

# RTOFS Global

## v1.1.0

EMC-CCB Meeting May 12, 2015

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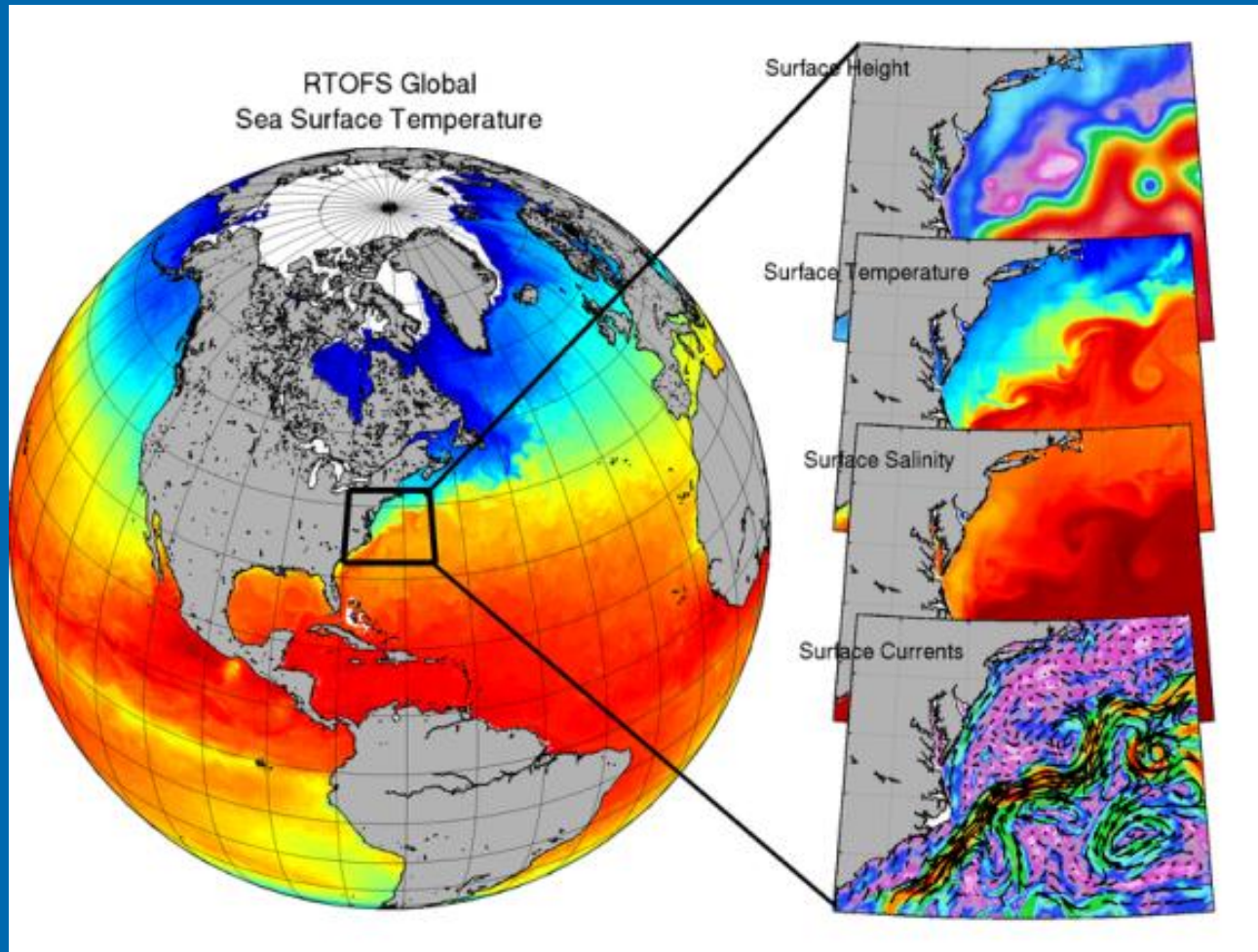
# Outline

- Current status of RTOFS Global v1.0
- Upgrades for v1.1
- Evaluation
- Resource/product changes for v1.1.

# RTOFS-Global v1.0

- RTOFS Global is the first global eddy-resolving ocean forecast system at NOAA/NCEP implemented in close collaboration with the US Navy.
- This global system is based on a 1/12 degree **HYCOM** (**HY**brid **C**oordinate **O**cean **M**odel) developed by the US Navy with a Pan-Am Global Grid (4500 x 3928).
- The system has 32 vertical hybrid layers (isopycnal in the deep, isolevel in the mixed layer and sigma in shallow waters).
- The initialization is based on a daily live feed of analysis fields provided by NAVOCEANO from a 3D-VAR data assimilation scheme (NCODA) developed by the US Navy which assimilates daily observations (T,S, U,V and sea surface height) in a sequential incremental update cycle.
- The daily global ocean forecasts at NCEP are forced with the GFS surface fluxes of radiation, precipitation and momentum.
- **Strong collaboration with US Navy, leveraging core HYCOM and data assimilation developments at NRL.**

# 1/12 Degree Global Domain



## Primary Users:

### NWS:

EMC, OPC, NHC,  
WFO/NWPS

### NOS:

CO-OPS, IOOS RA's

### OAR:

OWAQ, AOML/HRD

US Coast Guard

**Primary research partners:** NRL, ESRL, AOML, NESDIS, JCSDA, JAEA (Japan), UMD, FSU, MSU, INCOIS (India)

# Current Status

- NCEP implemented RTOFS-Global v1.0 in operations on 10/25/11
- NAVO is delivering initialization data daily.
- MMAB/EMC has converted Navy model to be forced with GFS/GDAS fluxes.
- Multiple data distribution channels have been developed:
  - NOMADS (operational)
  - FTP (operational)
  - AWIPS (operational)
  - ~~NOMADS (development)~~

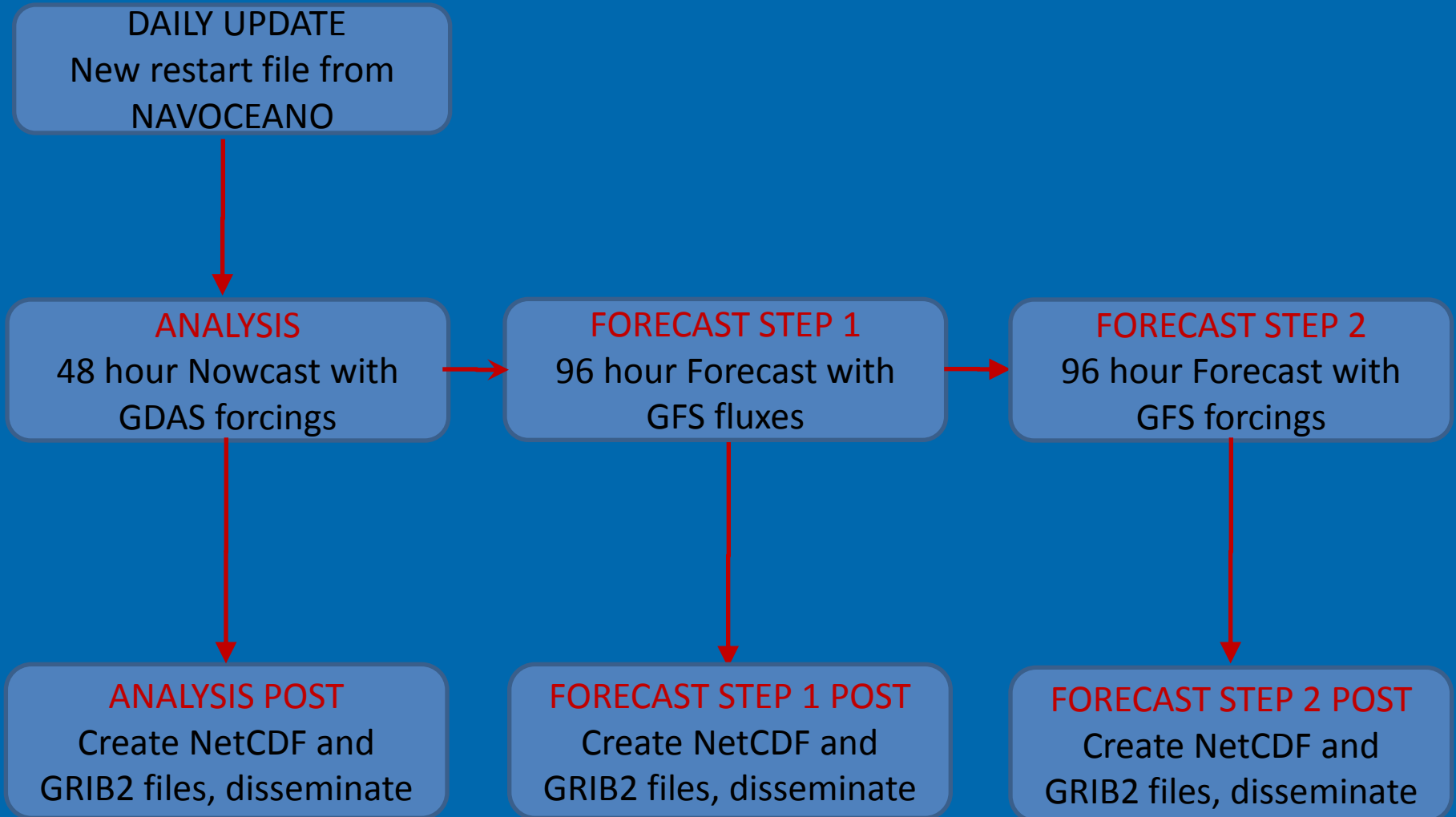
# Model run setup

RTOFS-Global using 00z – 12z cycles:

- 00z cycle: Dedicated to model initialization:
  - For now, take data from Navy, propagate several days as needed to adjust to GDAS/GFS forcings.
  - Will become full assimilation cycle using last 5-7 days of real time data, **MOA with Navy on implementing NCODA at NCEP.**
- 06z cycle; Forecast days 1-4
- 12z cycle: Forecast days 5-8
- 18z cycle (in reserve)

# RTOFS-Global Job Structure

## Overview of Stages



# Version 1.1.0

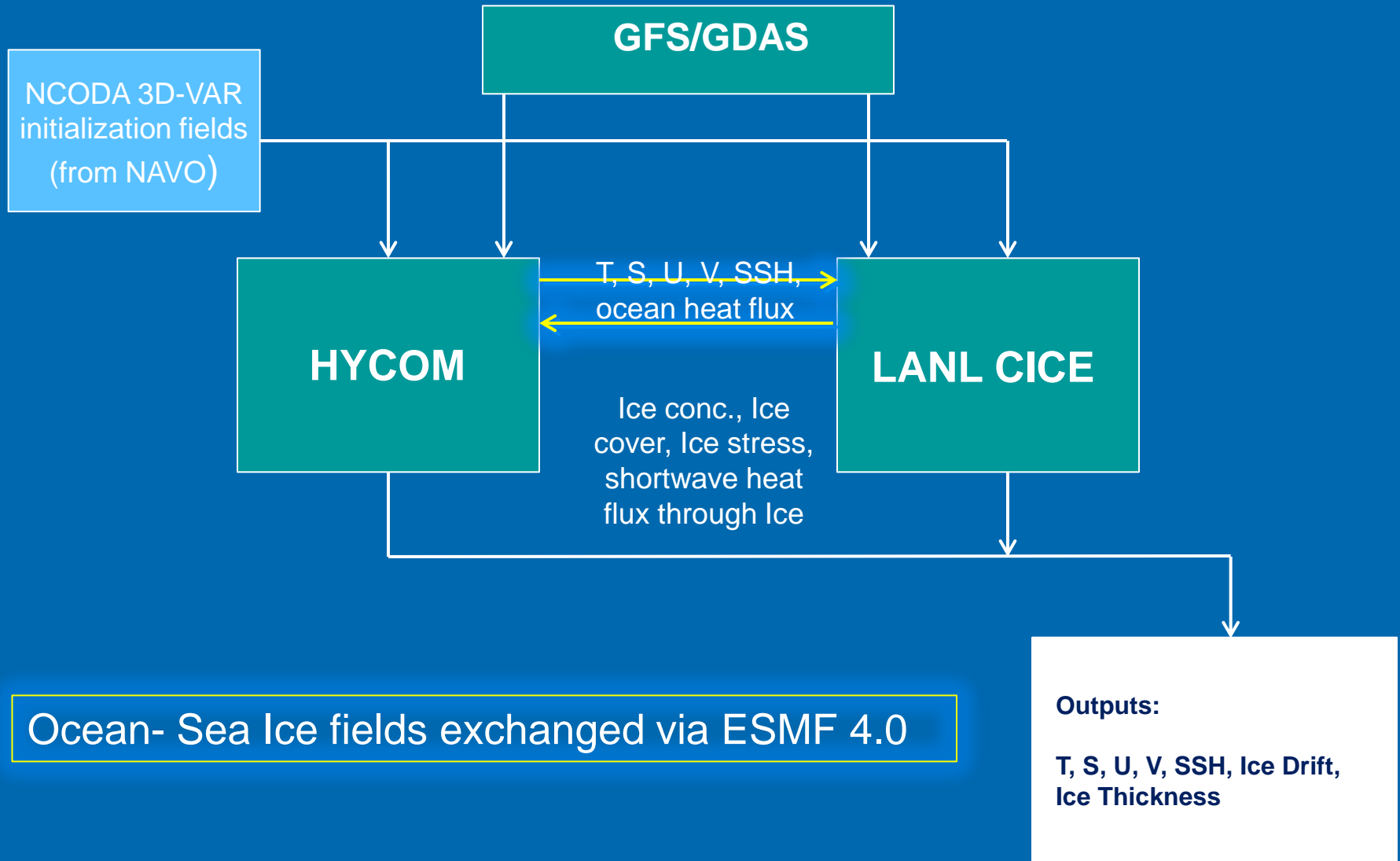
## Primary upgrades:

- 41 hybrid layers (increased from 32 layers), iso-levels mostly in the top 200m
- Improved bathymetry which allows better representation of shallow points (minimum depth 5m)
- Updated climatology fields from GDEM 3 to GDEM 4
- An updated equation of state (17 terms vs 9 terms)
- Two-way coupled HYCOM with Los Alamos **CICE** (**C**ommunity **I**ce **C**od**E**) (which replaces Energy-Loan Sea-Ice model)
  - 1 hour coupling frequency
  - Using ESMF v4.0 (non-NUOPC)

**Developed fully at US Navy (GOFS 3.1) with ongoing independent validation.**



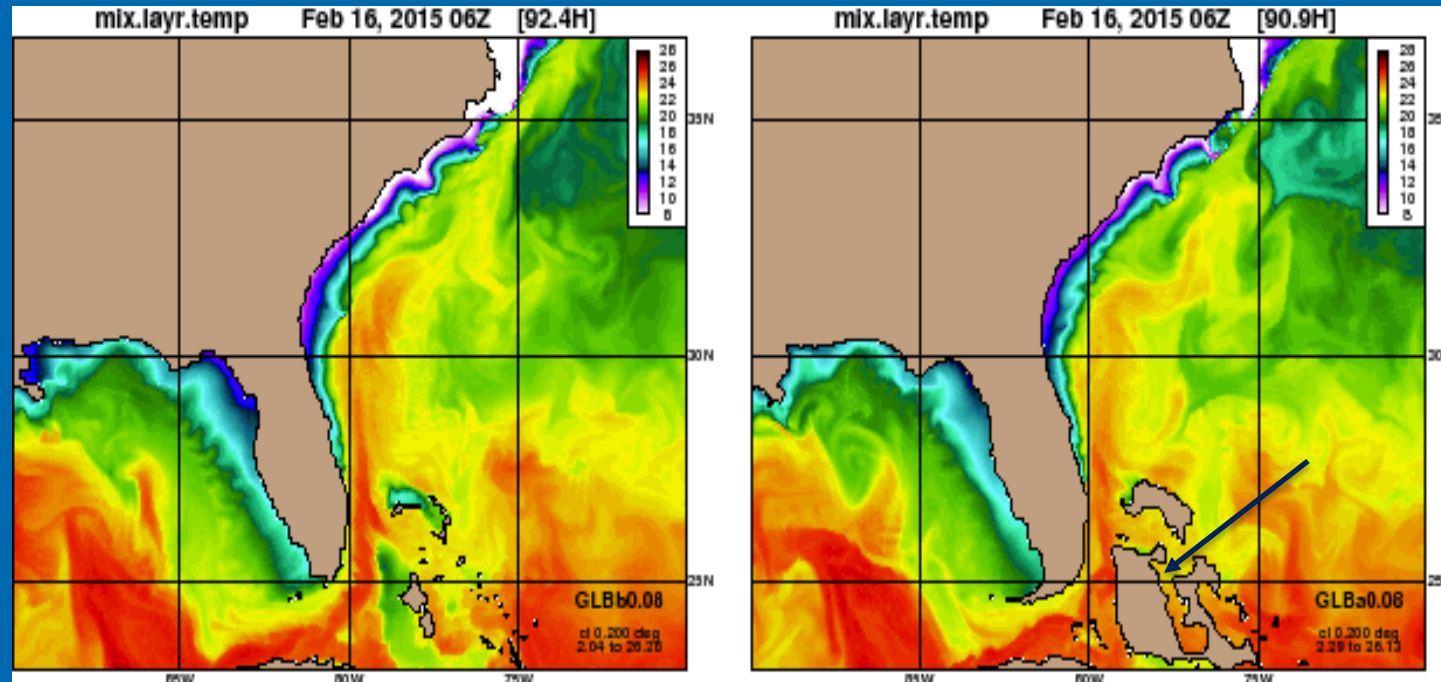
# HYCOM CICE coupling



# Evaluation

- Coastline/water mass representations
- GS Location
- SSH comparisons
- SST comparisons
- Florida Cable transports
- Profile metrics
- Polar Ice cover

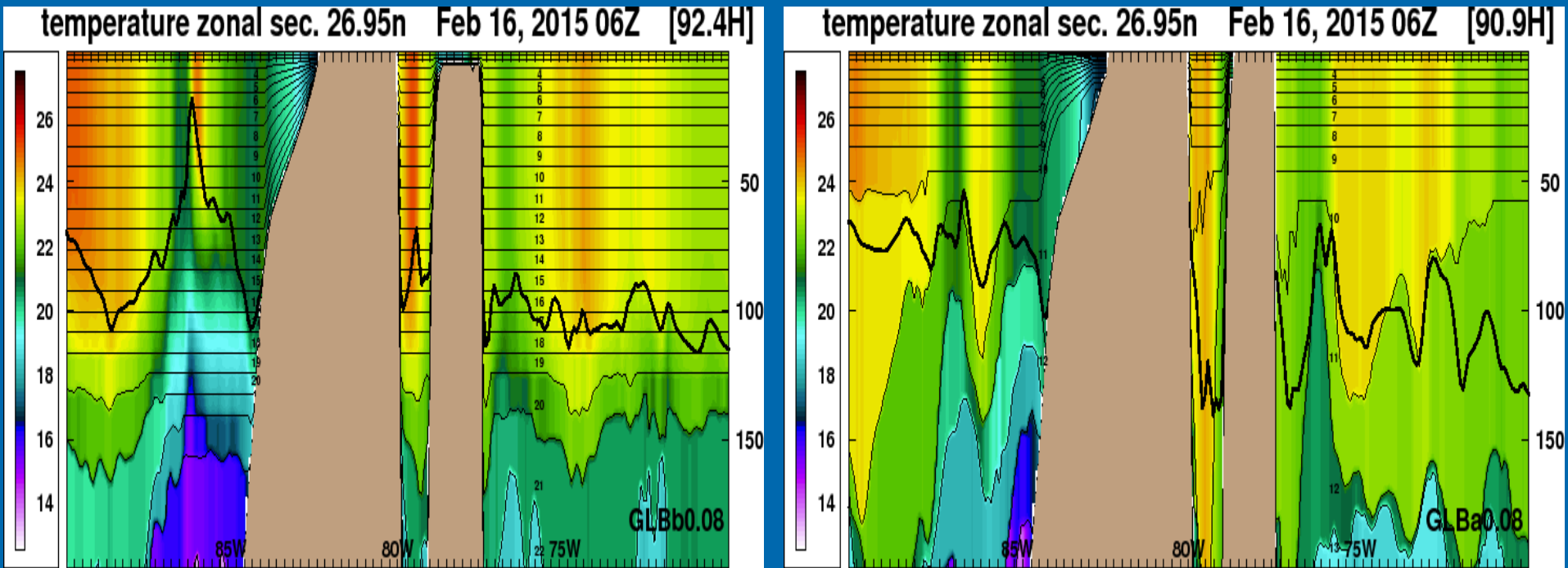
# RTOFS v1.1 vs RTOFS v1.0 Improvements in Bathymetry



RTOFS-Global SST v 1.1 (left) and version 1.0 (right). The shallow region north of Grand Bahamas is present in version 1.1 while it was masked as land in version 1.0.

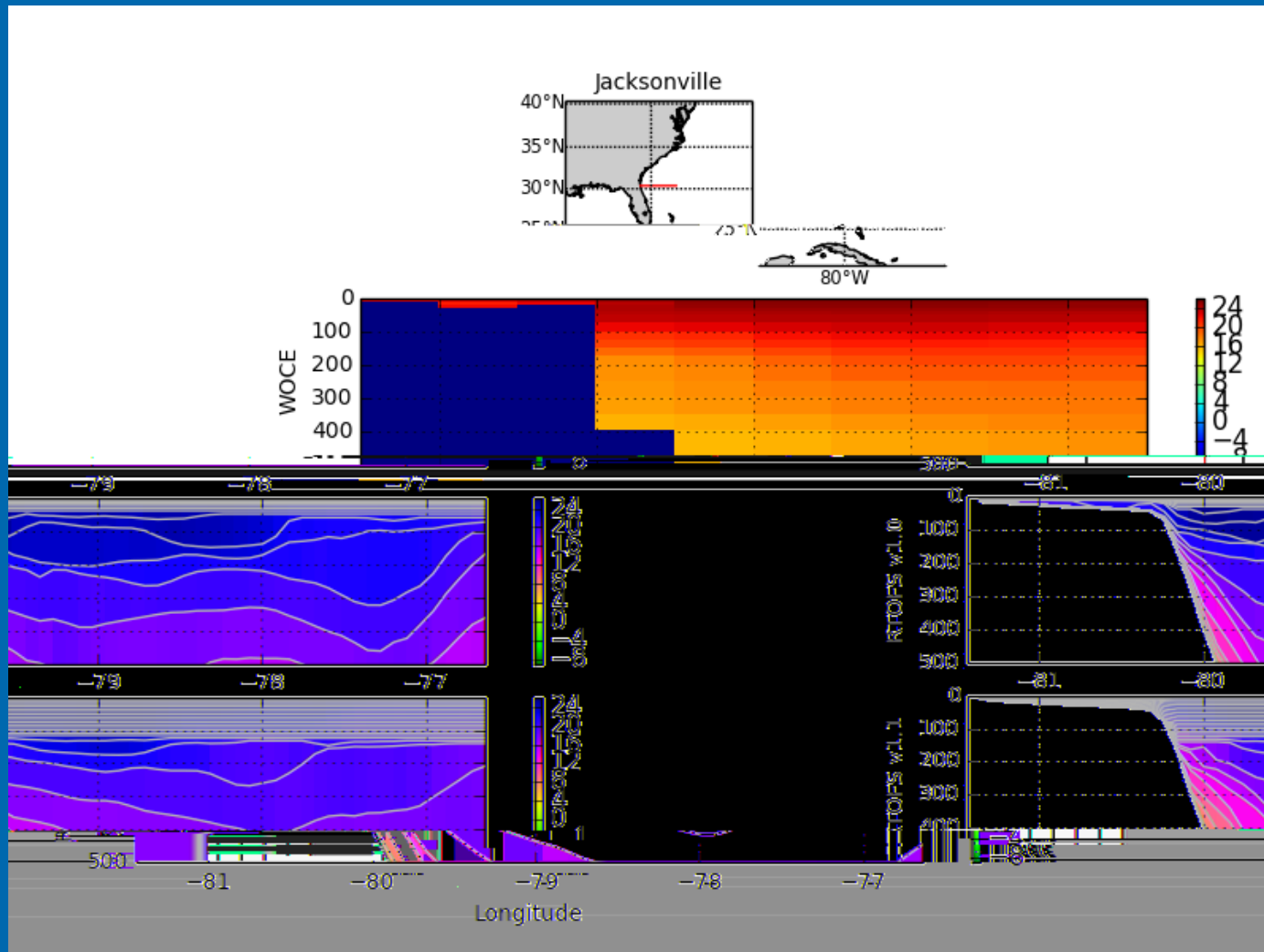
# RTOFS v1.1 vs RTOFS v1.0

## Zonal Temperature Cross Sections



Higher vertical resolution section at 27 N, passing just north of Grand Bahamas, from RTOFS-Global versions 1.1 (left) and version 1.0 (right).

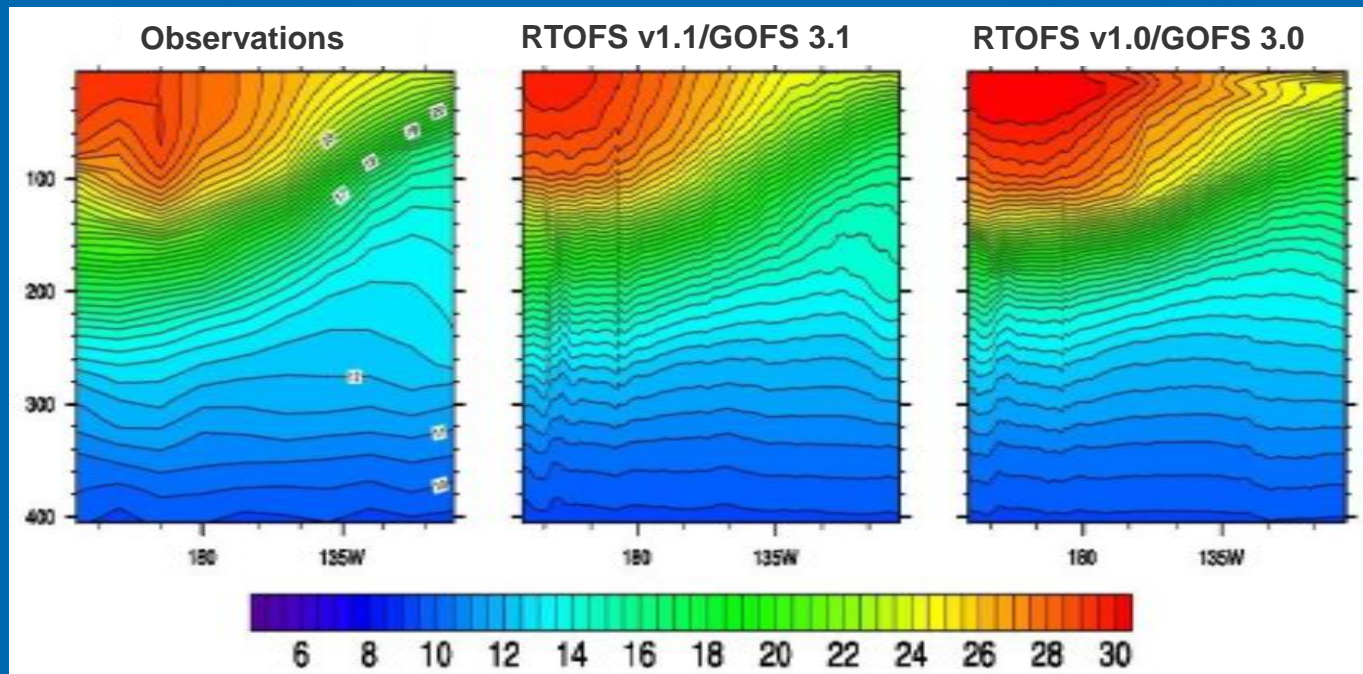
# WOCE vs RTOFS v1.0 vs RTOFS v1.1 Vertical Temperature Cross Section



Improved representation for both coastal ocean  
and deep ocean upper stratified layers

# Obs vs RTOFS v1.1 vs RTOFS v1.0

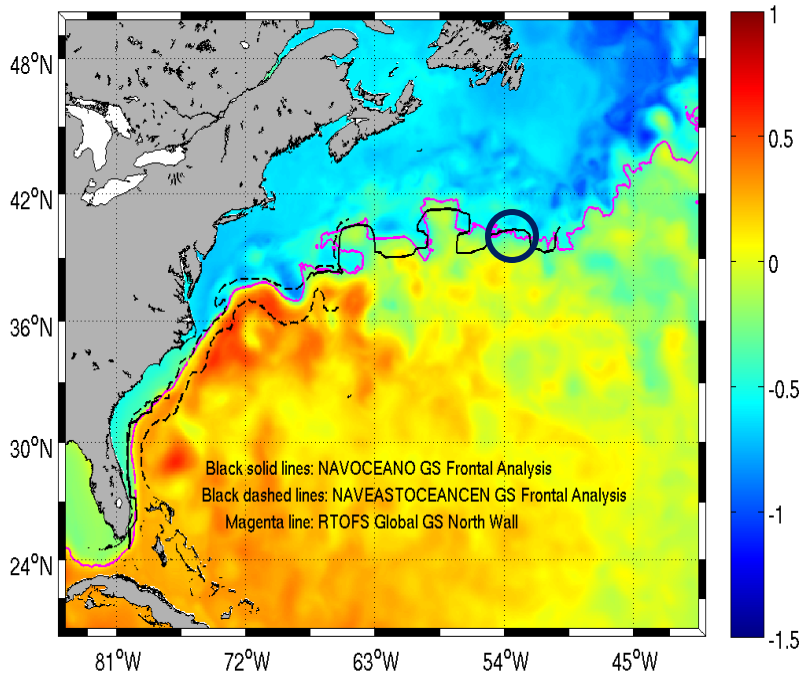
## Vertical Temperature Cross Section for Fall 2013



Better representation of warm pool/cold tongue in equatorial Pacific  
(reference: Pat Hogan@NRL)

# RTOFS v1.1 vs RTOFS v1.0

Global RTOFS Parallel GS Location for 26-Apr-2015  
12°C isoth at 400m and SSH



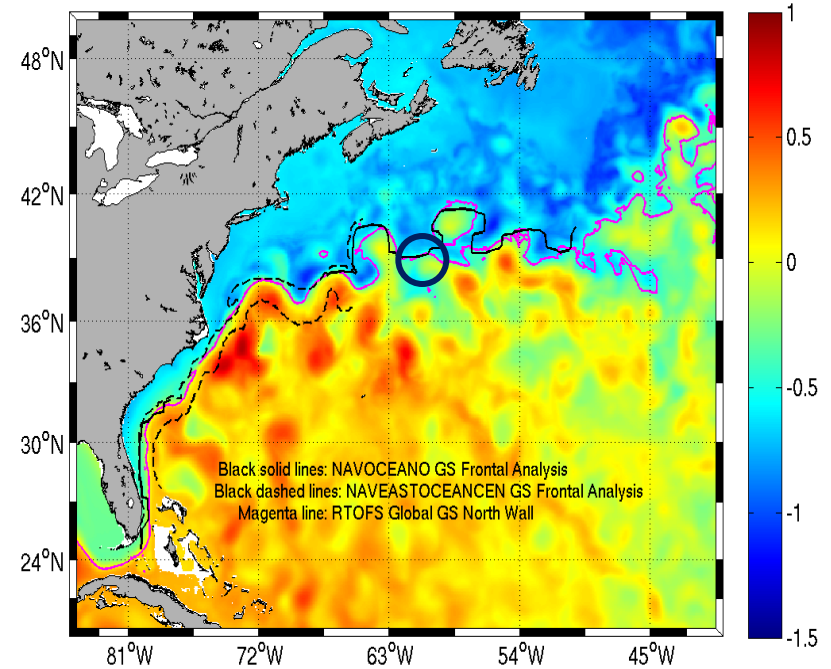
Black solid lines: NAVOCEANO GS Frontal Analysis  
Black dashed lines: NAVEASTOCEANCEN GS Frontal Analysis  
Magenta line: RTOFS Global GS North Wall

NAVOCEANO for 26-Apr-2015

NCEP/EMC/MMAB Global RTOFS PARALLEL NAVEASTOCEANCEN for 27-APR-15

27 Apr 2015

RTOFS Global GS Location for 26-Apr-2015  
12°C isoth at 400m and SSH



Black solid lines: NAVOCEANO GS Frontal Analysis  
Black dashed lines: NAVEASTOCEANCEN GS Frontal Analysis  
Magenta line: RTOFS Global GS North Wall

NAVOCEANO for 26-Apr-2015

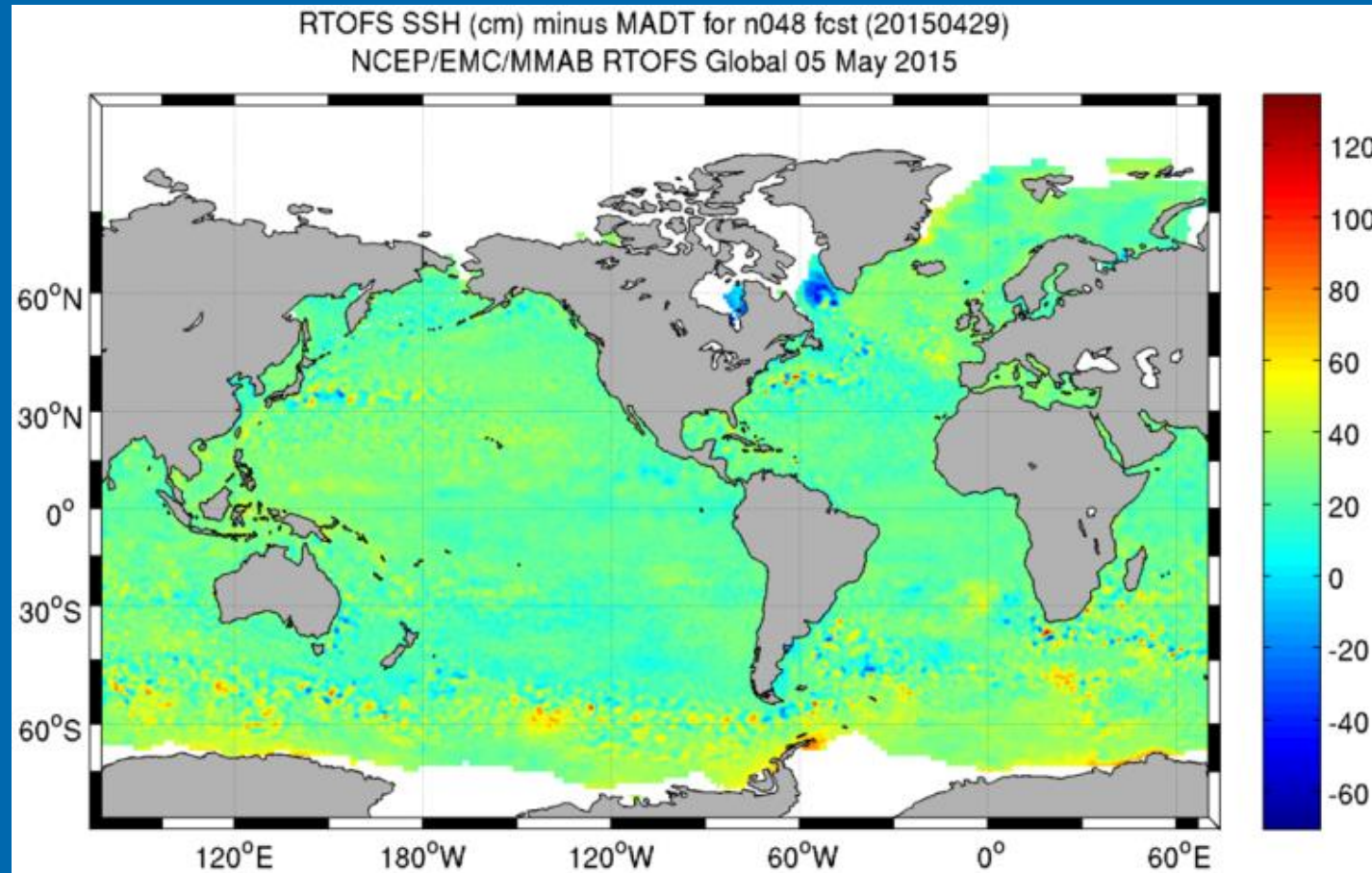
NCEP/EMC/MMAB RTOFS (Global)

NAVEASTOCEANCEN for 27-APR-15

27 Apr 2015

GS North Wall location very similar with small differences near meanders.  
OPC to help with quantitative Hausdorff distance measures

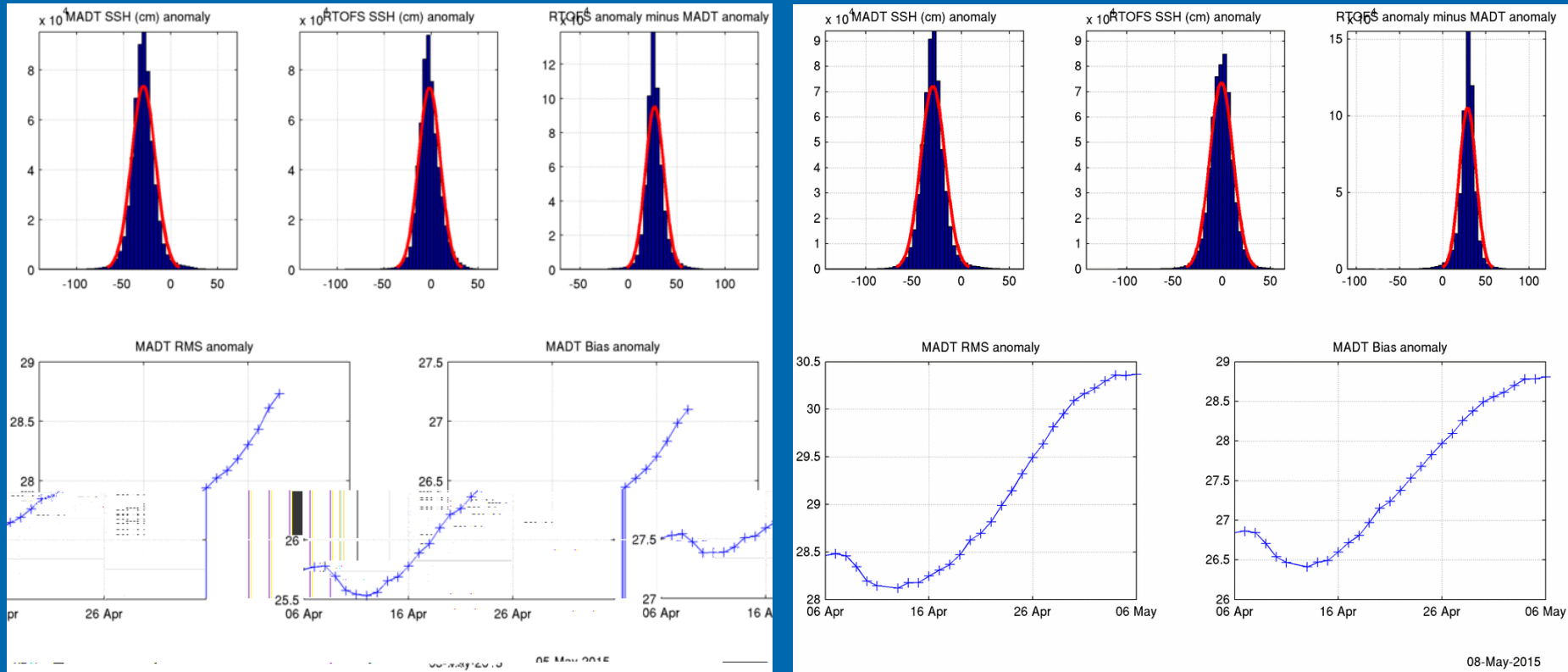
# RTOFS vs MADT SSHA



Most of the differences are in regions of large variability

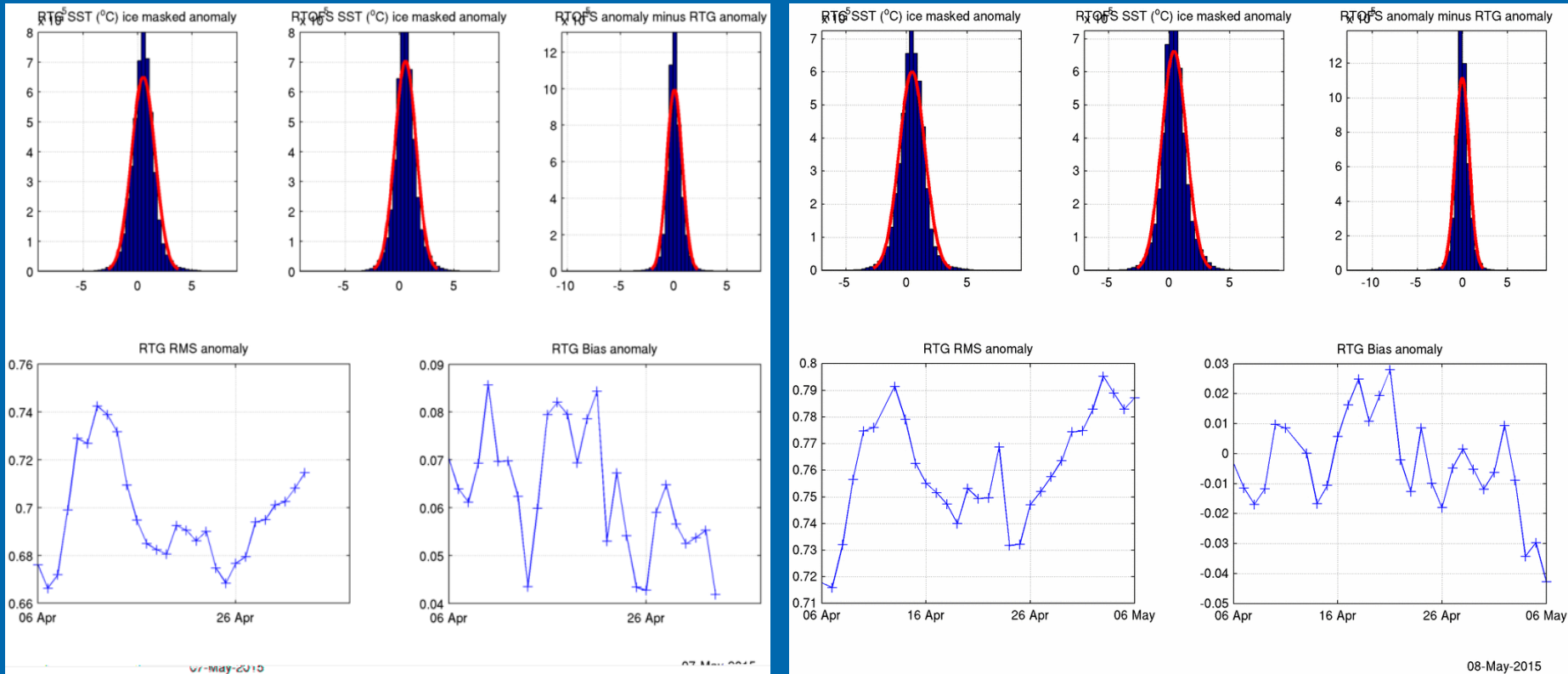


# RTOFS v1.1 vs RTOFS v1.0 vs MADT SSHA (Global)



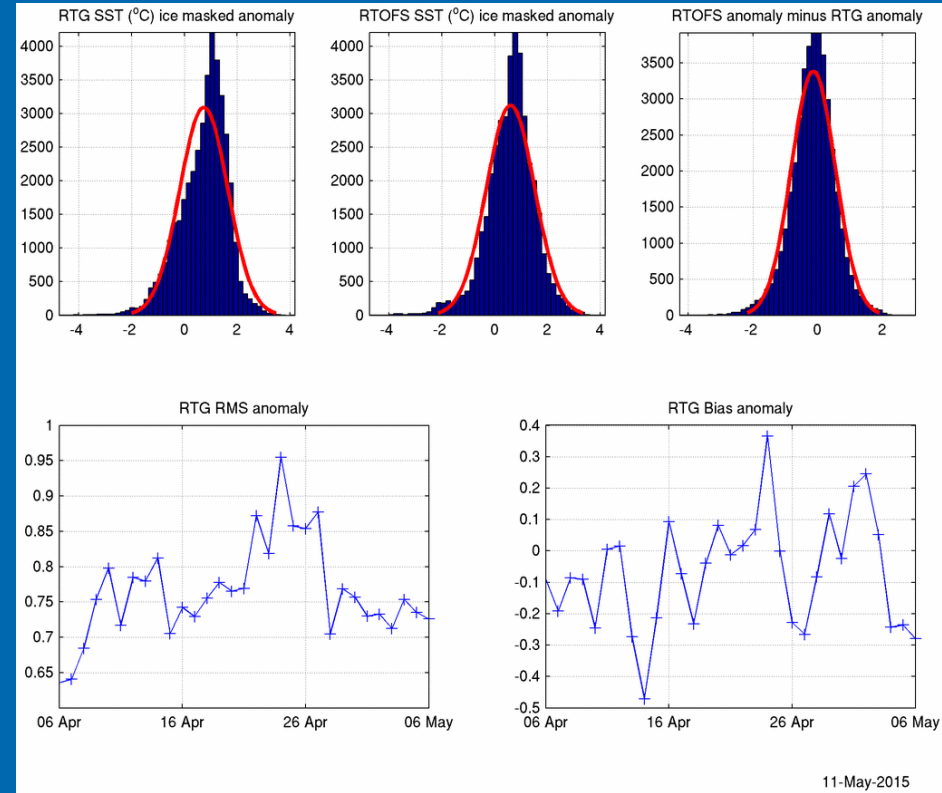
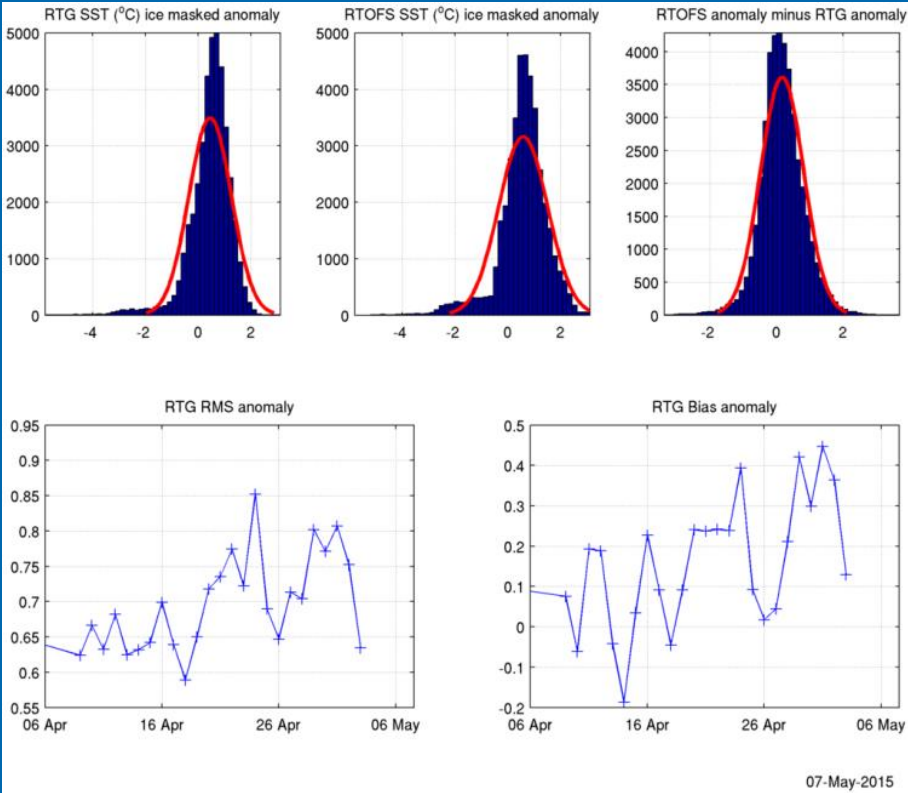
The two simulations are comparable with the parallel (left panel) performing marginally better (approx. 1 cm RMSE and bias).

# RTOFS v1.1 vs RTOFS v1.0 vs RTG SST (Global)



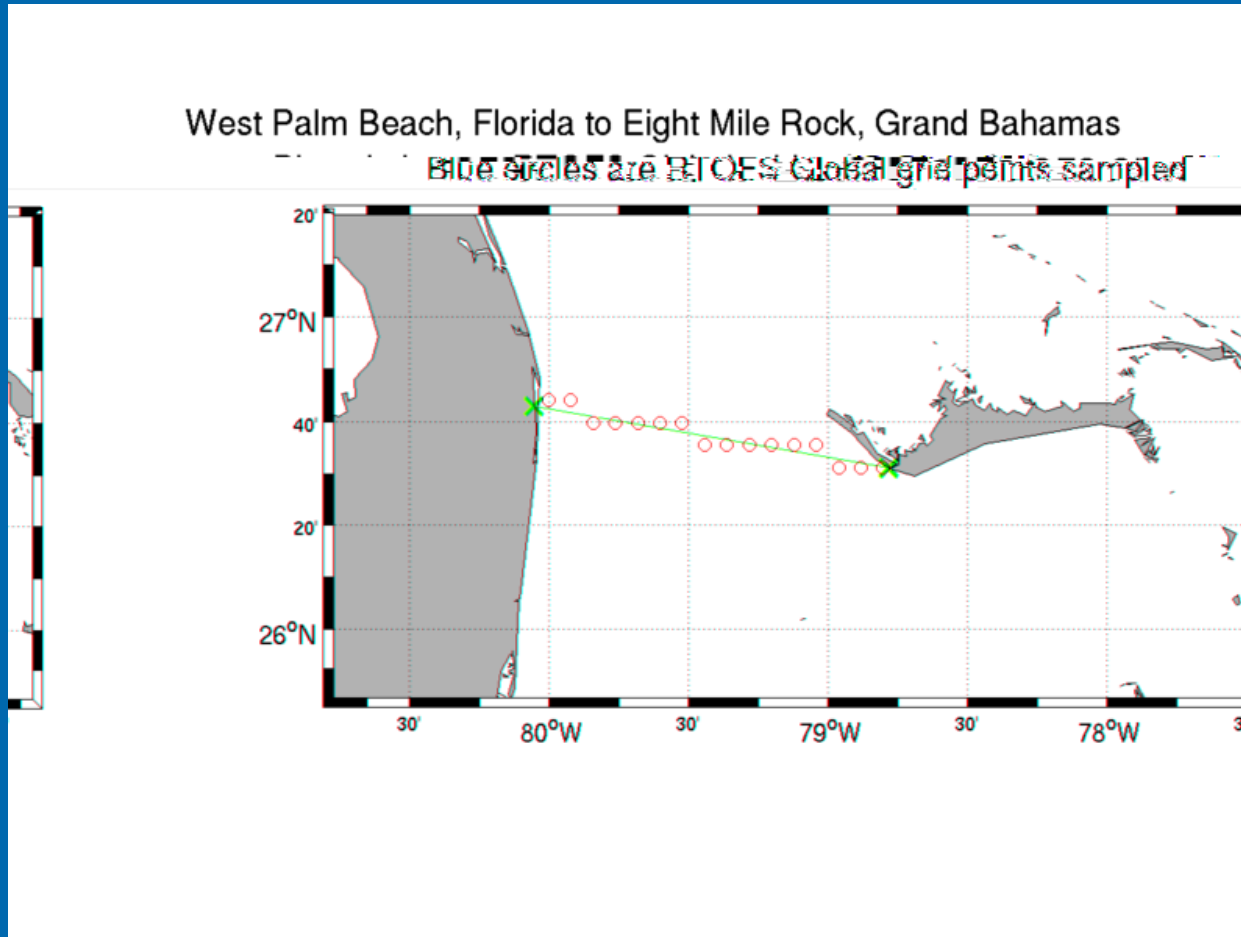
The two simulations are comparable with the parallel (left panel) performing marginally better with smaller RMSE but with a larger average bias/overestimation.

# RTOFS v1.1 vs RTOFS v1.0 vs RTG SST (Gulf of Mexico)



The two simulations are comparable with the parallel (left panel) performing marginally better with smaller RMSE but with a larger average bias/overestimation.

# Florida Cable Transports



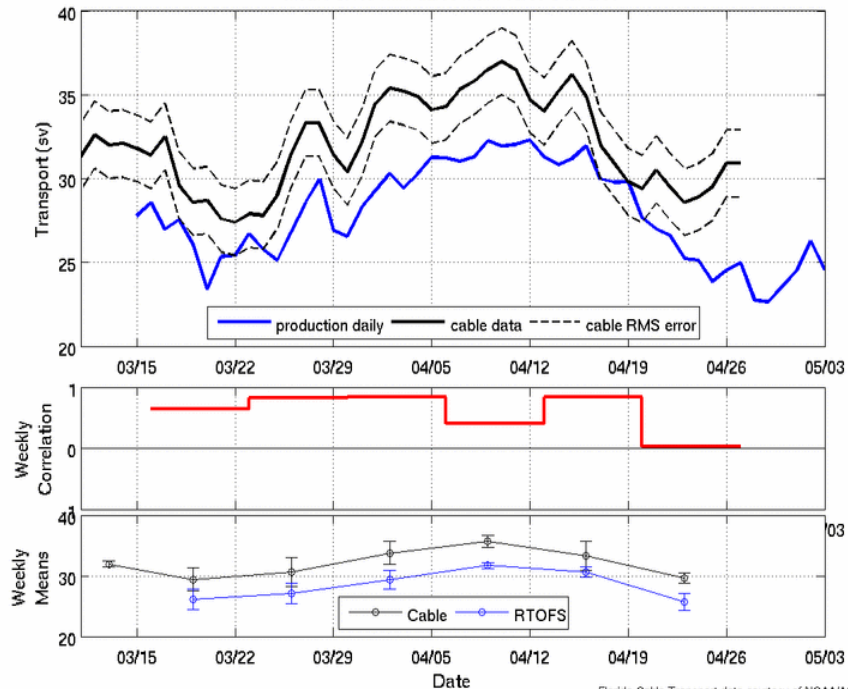
The transport variations of the Florida current using a submarine cable (data from NOAA/AOML ).

# Florida Cable Transports

## RTOFS v1.1 vs RTOFS v1.0

Florida Cable Transport compared to Global RTOFS Transport

Mean: 27.85 Min: 22.66 Max: 32.30 Std: 2.86

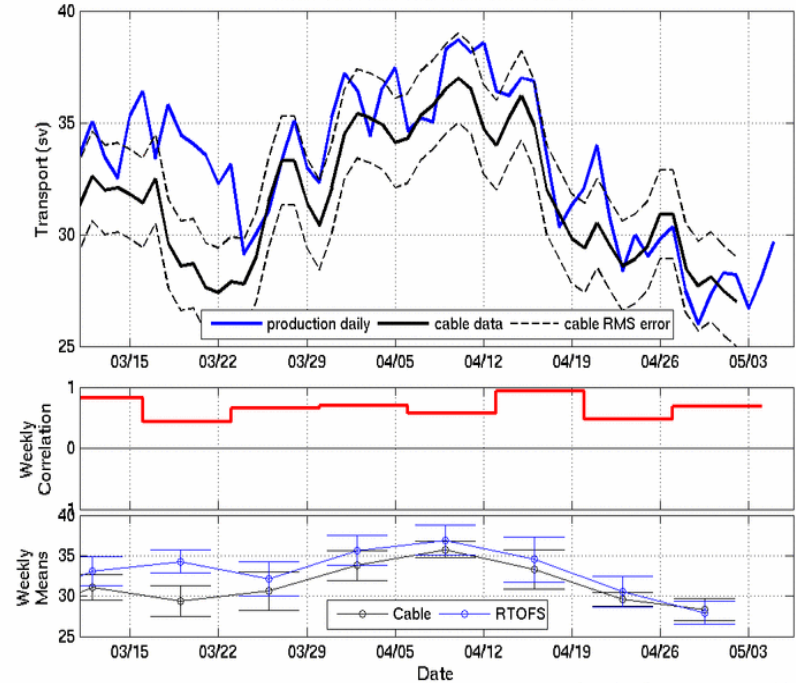


NCEP/EMC/MMAB Global RTOFS PARALLEL

Florida Cable Transport data courtesy of NOAA/ACML/PHOD  
06-May-2015

Florida Cable Transport compared to RTOFS Global Transport

Mean: 30.81 Min: 18.27 Max: 38.71 Std: 3.50

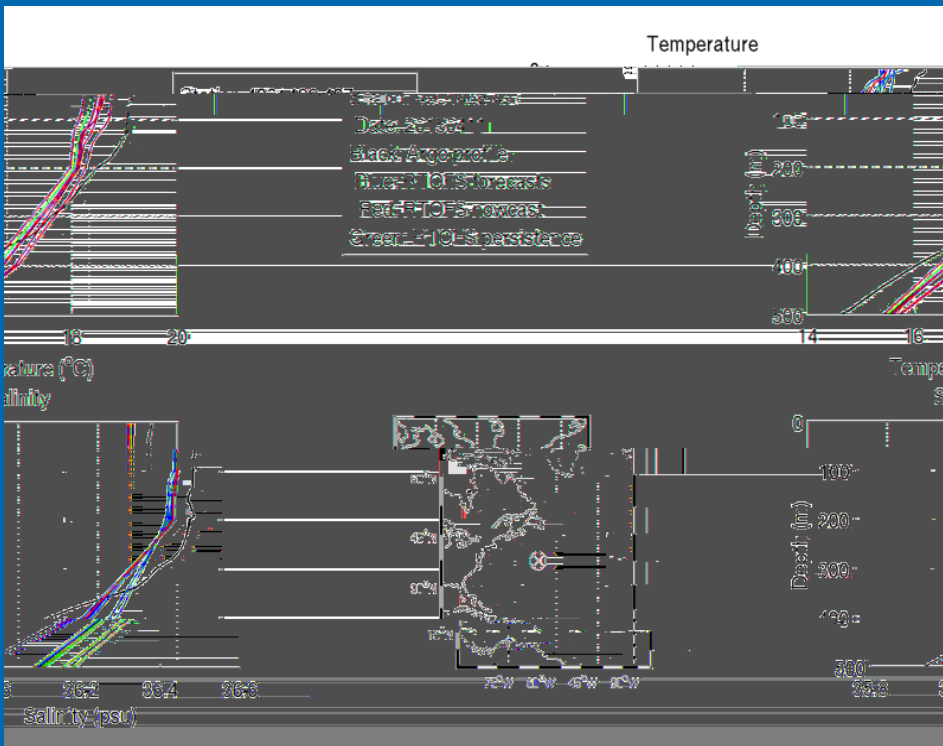


NCEP/EMC/MMAB RTOFS (Global)

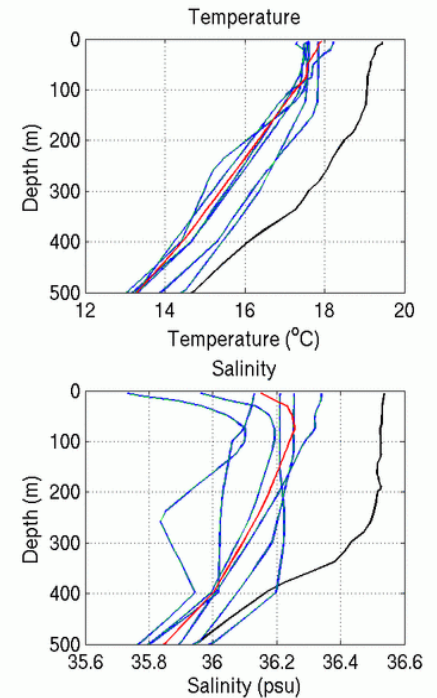
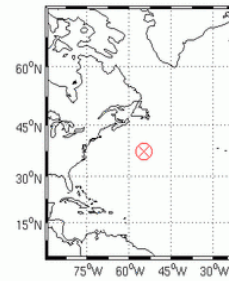
Florida Cable Transport data courtesy of NOAA/ACML/PHOD  
06-May-2015

Parallel (left panel) underestimates while prod overestimates. Less variability in the parallel due to higher vertical resolution of the fast moving current in the top 200m.

# RTOFS v1.1 vs RTOFS v1.0 Vs ARGO

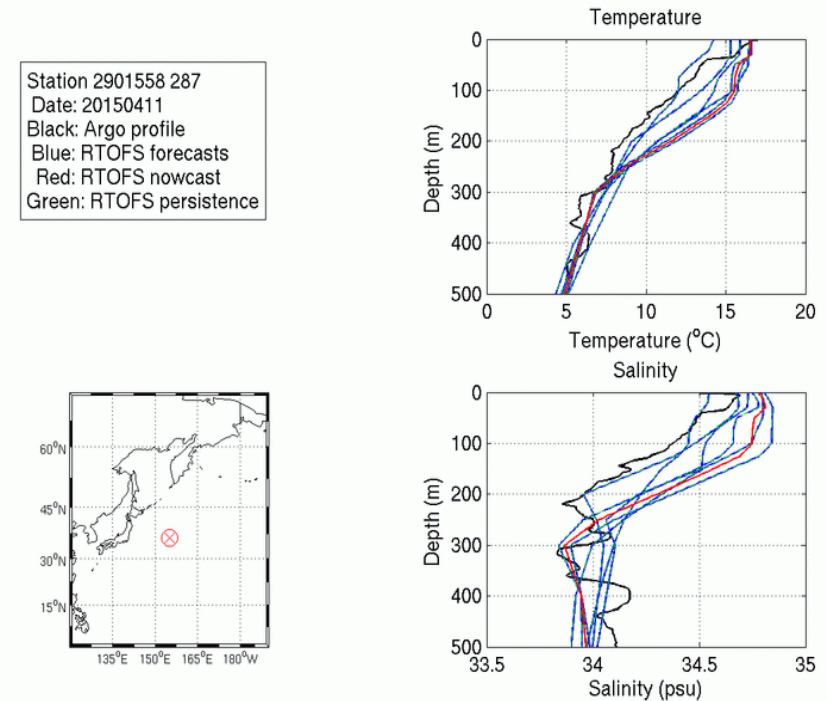
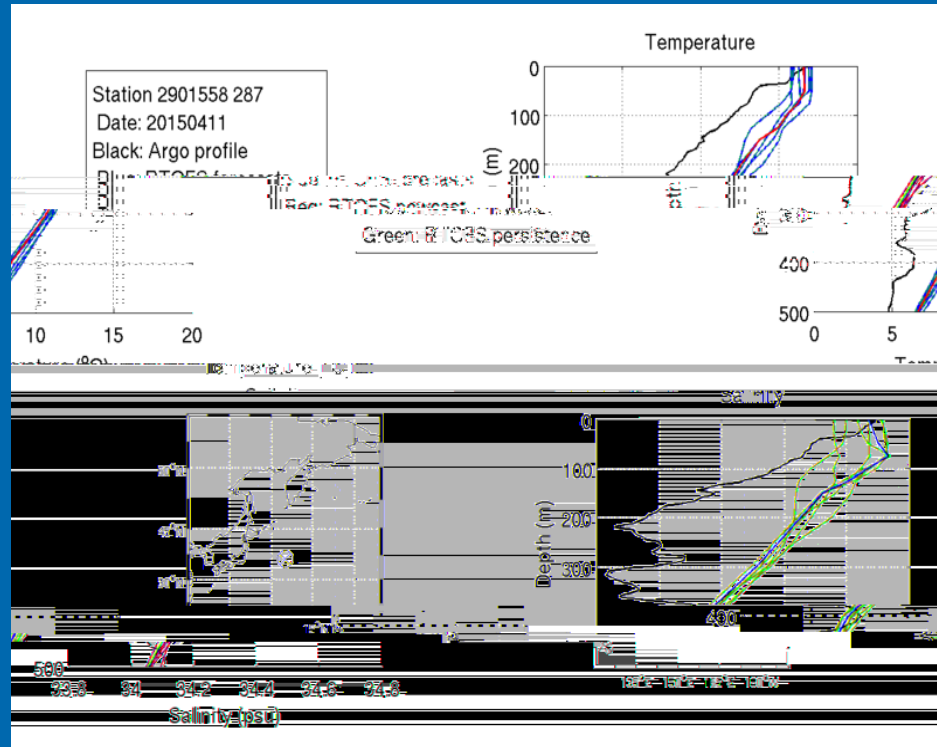


Station 4901466 497  
Date: 20150411  
Black: Argo profile  
Blue: RTOFS forecasts  
Red: RTOFS nowcast  
Green: RTOFS persistence



At this location, both parallel (left panel) T & S profiles show much better agreement with ARGO data and significantly less variability in forecasts especially for salinity.

# RTOFS v1.1 vs RTOFS v1.0 Vs ARGO

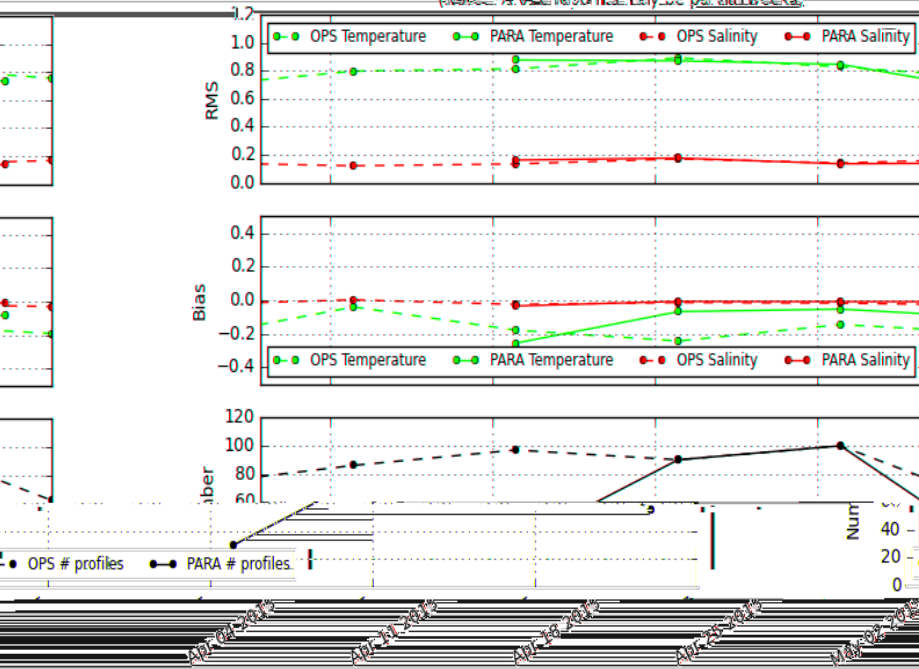


While at this location, production (right panel) T & S show much better agreement with ARGO data but enhanced variability in forecasts especially for salinity.

# RTOFS v1.1 vs RTOFS v1.0 Vs ARGO

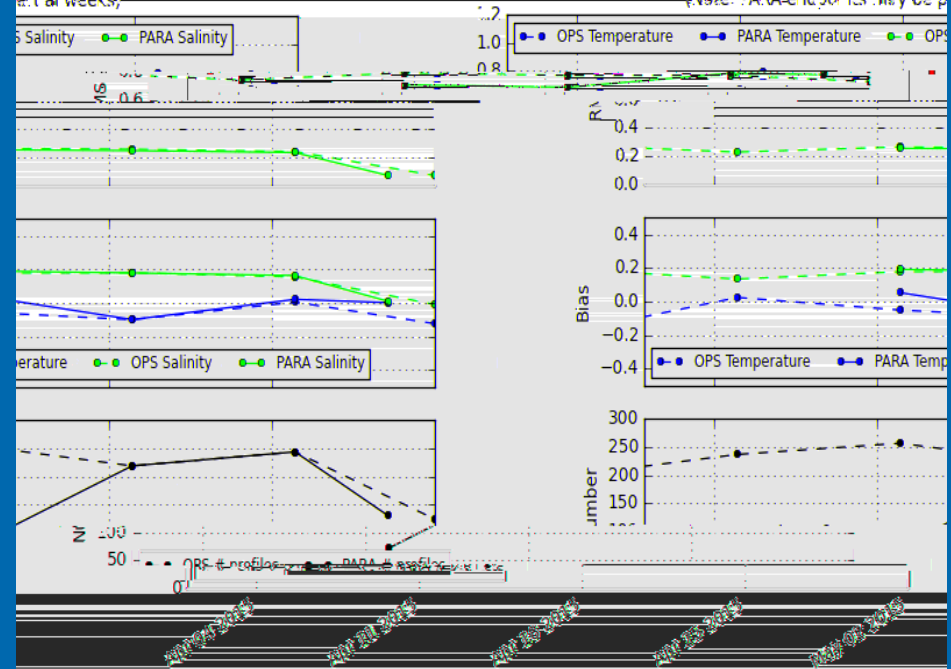
Gulf Stream Region Weekly Averages

(Note: A.V.A. end points may be partial weeks)



Kuroshio Region Weekly Averages

(Note: A.V.A. end points may be partial weeks)

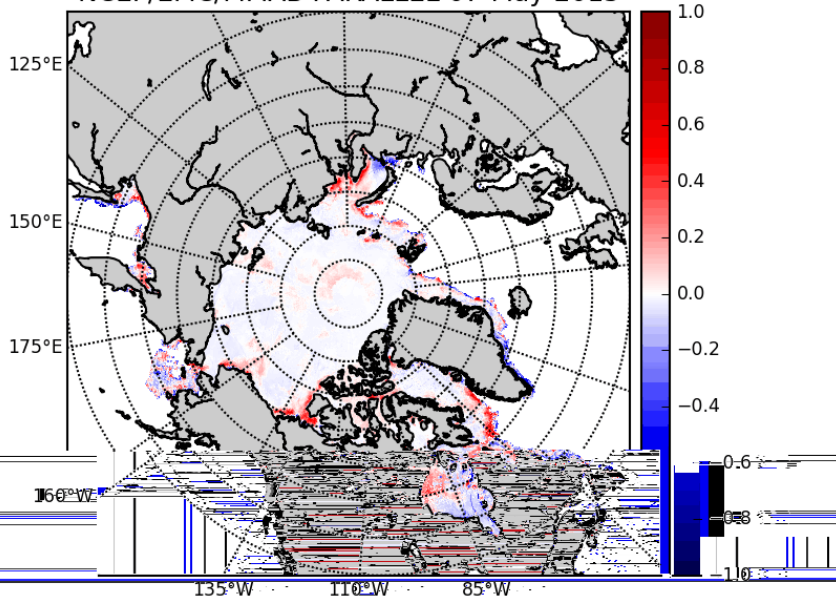


Weekly averaged (and depth averaged) profiles for these two regions show little difference between prod and para.

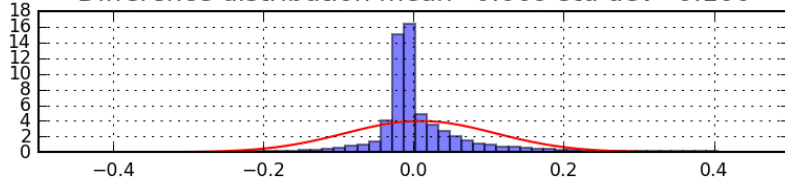


# Sea Ice Cover RTOFS v1.1. vs RTOFS v1.0 vs Analysis

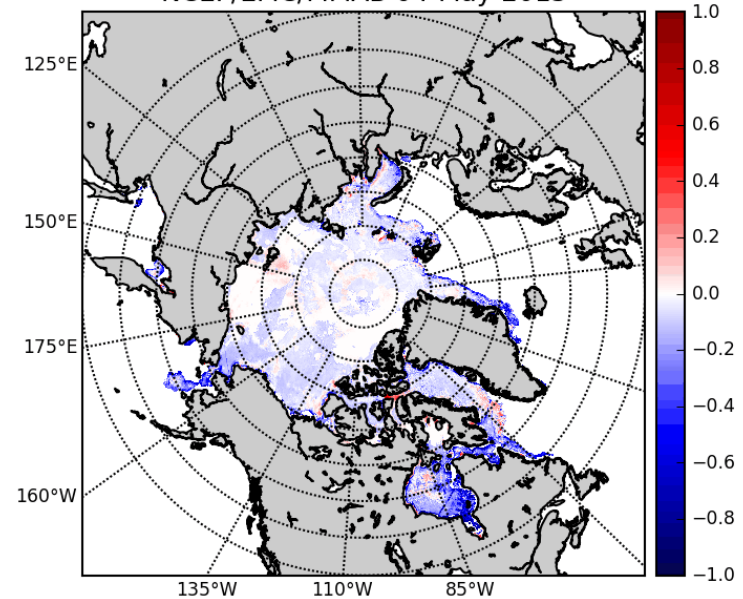
RTOFS PARALLEL minus NCEP ice cover for 20150503  
NCEP/EMC/MMAB PARALLEL 07-May-2015



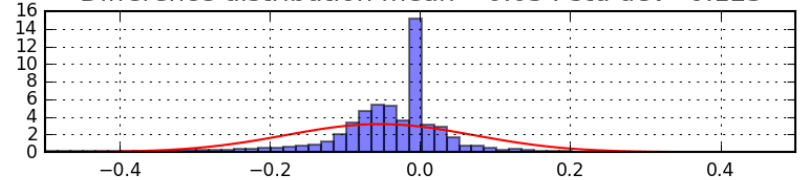
Difference distribution mean=0.009 std dev=0.100



RTOFS minus NCEP ice cover for 20150503  
NCEP/EMC/MMAB 04-May-2015

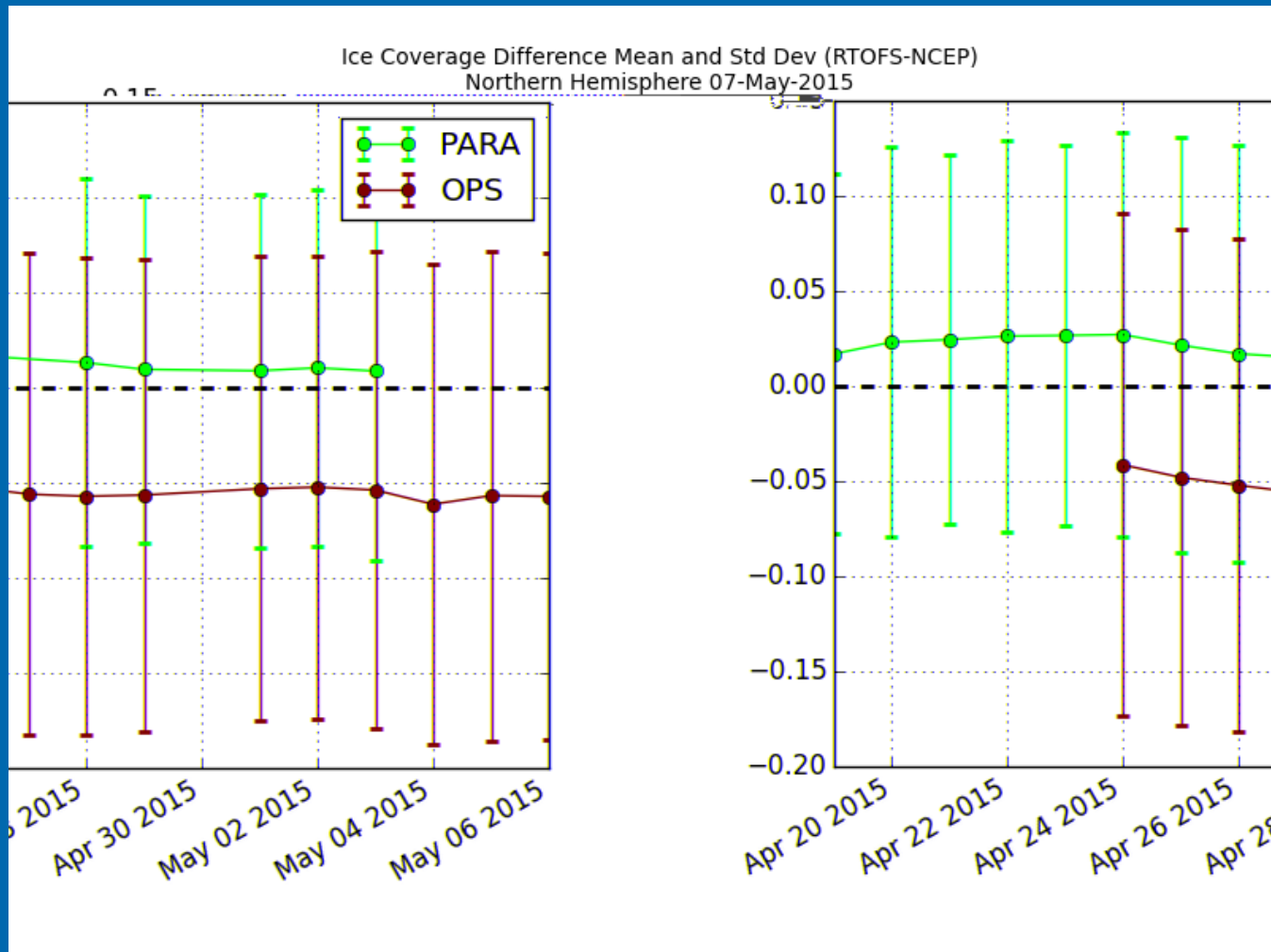


Difference distribution mean=-0.054 std dev=0.125



Differences in the Arctic region (May 2015)

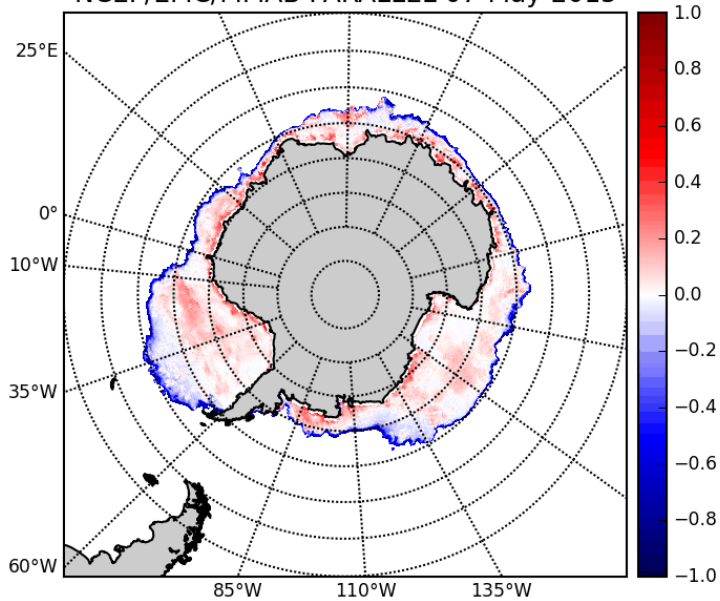
# Sea Ice Cover RTOFS v1.1. vs RTOFS v1.0 vs Analysis



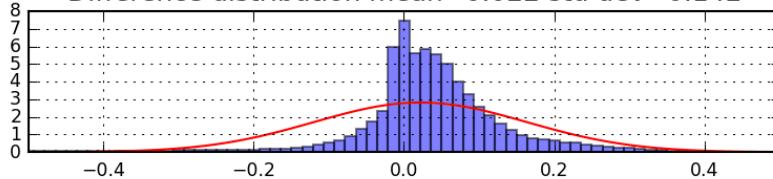
Mean differences in the Arctic region

# Sea Ice Cover RTOFS v1.1. vs RTOFS v1.0 vs Analysis

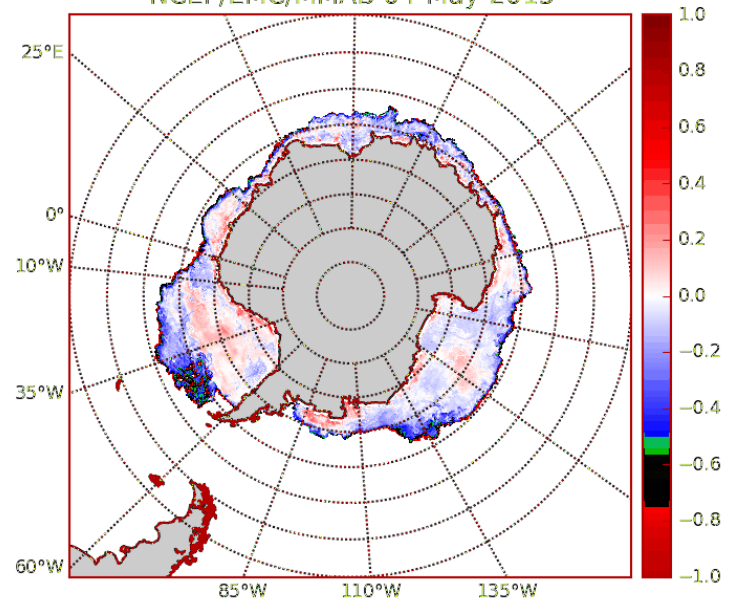
RTOFS PARALLEL minus NCEP ice cover for 20150503  
NCEP/EMC/MMAB PARALLEL 07-May-2015



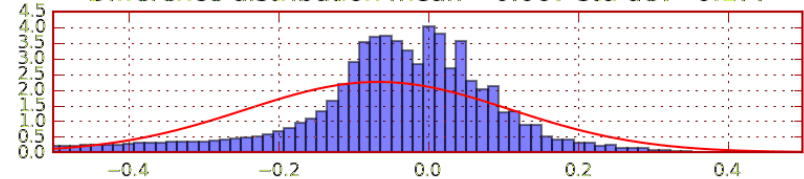
Difference distribution mean=0.022 std dev=0.142



RTOFS minus NCEP ice cover for 20150503  
NCEP/EMC/MMAB 04-May-2015

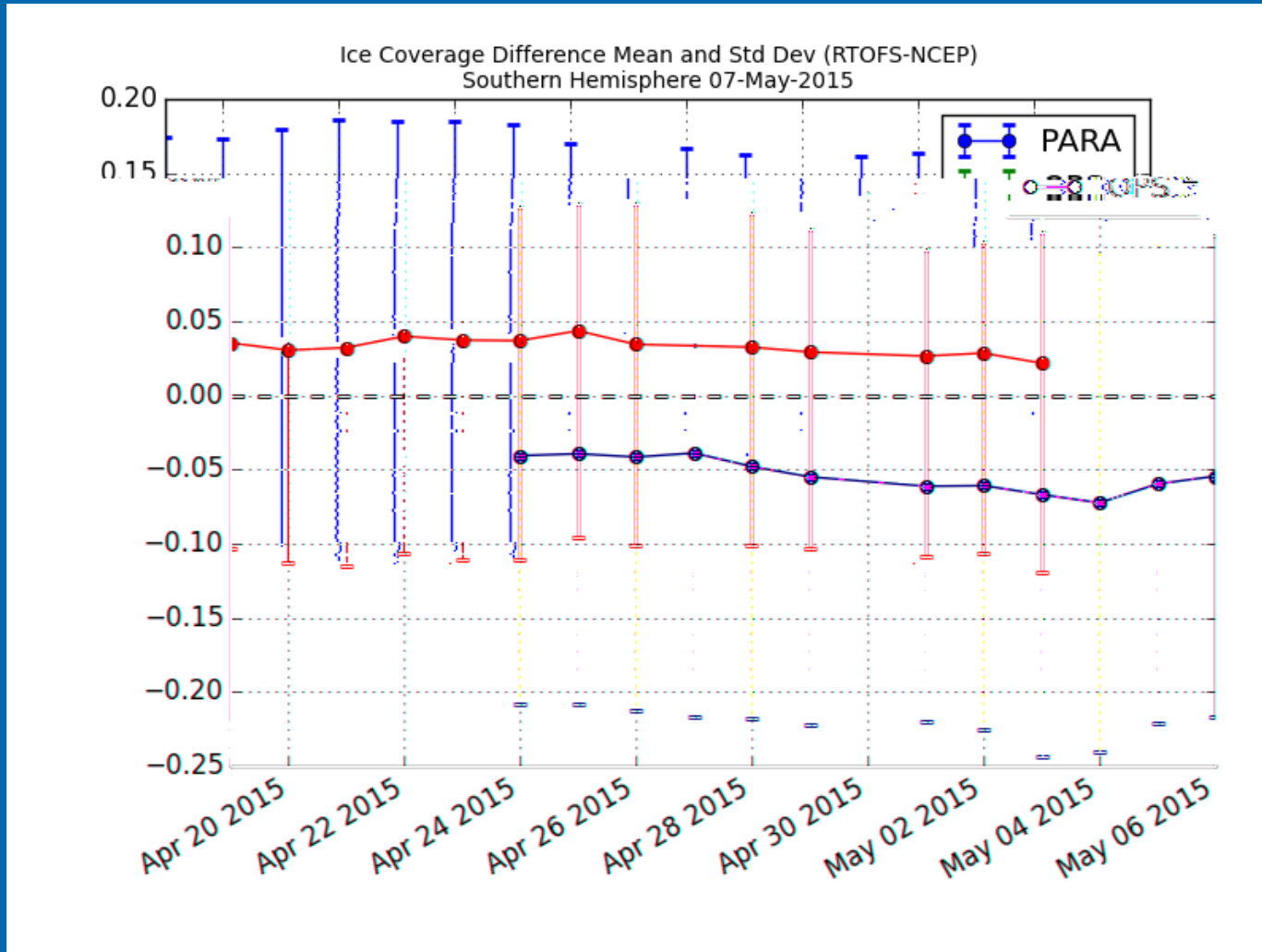


Difference distribution mean=-0.067 std dev=0.177



Differences in the Antarctic region (May 2015)

# Sea Ice Cover RTOFS v1.1. vs RTOFS v1.0 vs Analysis



Mean differences in the Antarctic region

# Version 1.1.0

## Primary impacts:

- Better coastline/water-mass representation for coupled applications (air-sea fluxes for Hurricanes)
- Finer resolution for mixed layer (9 additional near surface layers)
- Improved vertical coastal resolution for downstream applications
- Improved Sea Ice coverage in polar regions
- Additional ice products/forecasts (ice thickness, ice concentration, ice drift and speed)

# Resources

- CPU: **v1.1** 1800 PE or 75 nodes  
**v1.0** 2134 PE or 134 nodes
- Runtime: **v1.1** 18 minutes per day  
**v1.0** 10 minutes per day
- Disc: **v1.1** ~25% more than **v1.0** (CICE files, 41 levels, OPC products)
- Workflow: **v1.1** same as **v1.0**

# RTOFS-Global v1.0 Product Suite

- Class I : Global netCDF files on native horizontal grid but interpolated to isolevels. Delivery via NOMADS, ftpprd and ~~NODC archives.~~
  - Surface 3 hourly files (8 variables) ~ 120 GB per cycle
  - Volume 3d files daily (8 variables, 33 Z levels) ~ 160 GB per cycle.

Target: General user; maximum flexibility for slicing/dicing data using NOMADS/OpenDAP servers (both GDS & TDS).

- Class II: Sub-regional and basin GRIB2 files on Mercator grid. Delivery via ftpprd and AWIPS.

Surface 3 hourly files (7 variables) ~ 5 GB per cycle

Target: Internal NWS needs to provide results on AWIPS or via FTP.

# RTOFS-Global v1.0 Product Suite

- Class III: Regional (CONUS-East, CONUS-West, Alaska) netCDF files.

Delivery via NOMADS and ftpprd.

- Volume 6 hourly files (u,v,T,S)

Target: Other centers within NCEP (NHC, OPC) and NOS OFS systems

- Daily graphics available via web (polar) with restricted access to daily monitoring metrics

Target: General public, collaborators



# RTOFS-Global v1.1 Additional Products

- Additional n000, f000 data for aggregated variables from GDS/NOMADS servers
- OPC: Global NetCDF files (time series of variables)

Delivery via OPC ftp servers.

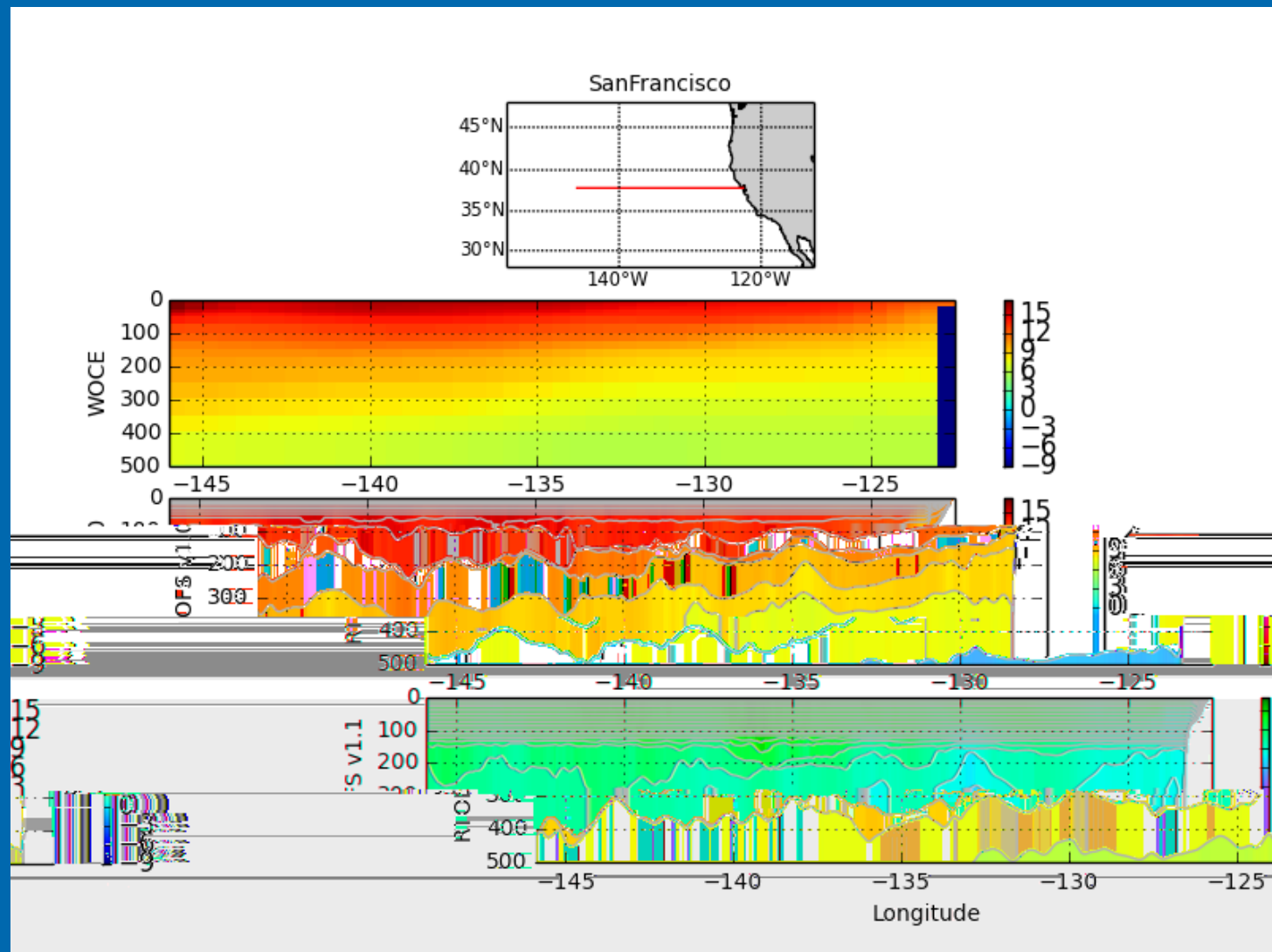
- Surface hourly files (u, v, T, S, SSH)

Target: OPC, USCG/SAROPS

- Product upgrade planned for FY16 Q2 (Sea Ice, HWRF-HYCOM, Ecosystems)

Back Up

# WOCE vs RTOFS v1.0 vs RTOFS v1.1 Vertical Temperature Cross Section



Higher vertical resolution for upper ocean processes (mixed layer)

# Recent upgrades for v1.0

- GRIB2 output to ops (OSIP) (Dec: 2013)
- Seven NOS regions use BC's in Coastal Ocean Modeling Framework (March 2014)
- 2 IOOS RA's (NANOOS, GOMOOS) also use v1.0 for BC's. (March 2014)