wave – atmosphere – ocean
  - Tentative test case for this is the CFS as the different model components use similar data assimilation approaches

## Data assimilation for Sea Ice

- CPO/CVP supported project with Jiping Liu (SUNY Albany)
- Focus is on CFSv3 (starting from CFSv2 algorithm)

## Coupled Atmosphere-Ocean-Ice System

- Leverage developments of common building blocks within NEMS
- NMMB-HYCOM-KISS
- Bias corrections to heat fluxes
- Focus on Sea-Ice predictability
- Use ensembles to minimize random flux errors
- New skill metrics
- Customize ice products for users
- To be funded by NGGPS

# PERFORMANCE METRICS

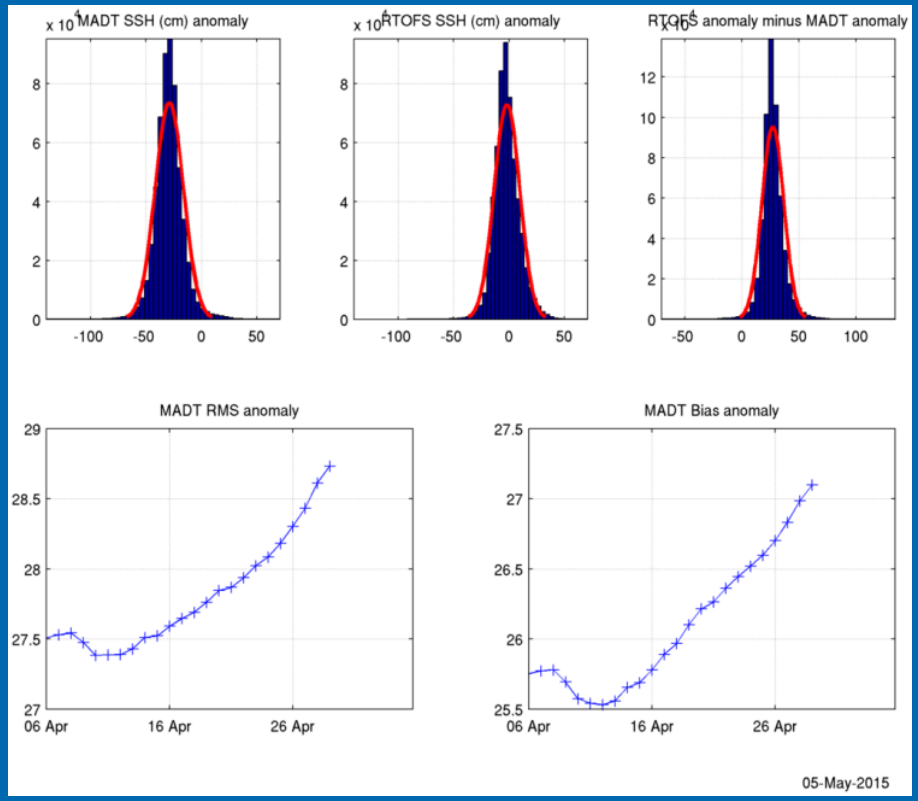
# OCEAN METRICS

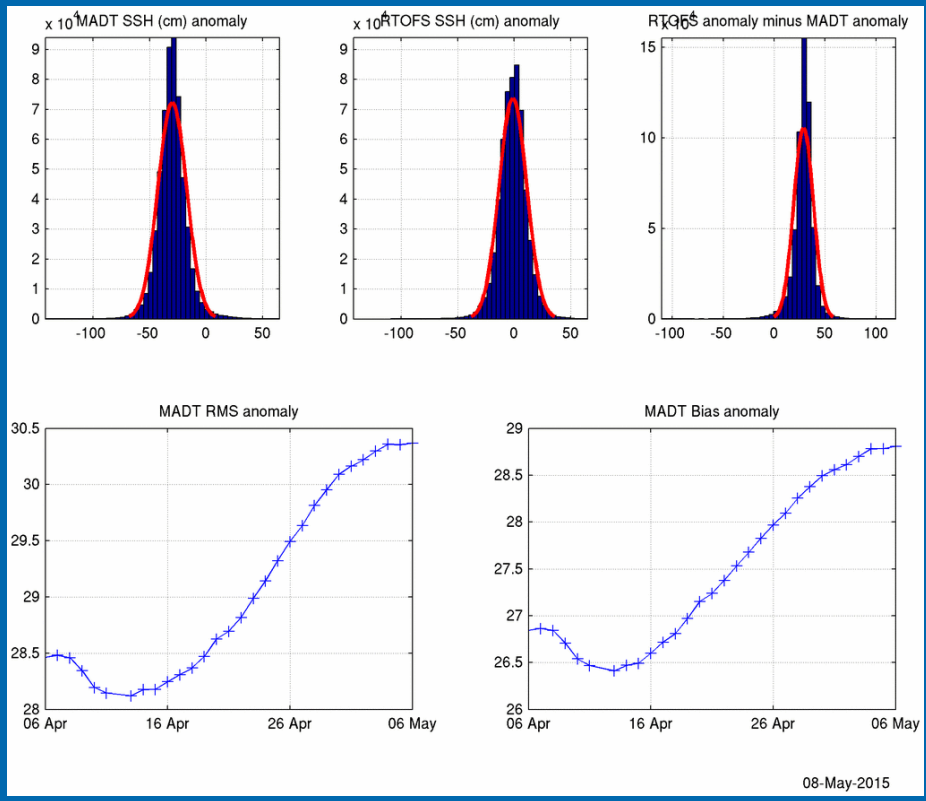
- Daily monitoring of fields using GODAE Class Metrics:
  - Class 1 (analysis of surface fields SST, SSH)
  - Class 2 (ARGO profiles, WOCE sections)
  - Class 3 (Florida Current transports, GS North Wall location)
  - Class 4 (Forecast skill metrics: SST, SSH, ARGO profiles)

  Daily metrics made available at:

  http://polar.ncep.noaa.gov/global/monitor/

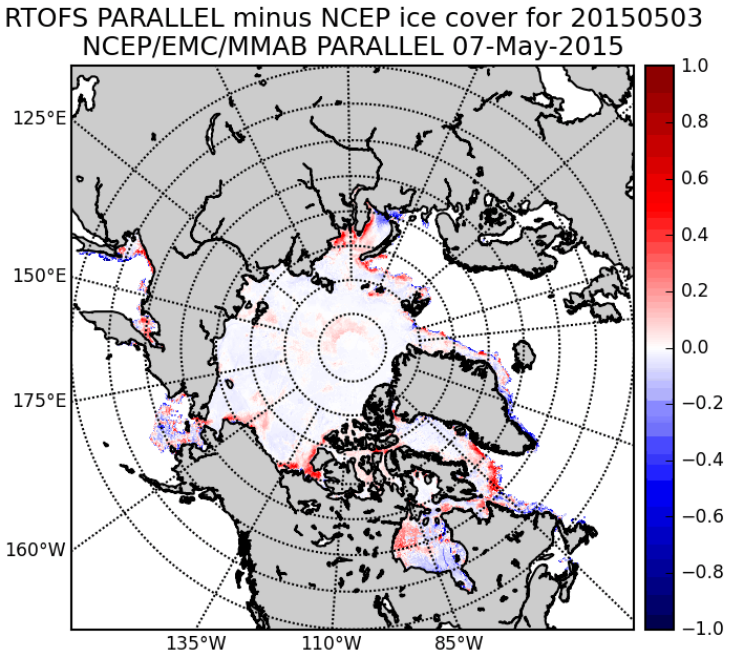
# RTOFS Para vs RTOFS Ops vs MADT SSHA

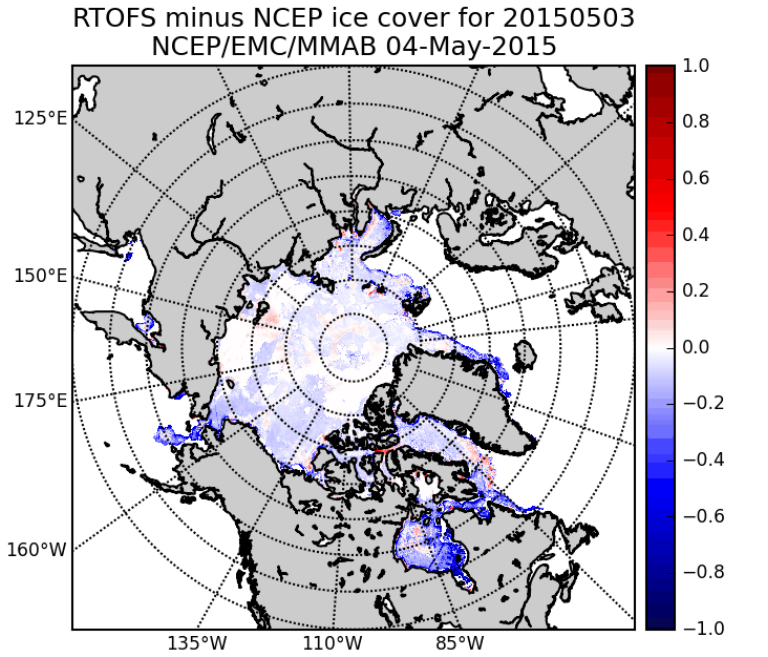



The two simulations are comparable with the parallel performing marginally better (approx. 1 cm RMSE).

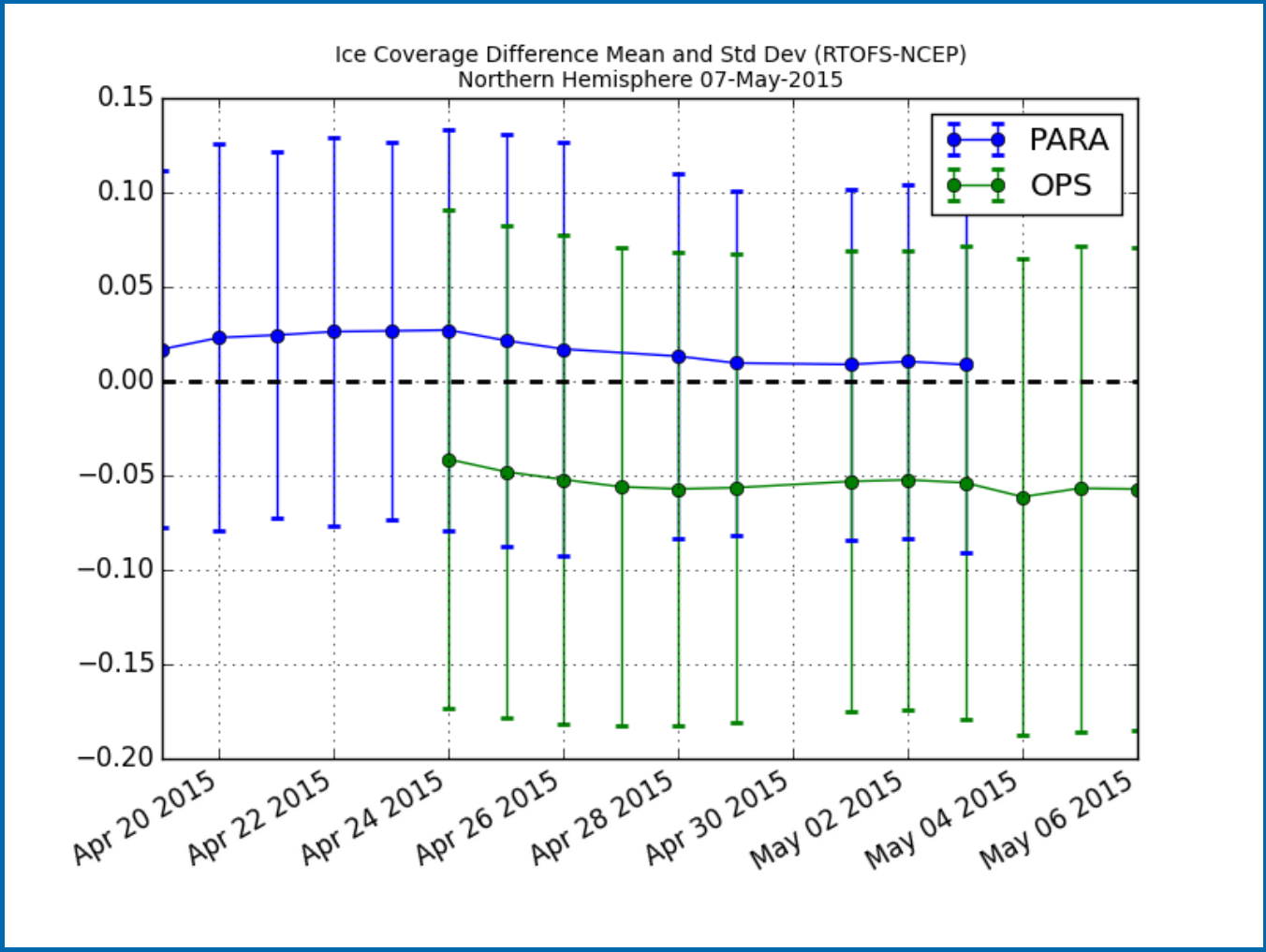
# Sea Ice Cover RTOFS Para vs RTOFS Ops vs Analysis




Differences in the Arctic region (May 2015)

# Sea Ice Cover RTOFS para vs RTOFS Ops vs  Analysis




Differences in the Arctic region (May 2015)

- Recent papers on Verification and Metrics

  - Garraffo et al., 2014. Modeling of 137Cs as a tracer in a regional model for the Western Pacific, after the Fukushima Daiichi Nuclear power plant accident of March 2011. *Weather and Forecasting. doi: http://dx.doi.org/10.1175/WAF-D-13-00101.1*

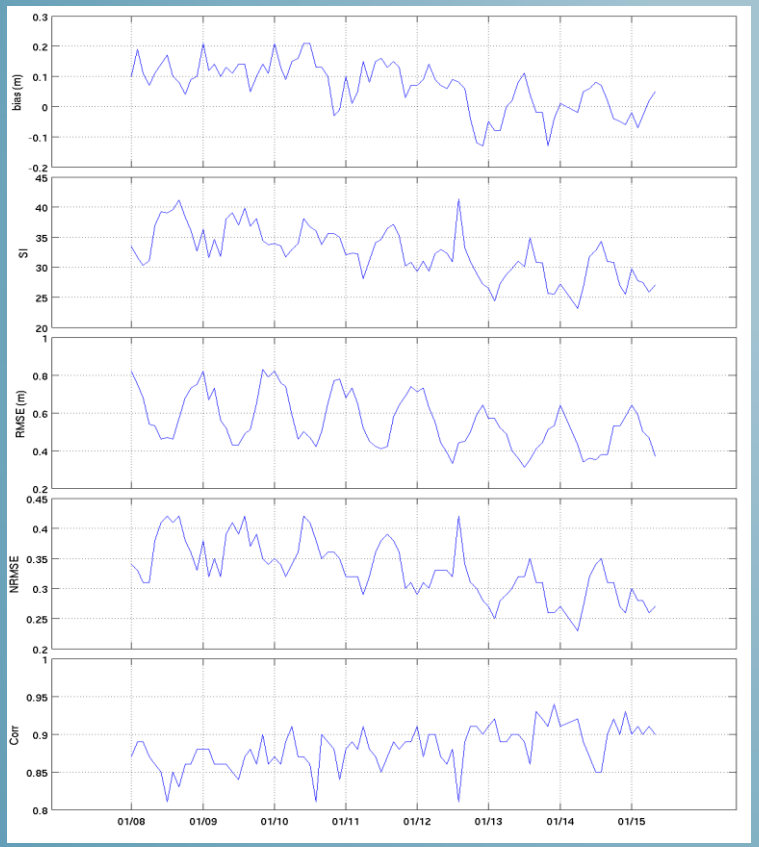
  - Ryan et al., 2015. GODAE Ocean View Class 4 forecast verification framework: Global ocean inter-comparison. *J Oper Oceanogr. 7(3)*

  - Divakaran et al., 2015. GODAE OceanView Inter-comparison for the Australian Region. *J Oper Oceanogr. doi:10.1080/1755876X.2015.1022333*.

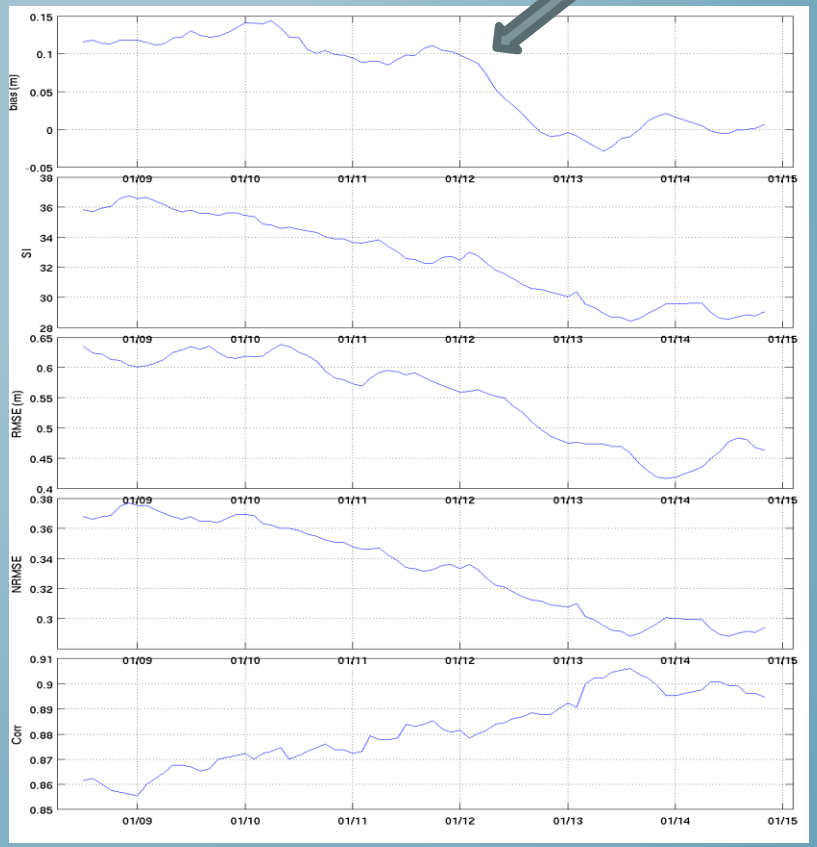
  - Hernandez et al., 2015.Recent progress in performance evaluations and near real-time assessment of operational ocean products. *J. Oper. Oceanogr. (accepted)*

# Global wave model skill scores for 72 hour forecast

New Physics introduced




Monthly skill scores




Seasonal skill scores

Skill scores based on comparisons at all available NDBC buoys
Time in MM/YY

# SEA ICE METRICS

- Daily Sea Ice Concentrations
- Sea Ice Drift Speeds
- Others: design remains a challenge

# COUPLED METRICS

- Immature
  - 500 mb anomaly correlation versus surface ocean winds
  - Significant wave heights versus sea surface temperature
  - Precipitation threat scores versus sea surface heights
  - Sea ice concentration versus tropical SST
- Not that there are no measures, but it must be developed/examined which measures, in which areas, are most important for assessing coupled systems.

# Back Up Slides

## Ocean Modeling Plans for Short-to-Medium Time Scales

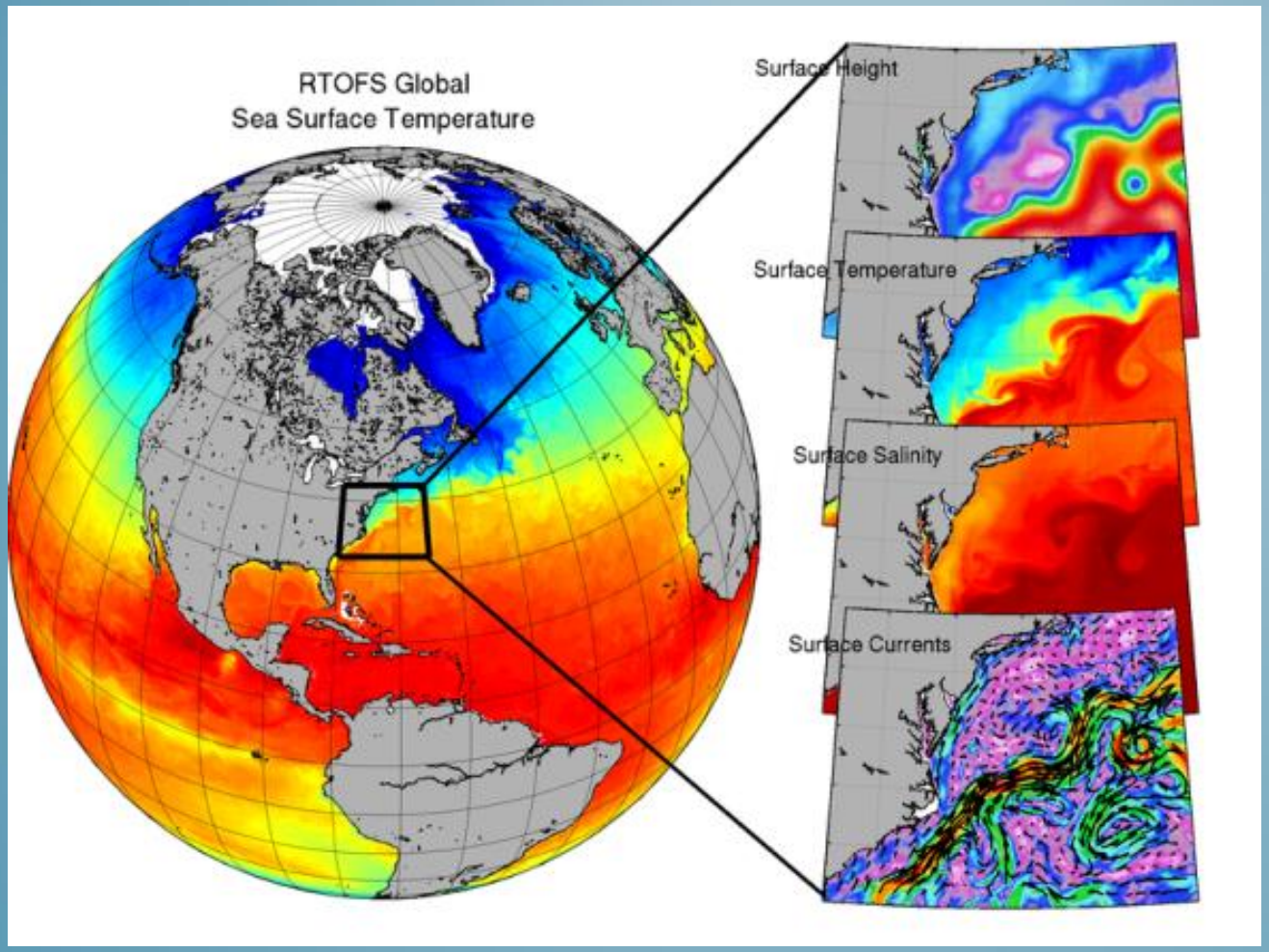
- **Basin scale models**:
  - RTOFS-Arctic: New model, coupled to NMMB, Sea Ice, Waves.
  - RTOFS-Atlantic: New finer grid.
  - RTOFS-Pacific: New model for East Pacific.
  - Deterministic (at 1/24° or 1/36° degree)
  - Nested in Global.
  - Coupled:
    - Waves for upper ocean mixing (and surface fluxes if coupled to atmosphere)
    - Ice and atmosphere for Arctic.
  - Ensembles (at 1/12 degree, 20-40 members), particularly for Arctic.

## Ocean Modeling Plans for Short-to-Medium Time Scales

- **Global:** deterministic, higher vertical resolution (~ 100), horizontal stays at 1/12°, coupled via ESMF in NEMS
  - — New data types for NCODA (SSS, Ocean Color, Sea-Ice Thickness, HF-Radar etc. )
  - — Better MLD, OHC, coupling with waves for Langmuir and Stokes mixing in ocean.
  - — Coupled Bio-Geo-Chemical module(s) for Eco-Forecasting Applications

- **HYCOM-HWRF**
  - — Coupling within NEMS with up to 100 hybrid layers
  - — Coupling with WW III®.
  - — Operational in Atlantic, East Pacific, West Pacific and Indian
  - — Development of apropos data assimilation modules

# RTOFS Users and Partners




Primary Users:

**NWS:** EMC, OPC, NHC, coastal WFO's

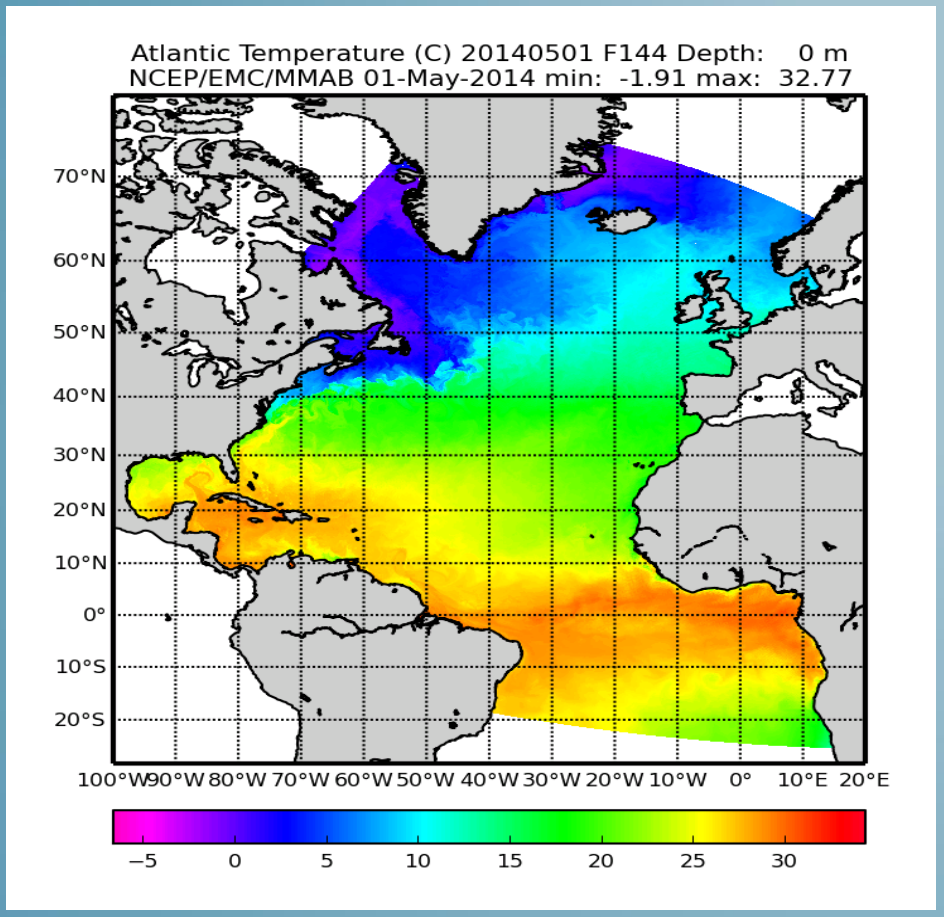
**NOS:** CO-OPS, CSDL,IOOS RA's

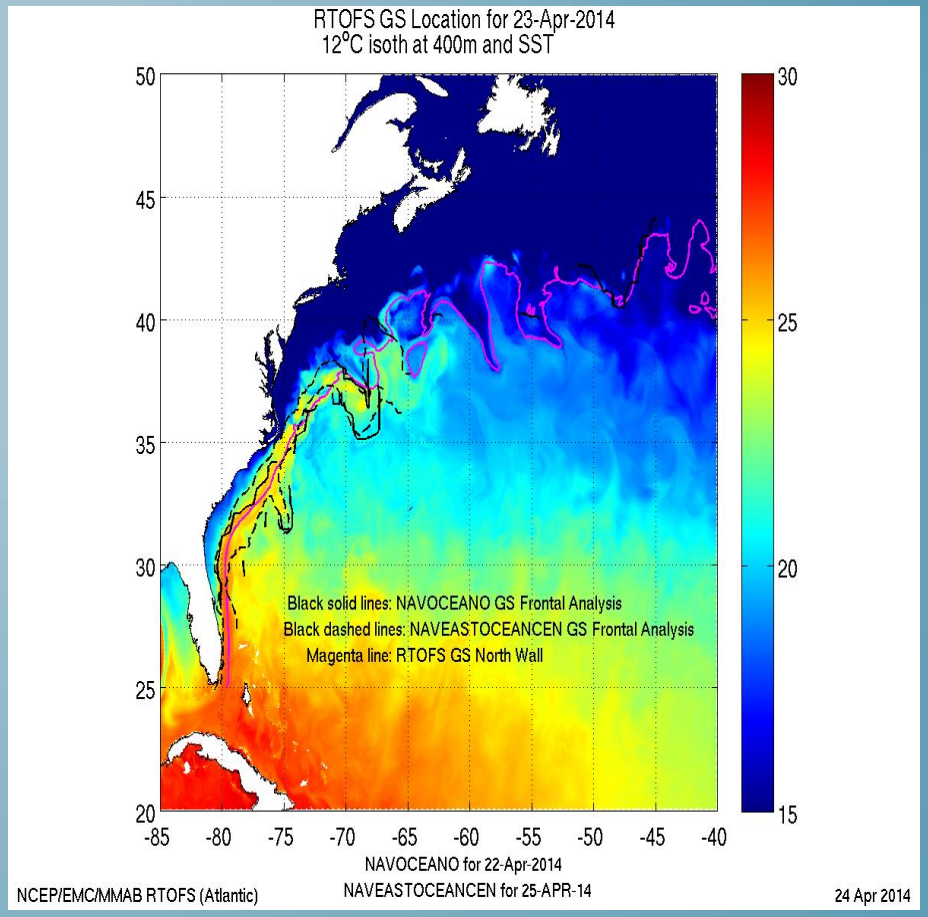
**OAR:** AOML/HRD

**DHS:** US Coast Guard

Primary research partners: NRL, ESRL, AOML, NESDIS/STAR, JPSS-RR, JCSDA, UMD, RSMAS, JAEA (Japan), UK Met Office, BOM (Australia)

# RTOFS Atlantic Current Status




- Higher resolution near US East Coast and Gulf of Mexico (4-5 km)
- Includes forcings from boundary and body tides (8 components)
- In-house configuration based on quasi 3DVar.