NGGPS Ocean/Waves/Sea Ice Projects

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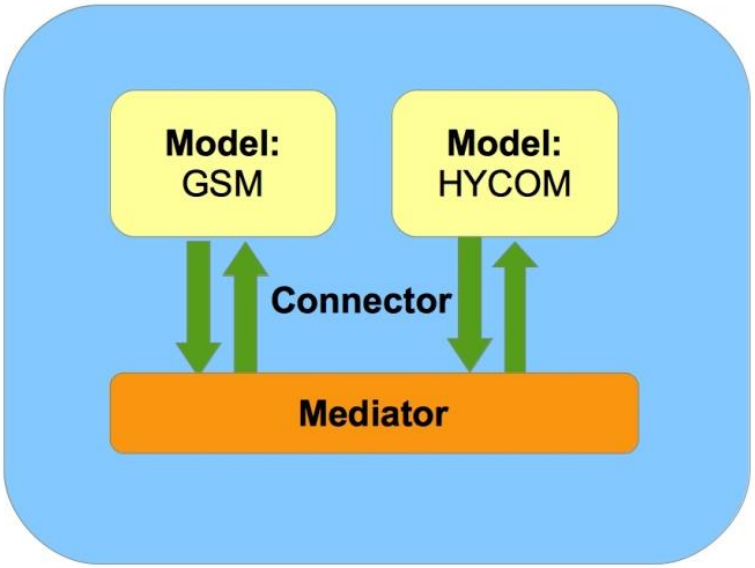
Outline

- EMC Ocean Projects (3)
- EMC Wave Projects (2)
- Other Internal/External Projects (2)
- Major Accomplishments
- Priority Focus for 2016
- Primary Needs
- Brief on NGGPS Sea Ice workshop (Ligia)

EMC: HYCOM in NEMS

- EMC Software Engineer/Scientist (1 FTE Supported by NGGPS)
- Collaborators : Cecelia's Group; NRL – Alan Wallcraft;
- Work Completed
  - A NUOPC cap for HYCOM using ESMF calls
  - HYCOM running coupled to GSM (GFS) in NEMS
- Work in progress
  - Adding HYCOM to the UGCS seasonal and weather-scale systems
  - Testing 3-way coupling with GSM-HYCOM-CICE
- Deliverables (end of year)
  - HYCOM running in NEMS in a 3-way coupled GSM-HYCOM-CICE system

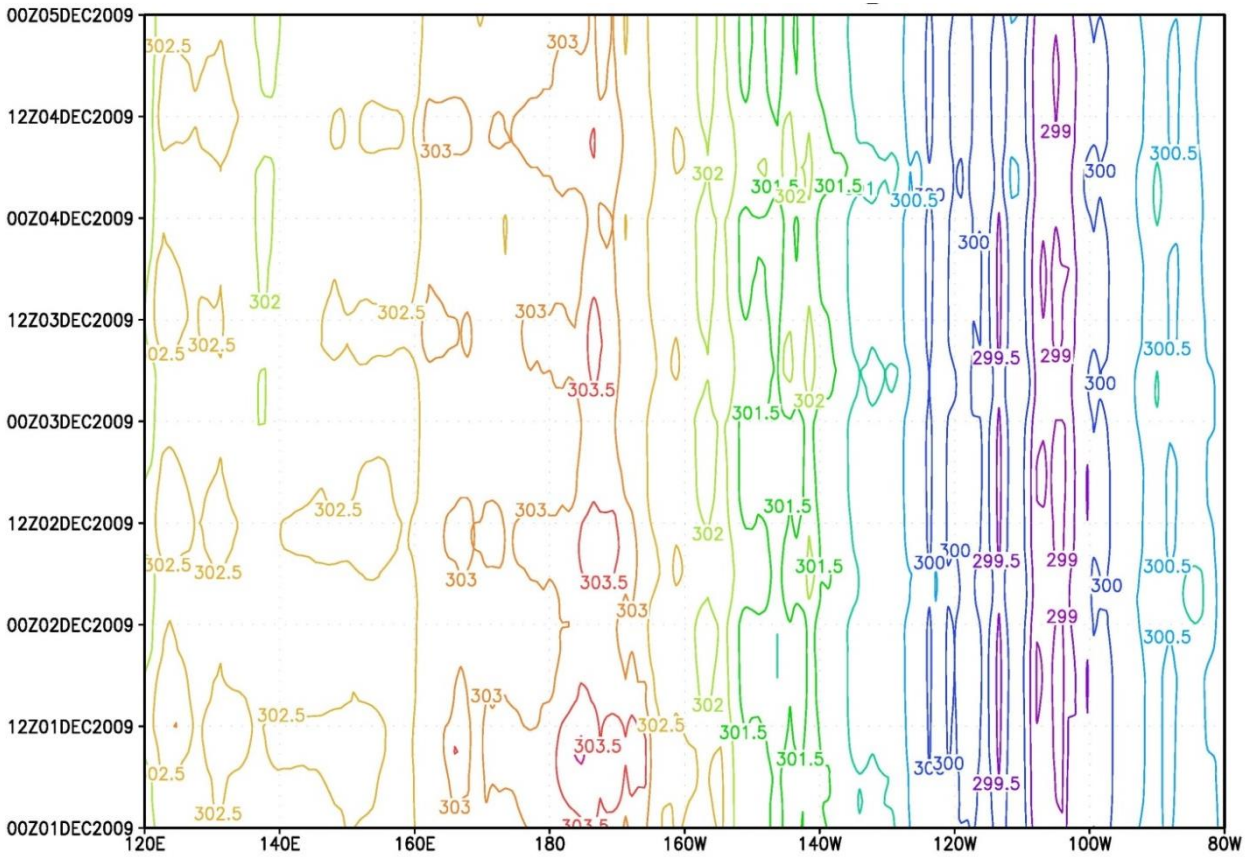
EMC: HYCOM in NEMS



- GSM uses the global Gaussian T126 grid
- HYCOM uses the global 0.24 degree tri-polar grid
- Coupling time interval between Mediator (coupler) and HYCOM: 2 hours
- Coupling time interval between Mediator (coupler) and GSM: 1 hour
- Length of run: 4 days

EMC: HYCOM in NEMS

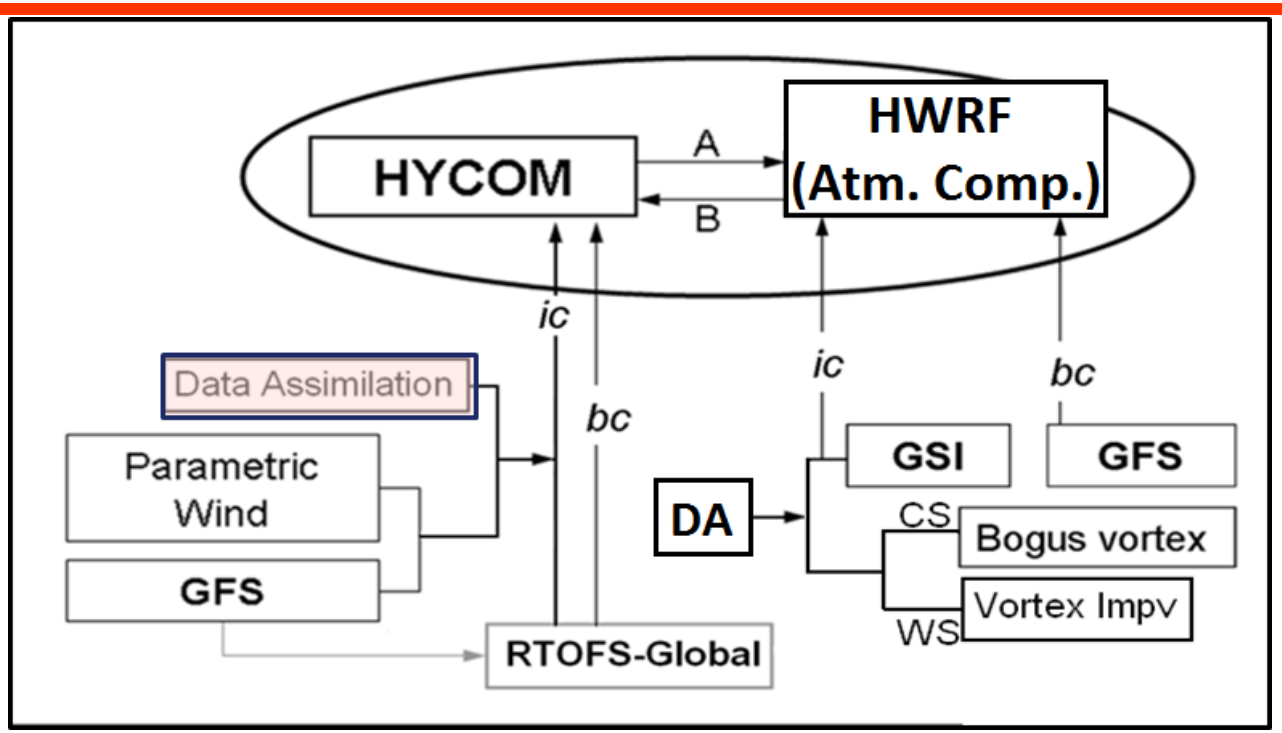
SST along 3ºN



EMC: HYCOM-HWRF Coupling

- EMC Software Engineer (1 FTE supported by NGGPS)
- Collaborators : URI, AOML
- Work Completed
  - Porting of HYCOM running scripts to HWRF infrastructure (in Python)
- Work in progress
  - Build a robust initialization procedure for the coupled system
  - Testing of the coupled system in real-time
  - Investigate 3-way coupling with WaveWatch III®
- Deliverables (end of year)
  - Operationally ready HYCOM-HWRF coupled system for all basins

EMC: HYCOM-HWRF Coupling



Exchange Variables

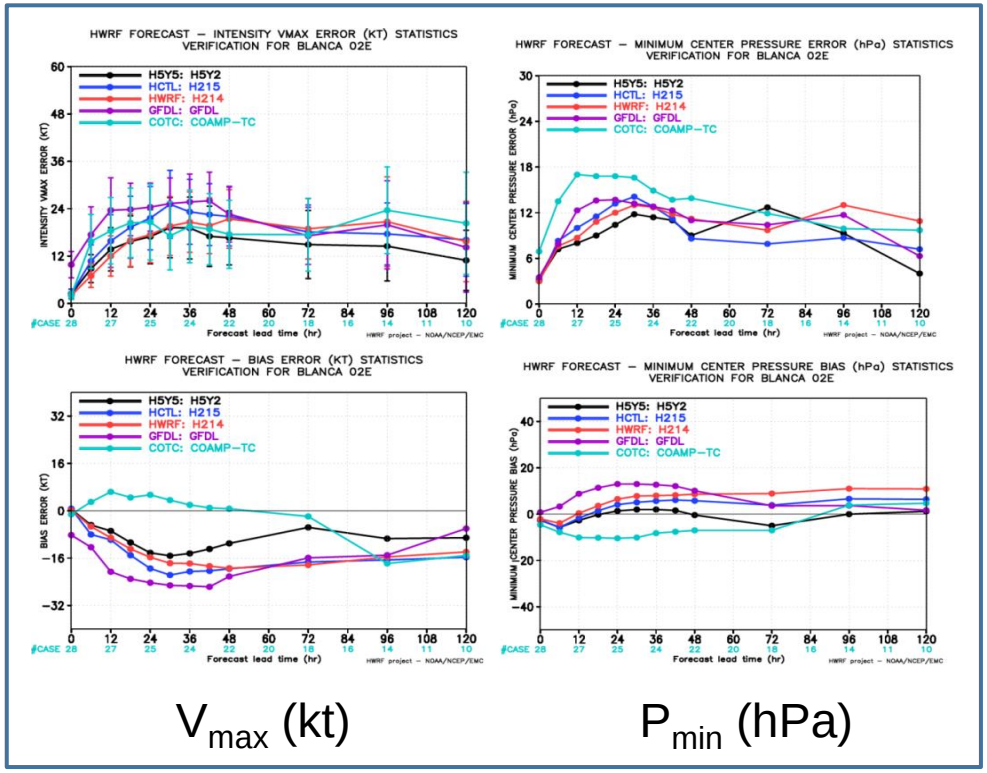
A: Sea surface temperature (SST)

B: 1. Precipitation
2. Atmospheric pressure
3. Heat fluxes
4. Wind stress

ic = initial Conditions
bc = boundary conditions
CS/WS = cold/warm start
DA = data assimilation
GFS = Global Forecast System
GSI = Gridpoint Statistical Interpolation

EMC: HYCOM-HWRF Coupling

Hurricane Blanca (2015): Intensity Forecast Verification



V_{max} (kt) P_{min} (hPa)

2015 HWRF coupled to HYCOM performs best for early lead hours, cf POM coupling, H214 and other non-HWRF's, as much as 12 kt (12h cf GFDL) or 11 hPa (12h cf COTC).

EMC: Operational Upgrades of RTOFS

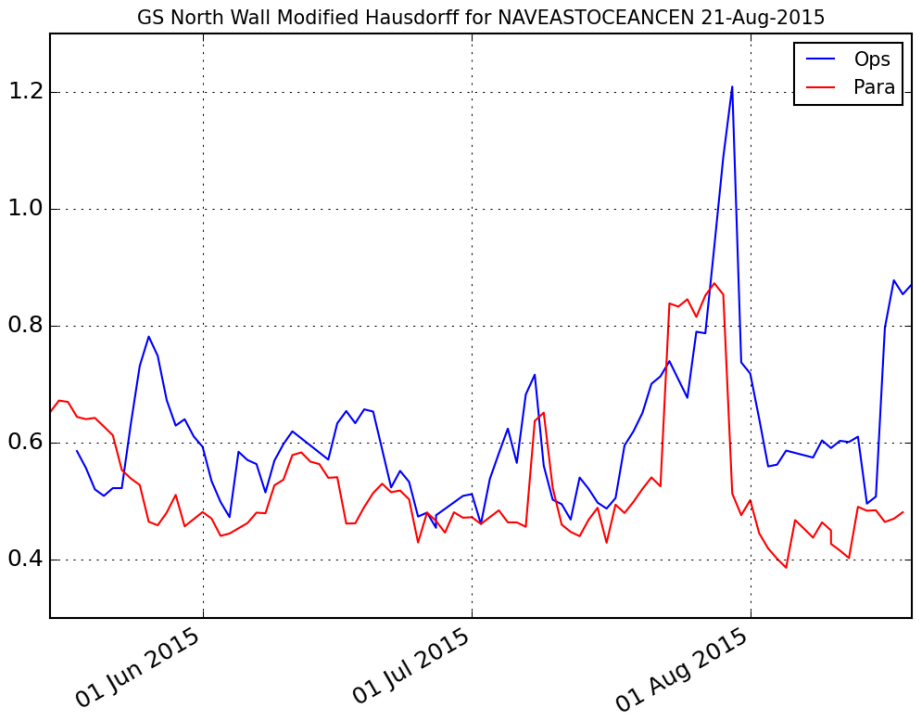
- EMC Scientist: New Hire (1 FTE supported by NGGPS)
- Collaborators : NRL – Stennis, NAVOCEANO
- Work Completed
  - Operational upgrade of Global RTOFS has been approved by NCEP OD
- Work in progress
  - Calculations of heat flux bias corrections based on 2016 GFS upgrade
  - Development of new products
  - Porting to Cray
  - Testing NCODA for test regions
- Deliverables (end of year)
  - Monthly heat flux bias corrections
  - New products for AWIPS/AWIPS2
  - Implementation on Cray

EMC: Operational Upgrades of RTOFS

Primary upgrades (developed by NRL):

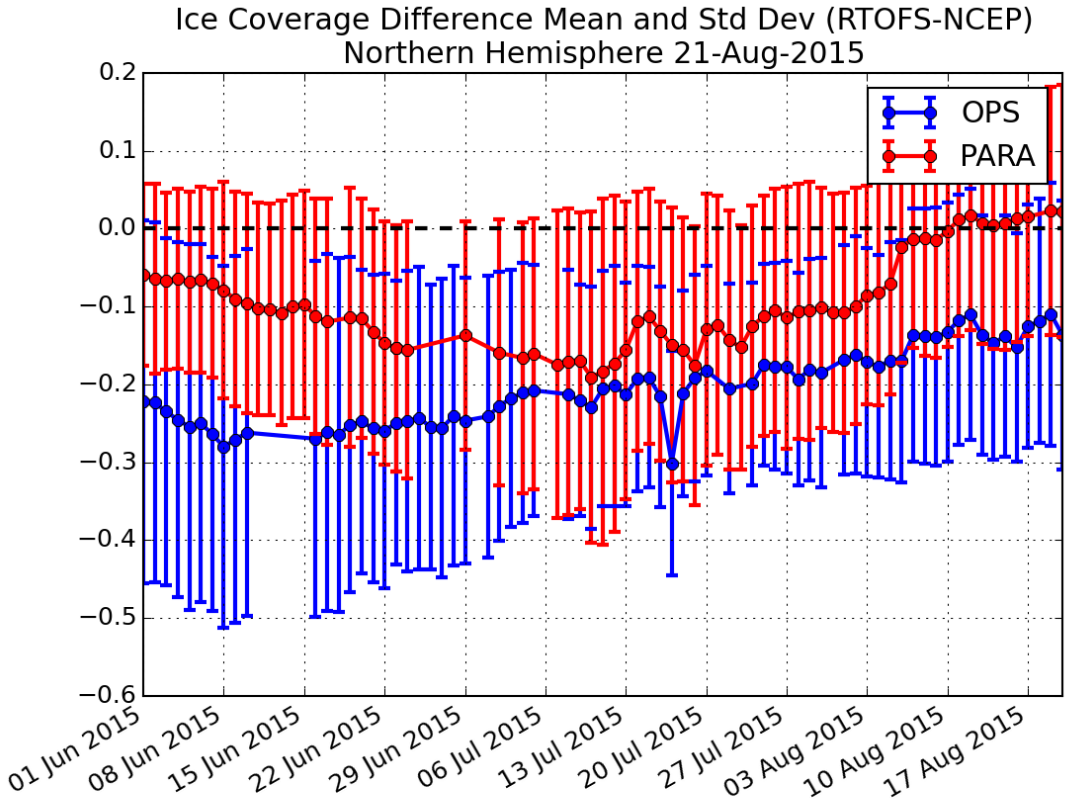
- 41 hybrid layers (increased from 32 layers)
  - Air-Sea boundary flux improvements for coupled applications (including Hurricanes)
  - Finer resolution for mixed layer (9 additional near surface layers)
  - Improved vertical coastal resolution for downstream applications (NOS OFS, IOOS RA's)
- Two-way coupled HYCOM with Los Alamos CICE (**C**ommunity **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

EMC: Operational Upgrades of RTOFS



RTOFS parallel better at following the GS North Wall estimate from IR imagery

EMC: Operational Upgrades of RTOFS



Mean differences in the Arctic region

EMC: Waves in NEMS

- EMC Software Engineer/Scientist (1 FTE Supported by NGGPS)
- Collaborators : NRL – Tim Campbell ; Cecelia's Group
- Work Completed
  - A NUOPC cap for the WAVEWATCH III model using ESMF calls
- Work in progress
  - Adding the WAVEWATCH III model to the UGCS seasonal system.
    - The wave model is being coupled one way so that the wind fields from GSM can be used to drive the wave model. Wave model has been verified to run using the GSM grids and wind field. Currently debugging to make the code run by passing wind fields through the coupler
- Deliverables (end of year)
  - Having the wave model run in the UGCS system one way (wave model driven with atmospheric model)
  - Build the feedback coupling from the wave model to the atmospheric model (sea state dependent drag formulation)
    - This is already computed inside the wave model right now. Need to build the coupling connections when the wind data transfer to the wave model is complete and working

EMC: Waves in NEMS

- Deliverables (end of next year)
  - Build the connections between the wave model and the ocean model
    - From the ocean model – currents averaged over wave representative depth
    - From the wave model – Stokes drift for wave induced Langmuir mixing, wave length for peak frequency (to provide representative depth)
    - Variables needed to parametrize wave induced mixing in ocean models are already being computed in the wave model, and both MOM6 and versions of HYCOM have developed wave induced mixing parametrizations.
- Future plans
  - Build ocean – wave –atmosphere coupled systems for global, regional and hurricane applications
    - Global development is currently under way for UGCS application
    - A coupled hurricane system (and associated physics packages) has been developed in partnership with URI using an in house NCEP coupler (will be transitioned to NEMS)
    - Planning talks have begun to couple waves model (in unstructured grid formulation) with atmospheric and circulation models (like FVCOM)

EMC: Wave Data Assimilation

- EMC Scientist (1 FTE supported by NGGPS)
- UMD collaboration : Steve Penny (leveraging with work for the coupled DA for the climate system ; other proposed research ideas to improve skill scores beyond week 2)
- See next slide for planned work
- Deliverables
  - An analysis of wave fields as part of RTMA ~ FY16
  - An LETKF based DA system for wave model ~ FY17 (prototype will be tested with the UGCS DA project)
  - A GSI based variational system for deterministic system ~ FY17

EMC: Wave Data Assimilation

Variational

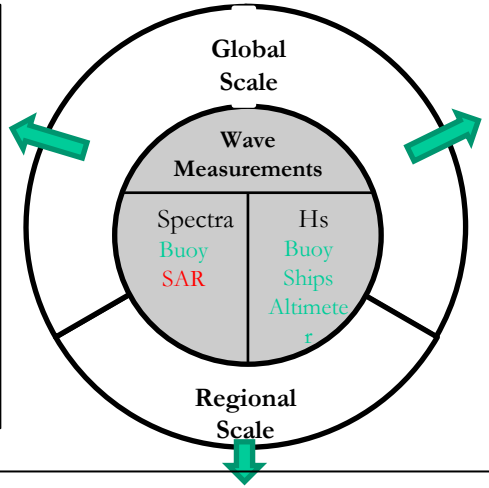
Objective: Development of Variational DA systems for Hs

Based on Behringer et al 1998

Previous Experience: 2D-Var DA for Hs (Chen et al 2004), 5D-Var DA for SWAN (Orzech et al 2014)

Delivarable : Operational Analysis of the Multi_1 and GLW (deterministic) wave field.

T2O: FY17.



Kalman Filter

Objective: Development of LETKF – WW3 systems for Hs

Based on LETKF (Penny et. al 2016)

Previous experience: Development of experimental prototype by Etala, 2015, (sponsored by JCSDA).

Delivarable : Operational Analysis of the GWES (ensemble) wave field.

T2O: FY17.

GSI in collaboration with Mesoscale Group

Objective: Adding Hs analysis product to URMA , **Based on** URMA (Pondeca et al 2011), **Delivarable** : High-resolution, hourly operational analysis of wave-height Hs (2.5 km spatial resolution). **T2O:** FY16.

Common Modules:

Data pre-processing for DA (Osychny, JCSDA project)

Weighting of Flampouris et al 2014

Leveraging:

1 - Use previous DA expertise in EMC, and state-of-art techniques,
2 - LETKF development made in tandem with strategy in CFS
3 – Provide datasets to project Improving GWES Products Beyond Week 2 (submitted to OSTI/NGGPS funding #2016-2004713)

UMD: Ocean-LETKF Software Development

- Lead PI: Dr. Steve Penny
- Collaborators: EMC, INCOIS (India), NASA GMAO, NRL-SSC and INPE(Brazil)
- Codebase available on Github.com repository for restricted access
- Baseline Ocean-LETKF data assimilation systems have been set up with MOM6 and HYCOM
  - Includes conversion to generalized vertical coordinate from standard z-coordinate
  - Includes improved optimization for large grids (due to higher resolution)

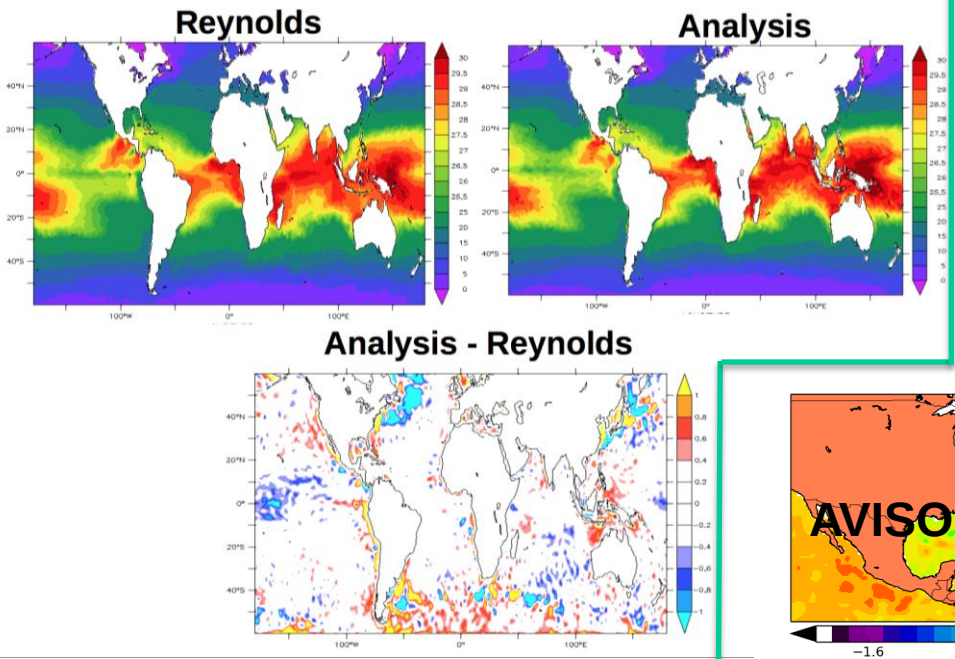
UMD: Ocean-LETKF Software Development

New Observation Types not currently assimilated in operations (type and progress to date):

- L2 SLA Altimetry (21-yr reanalysis experiment)
- L2 SST (initial validation completed)
- L2 SSS (initial validation completed)
- L2 ADT Altimetry (early testing phase)
- GDP Surface drifter velocities (early testing phase)

UMD: Ocean-LETKF Software Development

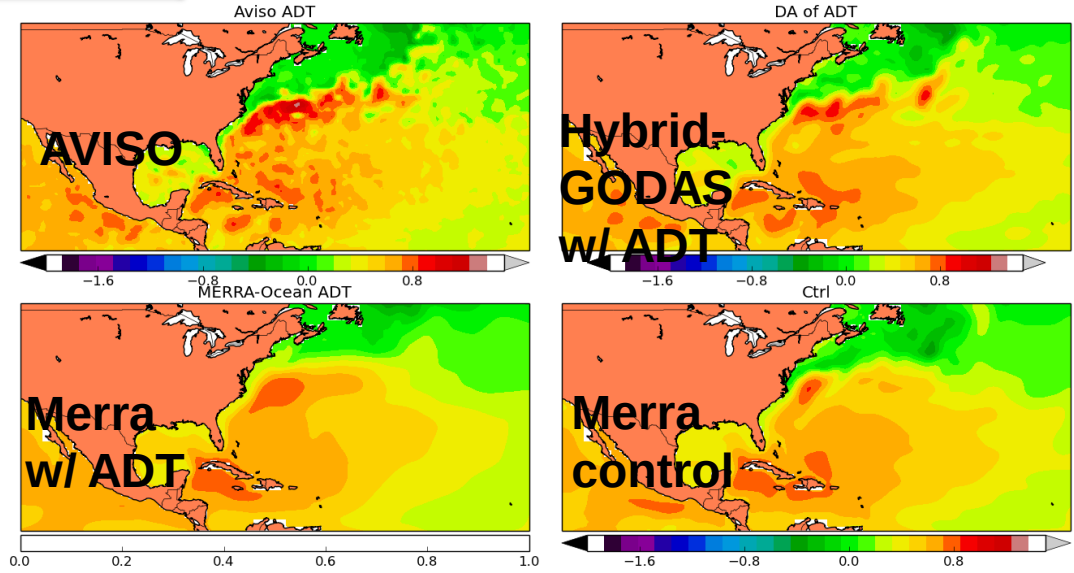
L2 SST assimilation



Assimilation of L2 SST generates SSTs close to Reynolds analysis, but additionally consistent with in situ profile measurements.

Assimilation of Absolute Dynamic Topography (ADT) improves representation of SSH vs. assimilating Sea Level Anomalies (SLA).

Altimetry ADT assimilation



UMD: Ocean-LETKF Software Development

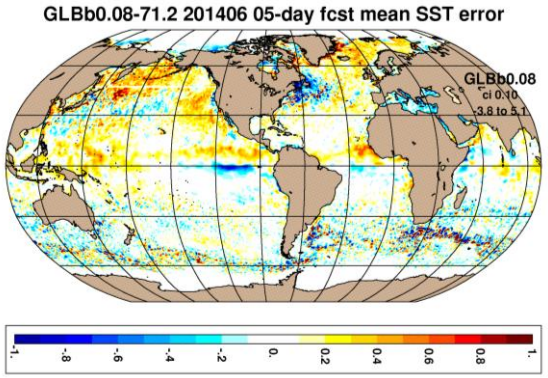
- Sea Ice-LETKF set up with GFDL's SIS model to support MOM6/SIS coupling for improved ocean state estimation in high latitudes
- Collaboration with CDAS/CFSv3 development team
- Developing plans for transition to operations, in coordination with CPC

NRL: Flux Bias Estimates from Different Atmospheric Forcing Products

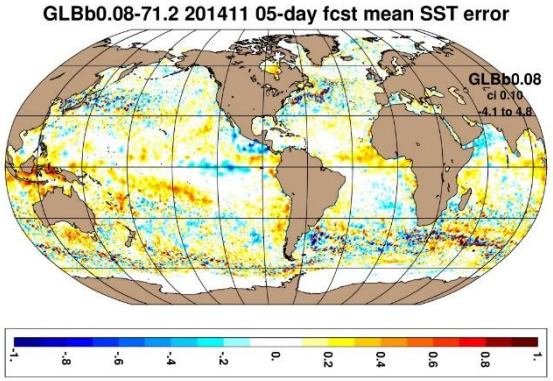
- Lead PI: Dr. Pat Hogan
- Collaborators: EMC
- Main objective: Examine the ocean response to Navy-NAVGEM and NCEP-GFS Atmospheric forcing. Determine biases and apply calibrations.
- Developed a method for calibrating total net surface heat flux based on ocean SST forecast error. Monthly averaged SST error is translated into a monthly net heat flux offset where 1°C SST error = -250 W/m^2.
- Both NAVGEM and GFS show a warm bias over the northern (southern) hemisphere in summer (winter). Both show an overall positive SST bias (ocean too warm).

NRL: Flux Bias Estimates from Different Atmospheric Forcing Products

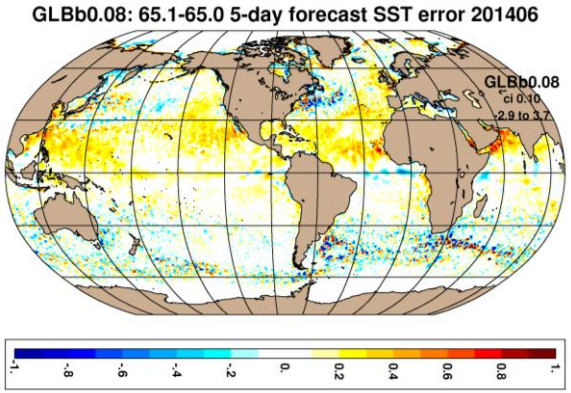
GFS June 2014



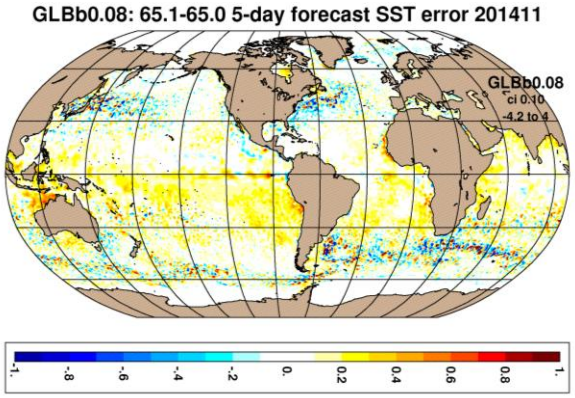
GFS November 2014



NAVGEM June 2014



NAVGEM November 2014



Both GFS and NAVGEM exhibit seasonal variability in SST forecast errors. Globally averaged SST forecast errors are similar, but there are differences in the spatial distribution.

NRL: Flux Bias Estimates from Different Atmospheric Forcing Products

	NAVGEM 1.3-forced HYCOM		GFS-forced HYCOM	
Month	SST error	Absolute SST error	SST error	Absolute SST error
01	0.07	0.14	0.06	0.16
02	0.08	0.14	0.07	0.15
03	0.07	0.14	0.06	0.15
04	0.08	0.14	0.07	0.15
05	0.07	0.14	0.06	0.16
06	0.07	0.14	0.05	0.16
07	0.06	0.15	0.06	0.17
08	0.07	0.15	0.06	0.16
09	0.07	0.14	0.05	0.15
10	0.07	0.14	0.07	0.15
11	0.08	0.14	0.07	0.16
12	0.09	0.15		

Globally averaged 5-day forecast SST error and absolute SST error (°C) relative to 1/12° global HYCOM hindcasts using analysis quality NAVGEM 1.3 and GFS forcing. Each month nominally has 10 forecasts.

Summary: Major Deliverables

- NUOPC caps for HYCOM and WaveWatch III models using ESMF calls, HYCOM coupled to GSM
- Baseline Ocean-LETKF data assimilation systems have been set up with MOM6 and HYCOM, under development for WaveWatch III.
- Operational upgrade of Global RTOFS has been approved by NCEP OD, waiting for Navy

Summary: Main Priority

Progress towards unified coupled systems:

- Functional one-way (and multi-way) coupling of Ocean, Wave and Sea Ice components within NEMS
- Continue development of coupled DA (ensemble based) methods

Summary: Major Need

- New hires (Ocean Data Assimilation, Sea Ice Modeling, Sea Ice Data Assimilation, Wave Coupling Development and/or Wave Code Manager)

Next: Report on NGGPS Sea Ice Workshop