



# The U.S. Navy's Sea Ice Prediction Capabilities: Present and Future Plans

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# Outline

- Arctic Cap Nowcast/Forecast System
- Sea Ice Outlook
- Global Ocean Forecasting System (GOFS 3.1)
- Regional COAMPS-Arctic
- Summary & Future Plans

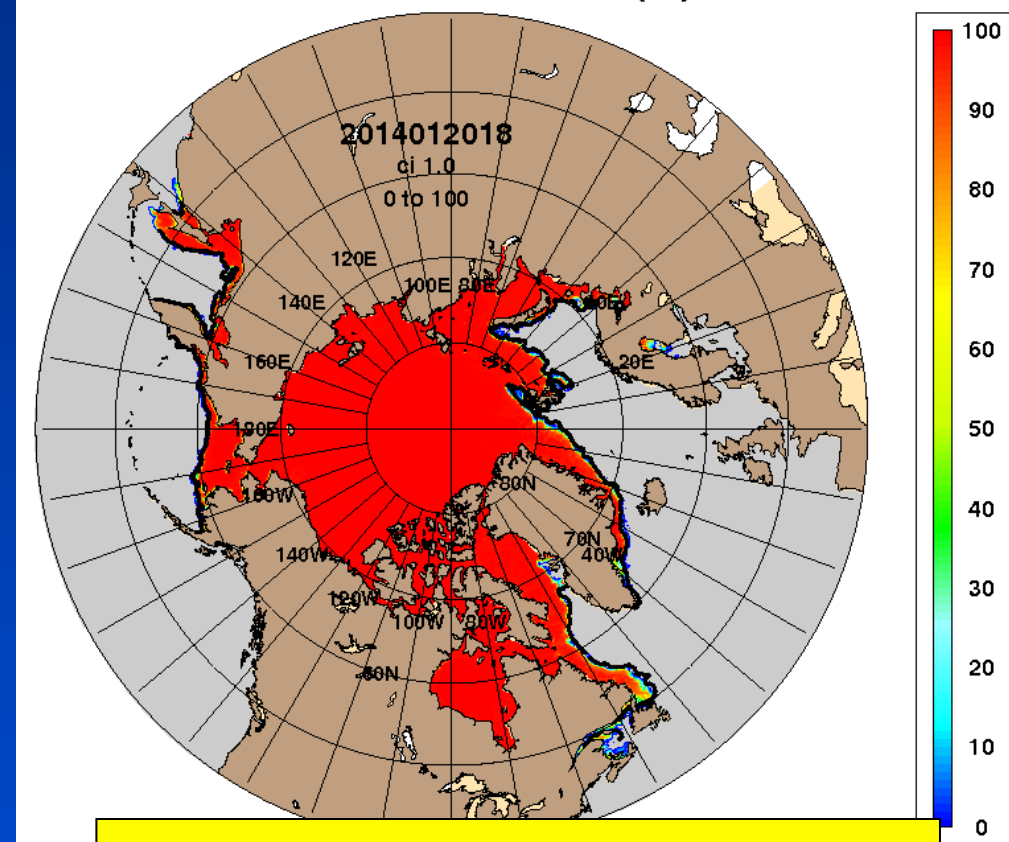


# Arctic Cap Nowcast/Forecast System (ACNFS)

- ACNFS consists of 3 components:
  - Ice Model:** Community Ice Code (CICE)
  - Ocean Model:** HYbrid Coordinate Ocean Model (HYCOM)
  - Data assimilation:** Navy Coupled Ocean Data Assimilation (NCODA)
- Declared operational Sept 2013
- ACNFS outputs nowcast/7-day forecasts of ice concentration, ice thickness, ice drift, sst, sss and ocean currents
- Products pushed daily to the U.S. National Ice Center (NIC) and NOAA

<http://www7320.nrlssc.navy.mil/hycomARC/>

ARCc0.08-03.8 Ice Concentration (%): 20140118



**Model grid resolution ~ 3.5 km**

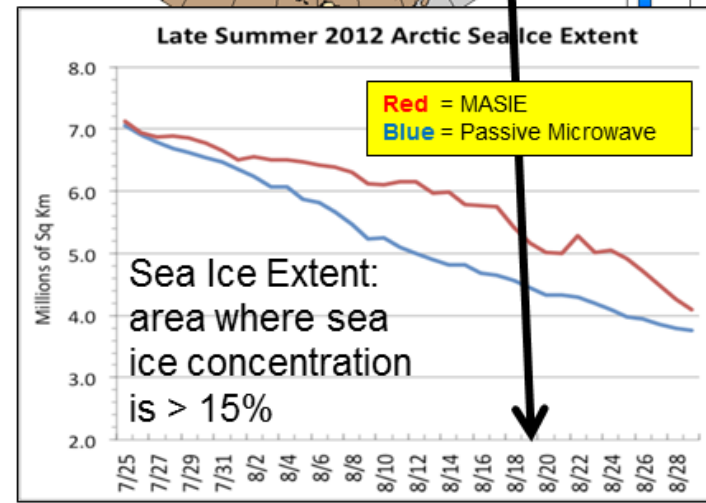
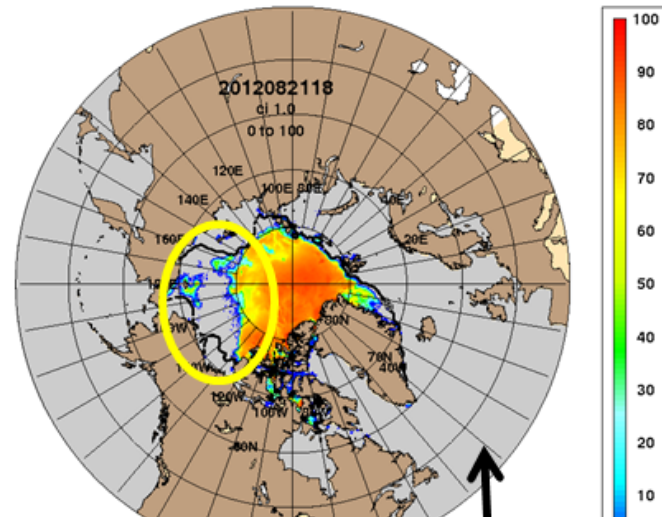
Black line is the independent ice edge location (NIC). Animation spans 18 Jan – 18 Feb 2014



# Ice Concentration Assimilation

- For the Navy, ice edge location for general transit, search and rescue is extremely important.
- Navy has been using passive microwave (PM) sea ice concentration from DMSP (SSM/I and SSM/IS) since early 1990's.
- During the summer, PM has known problems detecting melt ponds as open water.
- As a direct result of the OPTEST, NIC suggested the use of the Multi-sensor Analyzed Sea Ice Extent (MASIE) product.
- National Snow and Ice Data Center (NSIDC) has developed a blended ice concentration product using the MASIE ice mask and AMSR2.

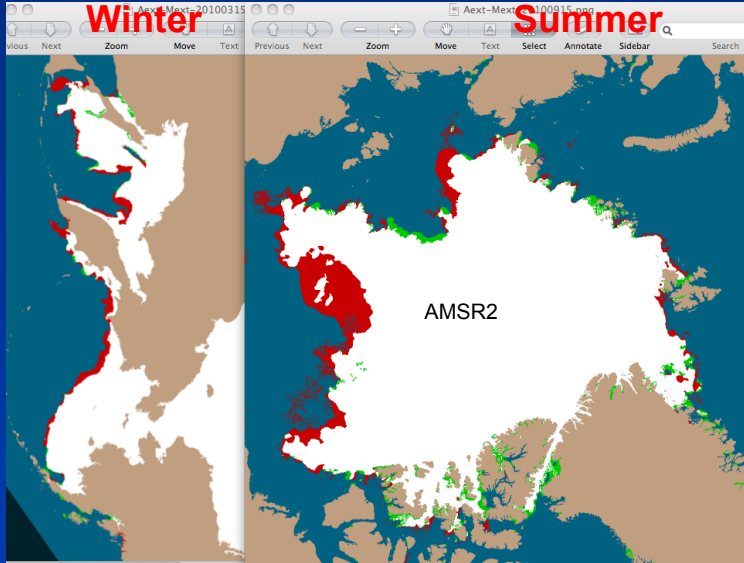
ARCc0.08-03.5 Ice Concentration: 20120819





# Ice Modeling Assimilation from Satellites

## NSIDC's blended product (MASIE + AMSR2)



Mean Ice Edge Error (km) between ACNFS and NIC's ice edge location July 2012 – July 2013

Region	ACNFS w/ SSMIS 25km res	ACNFS w/blended 4km res	% Improvement
Greenland	37km	28km	25%
Barents	28km	20km	28%
Laptev	66km	46km	30%
Sea of Okhotsk	38km	19km	51%
Beaufort	63km	33km	48%
Canadian Archipelago	53km	39km	27%
<b>Total Arctic</b>	<b>54km</b>	<b>32km</b>	<b>41%</b>

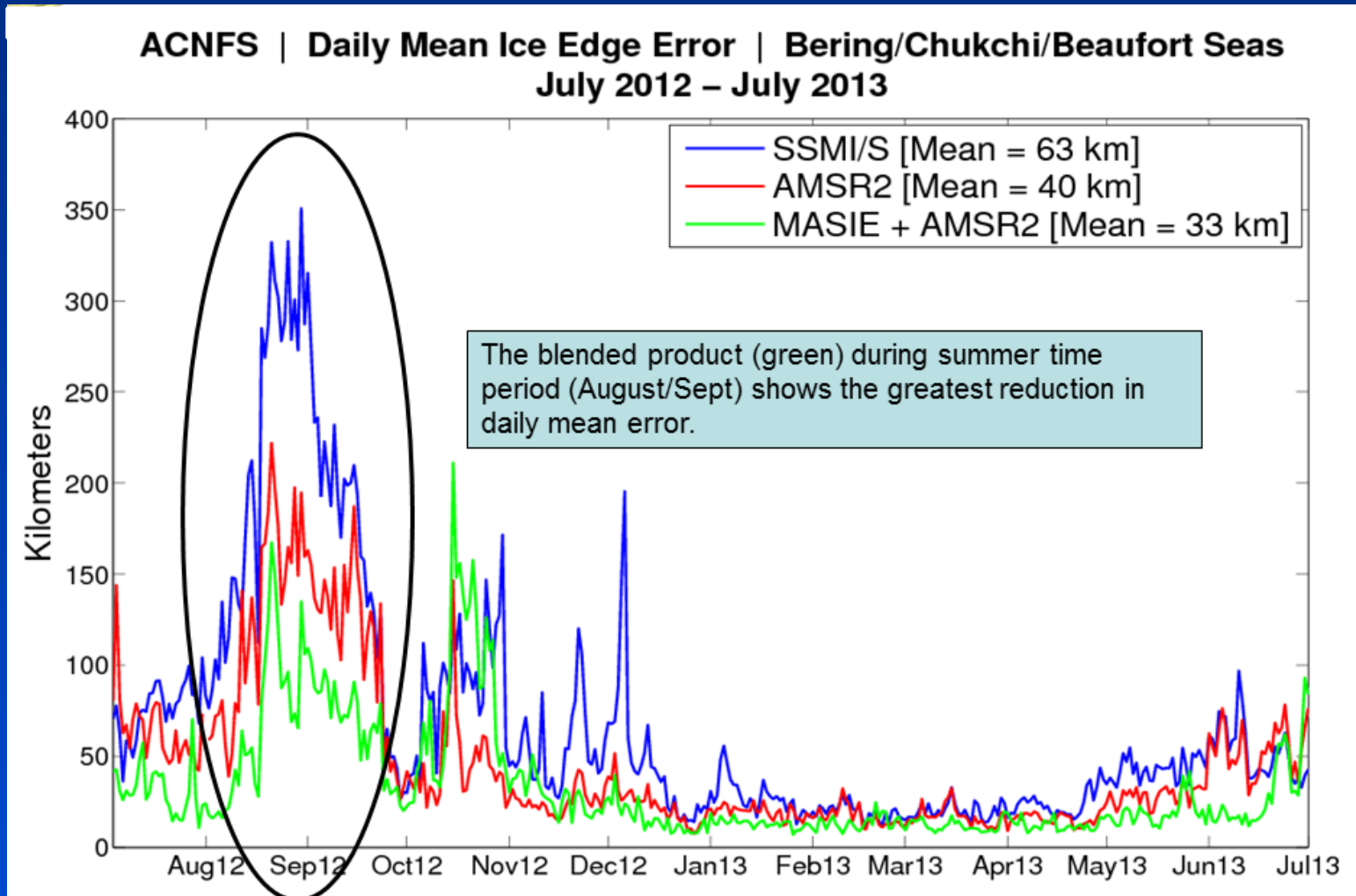
**RED** indicates areas where concentration was **added** by MASIE.

**GREEN** indicates areas where concentration was **removed** by MASIE.

Currently, MASIE has a 4 km resolution, a 1 km resolution product is scheduled to be released by May 2014.



# Improved Ice Edge with MASIE/AMSR2

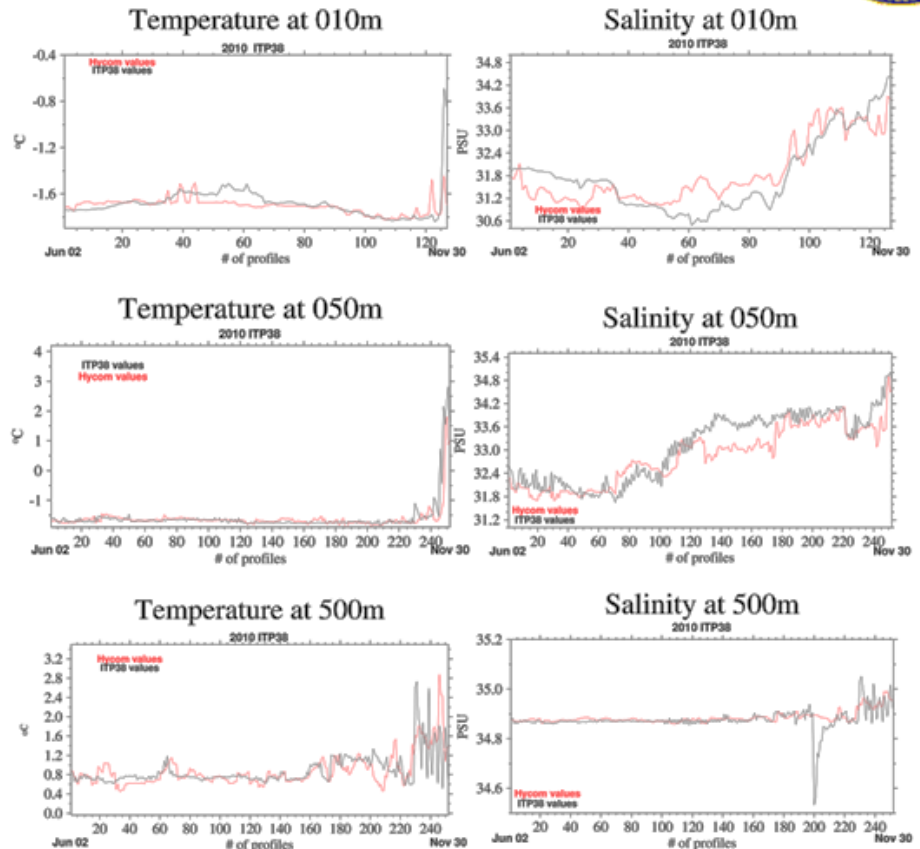
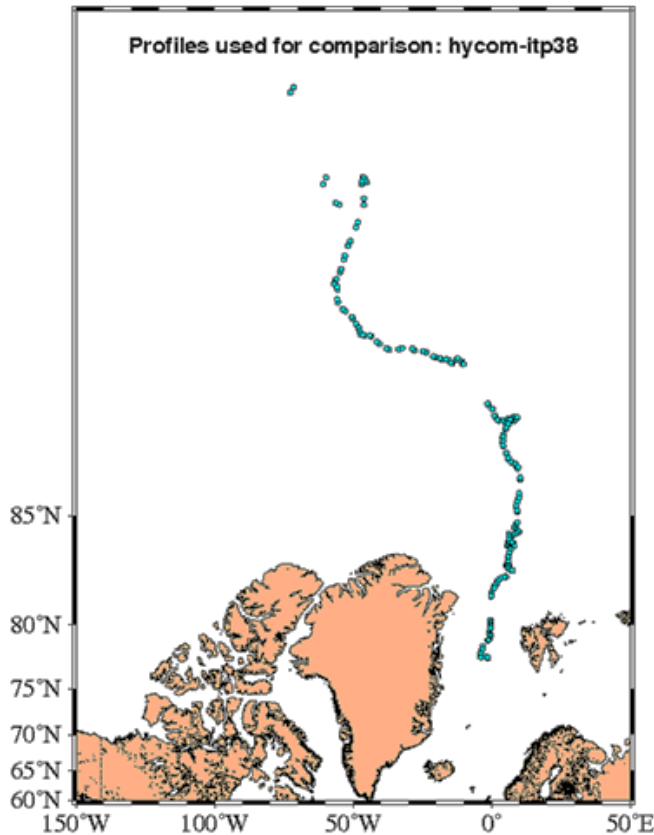






# ACNFS Assimilation of ITP Data

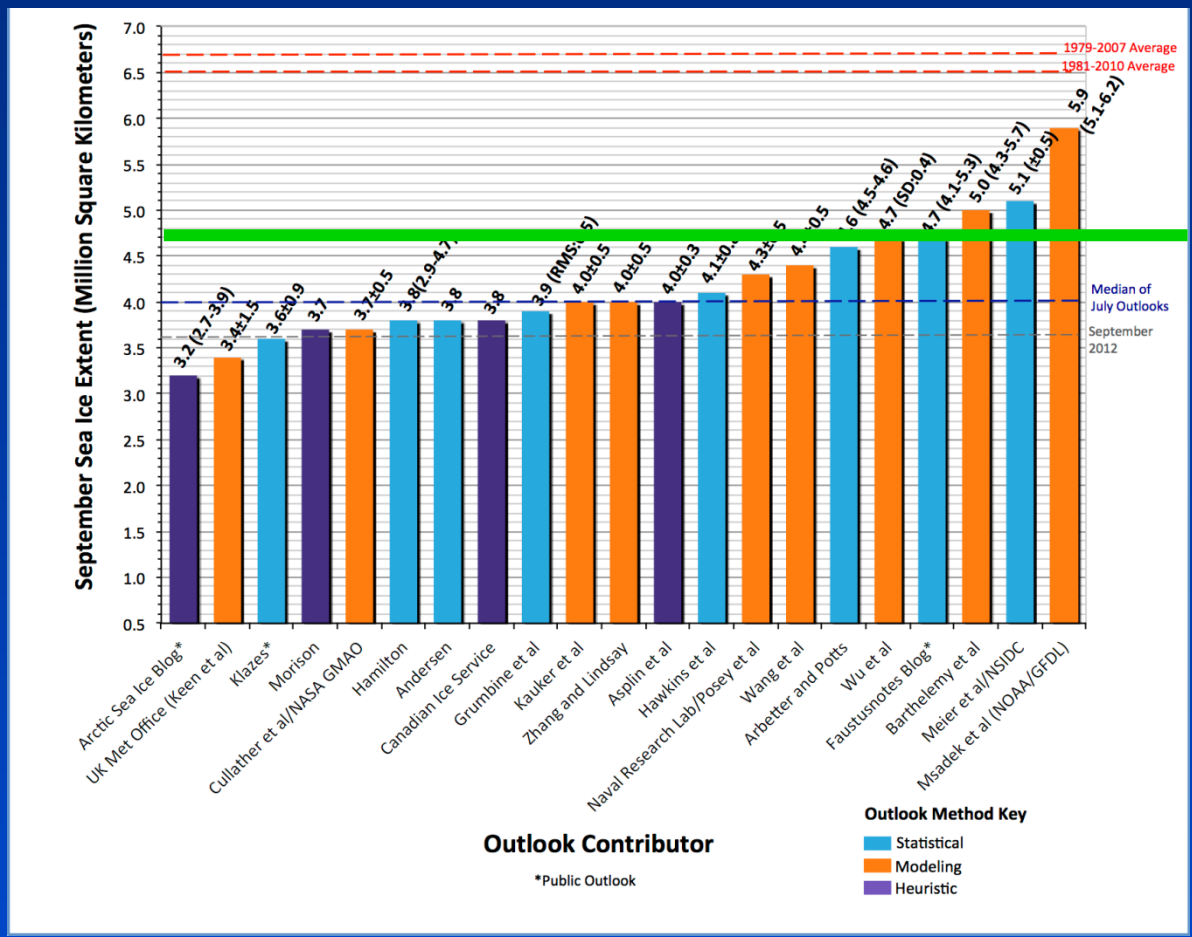
## Ice-Tethered Profile 2010



Model (red) versus observations (blue) for temperature (left) and salinity (right); data is assimilated into HYCOM ocean model. Highly correlated agreement when data is assimilated.



# 2013 Sea Ice Outlook (July Report)



**Observed  
Minimum ice  
extent**

## 2014 Plans:

- Run ensembles with GOFs 3.1 (global system) and ACNFS
- Generate map showing ice extent minimum

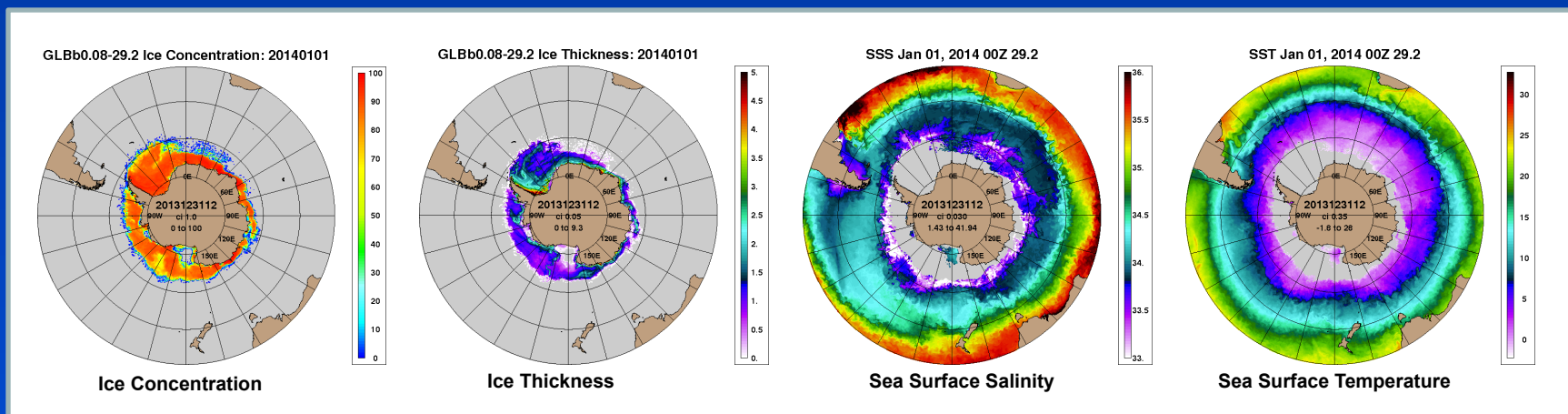
<http://www.arcus.org/search/seaiceoutlook>





# Global Ocean Forecast System (GOFS 3.1)

- 1/12° global two-way coupled HYCOM-CICE modeling system with data assimilation
  - 41 layer HYCOM/NCODA-3DVAR
  - Forced with Navy's NAVGEM out to 7 days
  - Will replace ACNFS





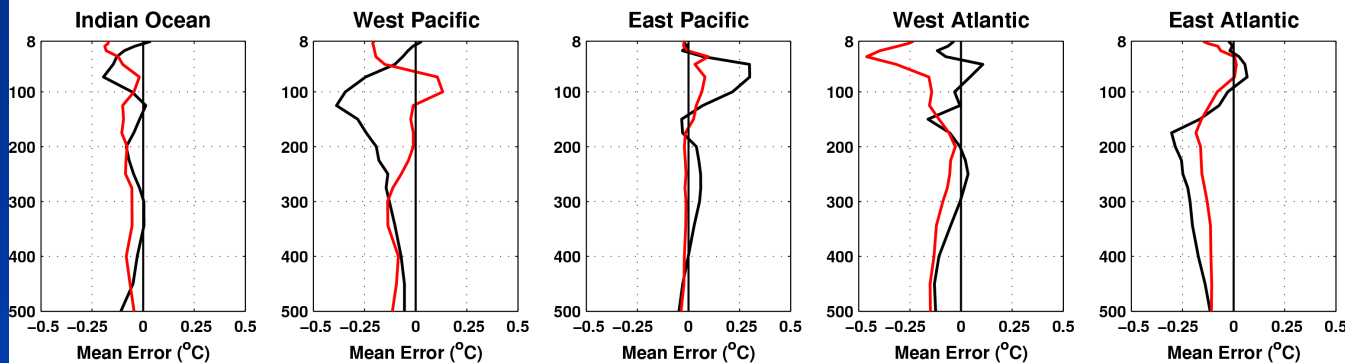
# Large Scale Ocean Prediction

## Preliminary temperature vs. depth error analysis

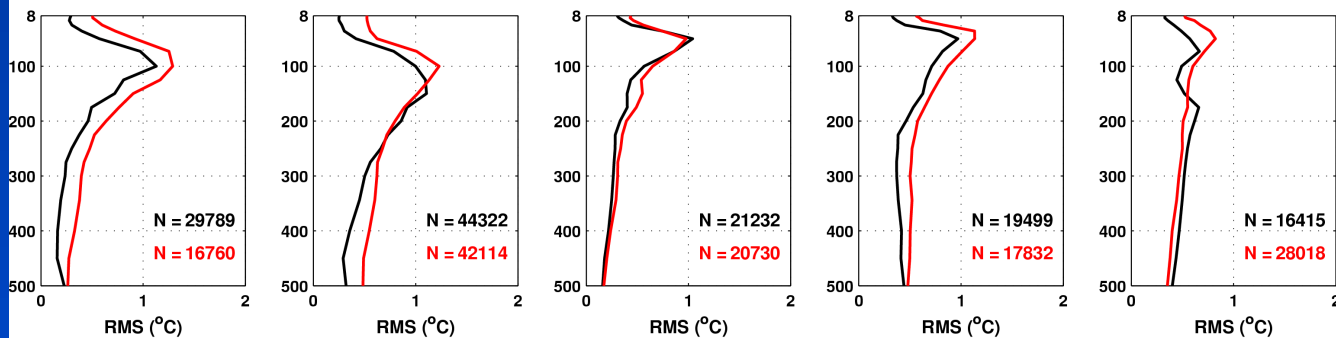
### GOFS 3.0 vs. GOFS 3.1

## Temperature vs. depth error analysis

Mean Error (C)



RMSE (C)



Analysis over the period August – December 2013  
Both use NAVGEM 1.1 forcing

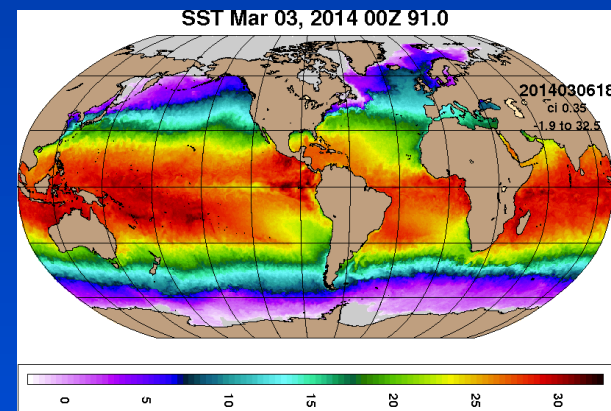


# GOFS & ACNFS vs independent NIC ice edge Northern Hemisphere

Mean ice edge error (km)	ACNFS	GOFS 3.1	% Improvement
Greenland/Norwegian Seas	36km	28km	22
Barents/Kara Seas	26km	29km	-13
Laptev/E. Siberian Seas	56km	27km	52
Sea of Okhotsk	32km	34km	-8
Bering/Chukchi/Beaufort Seas	45km	39km	13
Canadian Archipelago	44km	38km	12

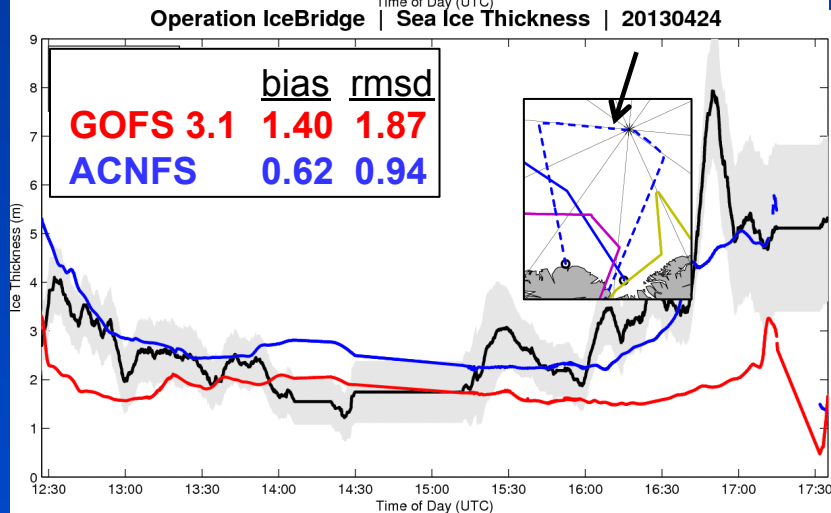
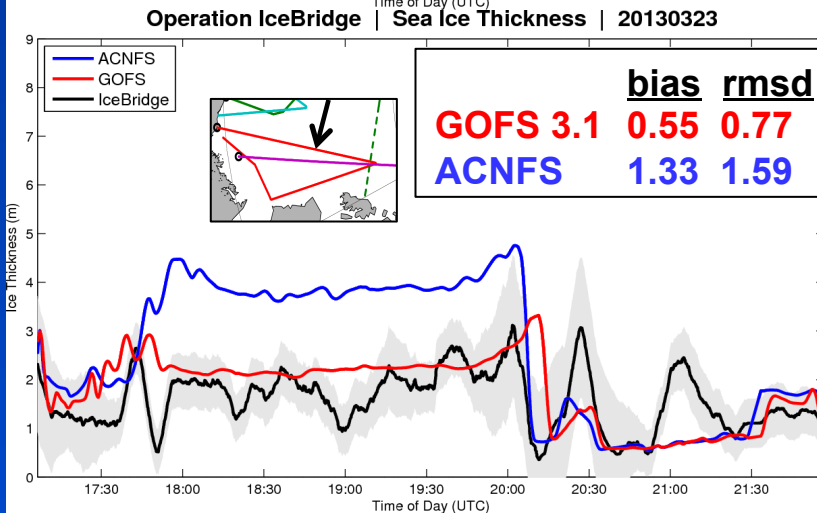
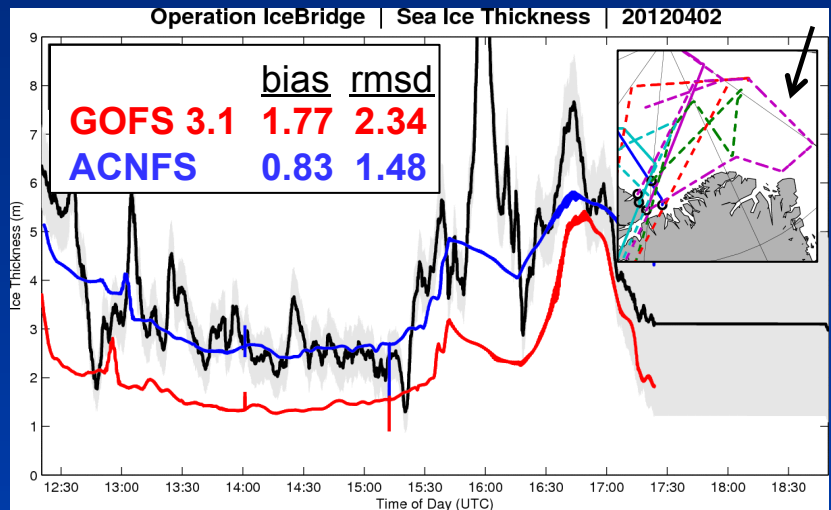
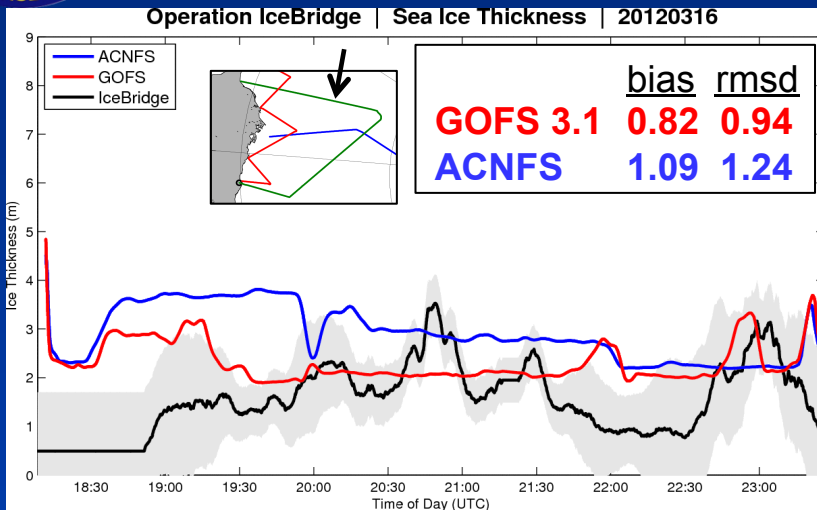
**If ACNFS and GOFS are both HYCOM/CICE/ data assimilation, why are there lower ice edge errors in GOFS?**

- 1) More realistic initial conditions (mainly better ice thickness)
- 2) Assimilating ice concentration data across the whole domain (not just along the ice edge)
- 3) Improved HYCOM code





# GOFS 3.1 & ACNFS vs. NASA IceBridge thickness data



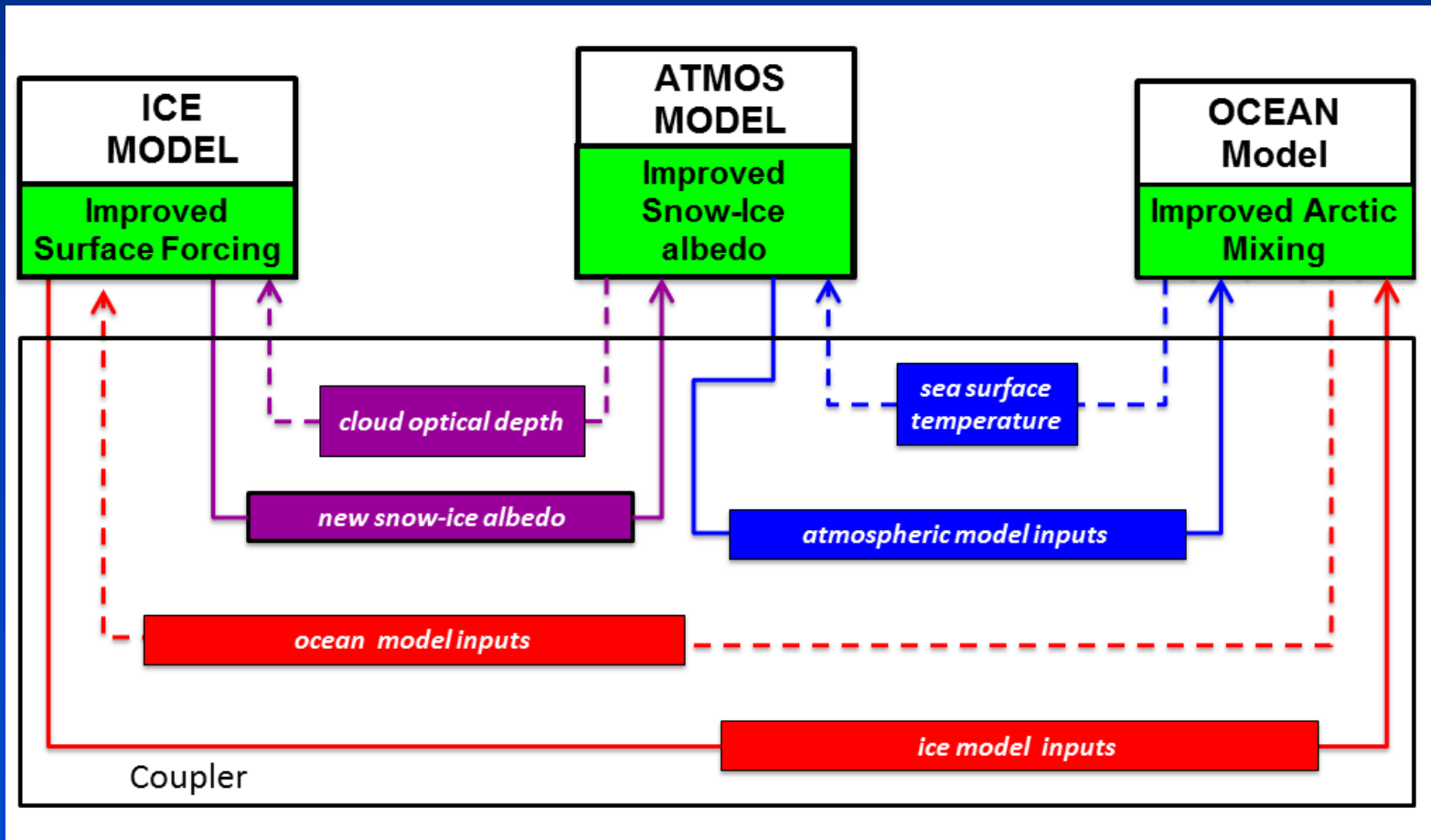
Assimilation of ice thickness data is necessary

13-15 May 2014

Operational Predictions: Status, Challenges and Opportunities for Progress



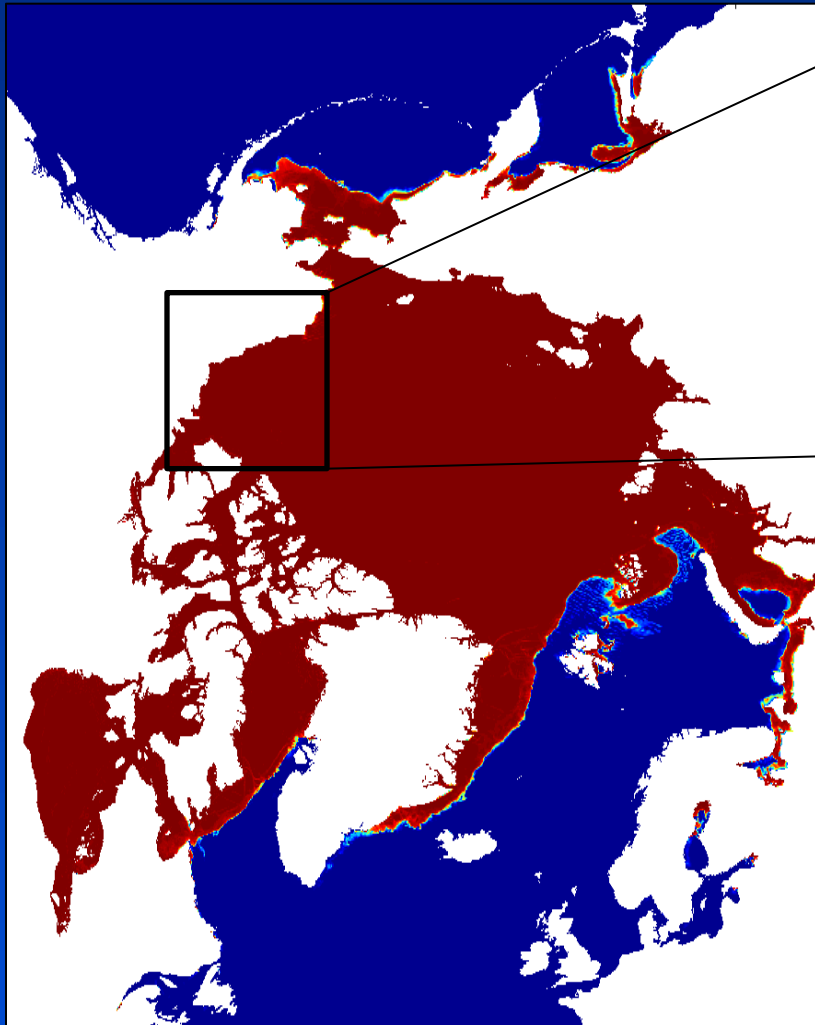
# Coupled Air-Ocean-Ice Modeling with COAMPS



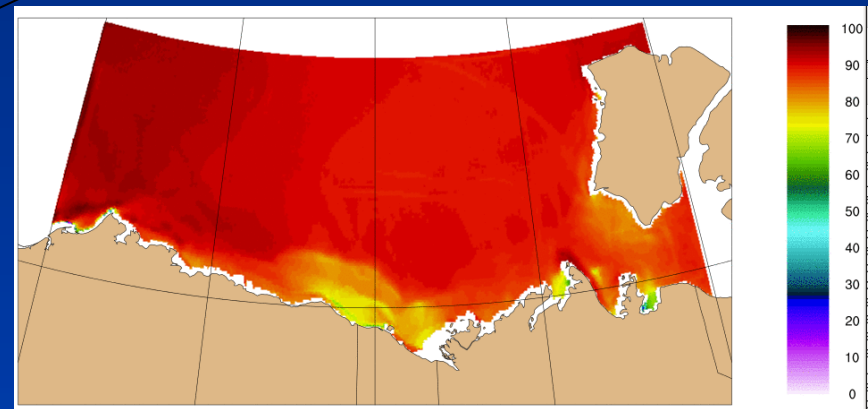


# Beaufort Sea Regional CICE

ACNFS



Regional CICE - Uncoupled



- Interpolate ACNFS restart to desired domain
- Rotated ACNFS to North-East coordinate system (could be arbitrary rotation).
- Made ocean forcing directly from ACNFS output. Required same interpolation method as ACNFS restart file

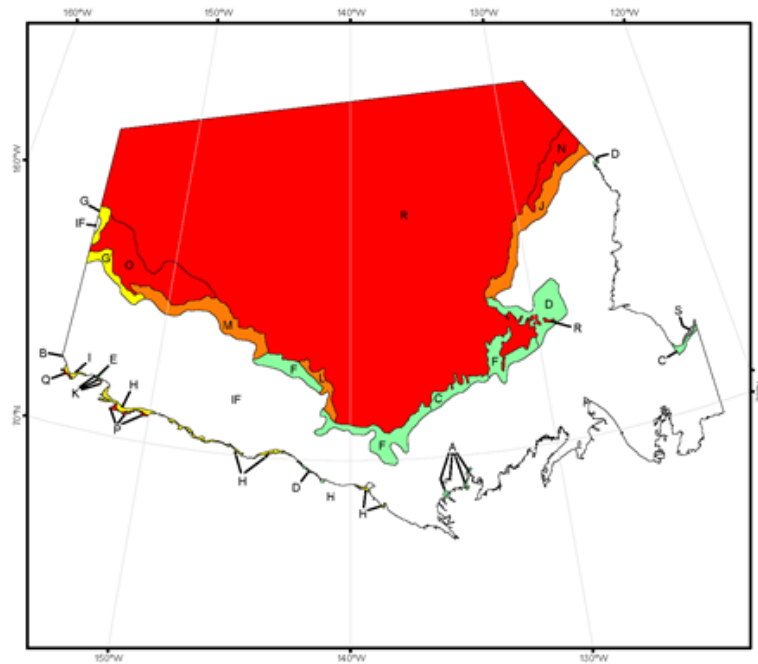
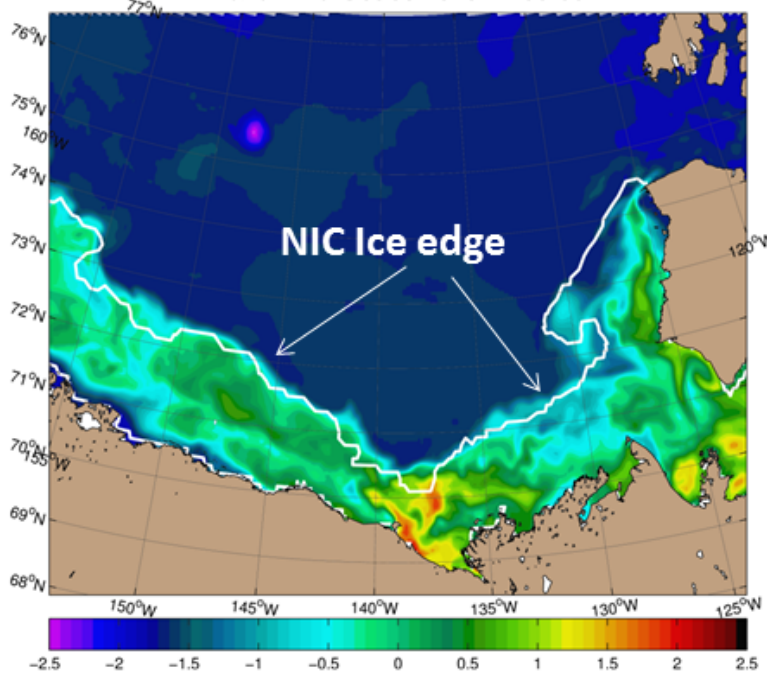




# NCOM Simulations Forced with COAMPS

October 3, 2013

COAMPS NCOM SST (°C) | Init: 2013100300  
Valid: Thu Oct 03 2013 12:00:00



NCOM initial/boundary conditions provided by HYCOM component in ACNFS



# Challenges

- Develop improved algorithms for deriving data products (i.e ice concentration) from satellites especially along the marginal ice edge.
- Gaining access to real-time river discharge from Canada and other nations as input to our coupled regional models.
- Assimilation of ice thickness data (in situ and satellite-derived) is a critical need.
- Access to under ice observations is near real-time for data assimilation.



# Opportunities

- Work jointly with NOAA in Sea Ice Outlook; add to ensemble mix with NOAA atmospheric forcing.
- Work with analysts at NIC for verification
- Work with 1) NASA ICESat-2 Early Adopter program and 2) ONR field programs (e.g., MIZ, Sea State DRI)



# Summary

- GOF3 3.1 will replace ACNFS as global operational coupled model in 2015
  - Plans to increase horizontal resolution of atmospheric forcing (NAVGEM)
  - Future upgrades of HYCOM (1/25 deg) will include tides and waves
- Regional COAMPS-CICE testing will continue through 2015
- Future efforts will investigate ice thickness assimilation