The US Navy's New Operational Capability in Global Ice Forecasting

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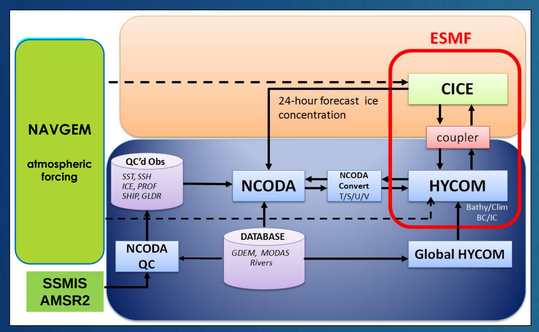
Abstract: Since the late 1990's, the US Navy has been forecasting ice conditions in the Northern Hemisphere. By the end of this year, a new operational system (Global Ocean Forecast System – GOFS 3.1) will produce sea ice related products for both the Northern and Southern Hemispheres. GOFS 3.1 is comprised of the two-way coupled Community Ice CodE (CICE) and the HYbrid Coordinate Ocean Model (HYCOM). The horizontal resolution is ~3.5 km near the North Pole and less than 4 km surrounding Antarctica. It is forecast by 3-hourly atmospheric output form the NAVy Global Environmental Model (NAVGEM) with ~31 km resolution. The system is run daily at the Naval Oceanographic Office (NAVOCEANO) and creates products (ice thickness, ice concentration, ice velocities, lead opening rates, sea surface temperature/salinity and ocean currents) out through 7 day forecasts.

The Naval Research Laboratory (NRL) has completed a validation of GOFS 3.1 ice/ocean products (Metzger et al., 2017). Currently the U.S. National Ice Center (USNIC) and NAVOCEANO are in the final phase of the operational testing before the system will be declared operational. This poster shows the error analyses of ice edge location, ice thickness ad ice drift compared against the current operational system, the Arctic Cap Nowcast/Forecast System (ACNFS) which only forecast ice conditions in the Northern Hemisphere.

Reference: Metzger, E.J., R.W. Helber, P.J. Hogan, P.G. Posey, P.G. Thoppil, T.L. Townsend, A.J. Wallcraft, 2017: "Global Ocean Forecast System 3.1 Validation Test", Naval Research Laboratory, NRL/MR/7320—17-9722.

Global Ocean Forecast System (GOFS 3.1)



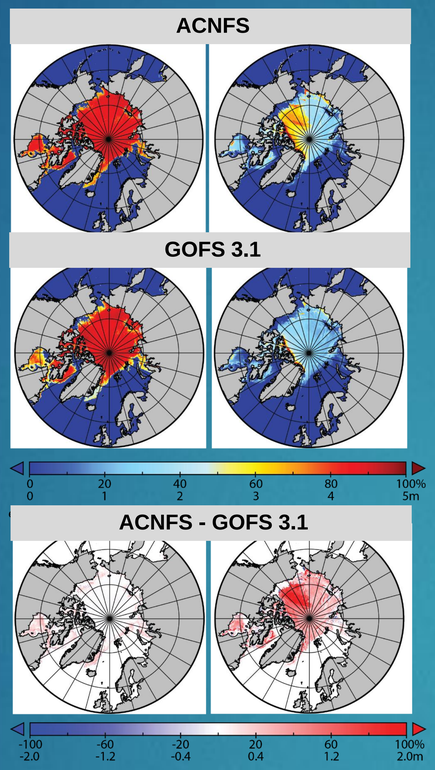
- CICE Output: Ice concentration, ice thickness, ice drift, lead opening rate
- HYCOM Output: SSH, 3D temperature, salinity, and ocean currents

GOFS 3.1 and ACNFS wiring diagrams are similar with the following GOFS 3.1 exceptions:

- Newer HYCOM source code (v2.2.86 vs 2.2.19)
- Improved bathymetry (30" GEBCO vs ETOP05)
- Improved vertical structure (additional 9 near surface layers)
- Improved Equation of State (17-term vs 9-term)
- Uses better representation of the ocean's vertical structure by constraining vertical gradients of temperature and salinity (ISOP vs MODAS)
- Assimilates the full ice concentration satellite observations using NCODA analysis ± 10% whereas ACNFS assimilates only along the ice edge.

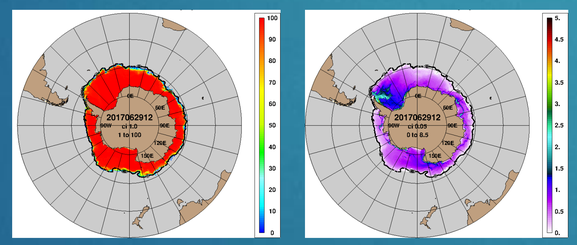
ACNFS vs. GOFS 3.1: 20 June 2016

Ice concentration (%) – left
Ice thickness (meters) – right



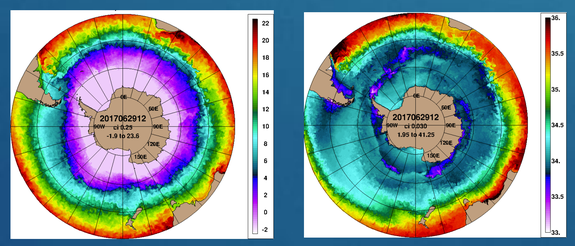
Ice/Ocean Prediction for the Southern Hemisphere

Ice concentration (%) – left
Ice thickness (meters) – right

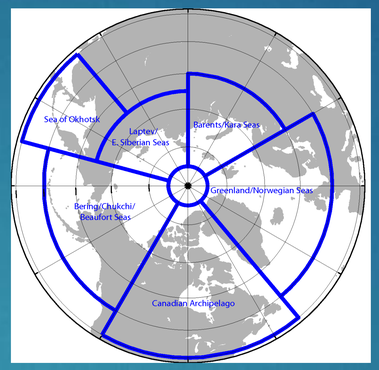


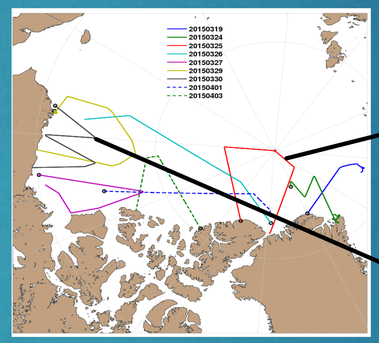
Black line is the independent USNIC ice edge

Sea Surface temperature (°C) – left
Sea Surface Salinity (psu) – right



Northern Hemisphere Ice validation regions





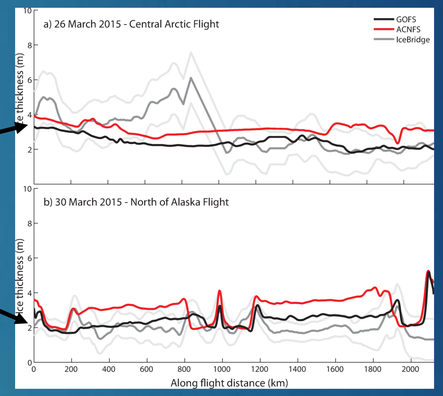
NASA Operation IceBridge 2015 flight paths

24-hour Ice Edge Location Error – Northern Hemisphere

24-hour Ice Edge Location Error (km)			
Region	GOFS 3.1	ACNFS	% Change
Greenland/Iceland/ Norwegian Seas	**20.6**	26.7	23
Barents/Kara Seas	**24.2**	26.3	8
Sea of Okhotsk	**18.9**	21.9	14
Bering/Chukchi/Beaufort Seas	**21.1**	25.5	17
Canadian Archipelago	**23.8**	24.0	1

- 24-hr forecast ice edge from GOFS 3.1 and ACNFS were compared against the USNIC independent ice edge.
- Comparison was made in Arctic regions (validation areas shown on left) from Feb – June 2015
- Overall, GOFS 3.1 had lower ice edge error than ACNFS
- Ice edge error in the Southern Hemisphere is comparable in magnitude to the Northern Hemisphere error

Comparison Against IceBridge Ice Thickness Flight Data



- IceBridge collects airborne remotely sensed measurements of ice thickness
- Serendipitous that flights are in a region where GOFS 3.1 and ACNFS have large thickness differences
- Flight paths marked by arrows (left) are the time series shown
- Black circle denotes the beginning of the flight path
- GOFS 3.1 generally has lower error in the regions of the Beaufort Sea and Canadian Archipelago
- ACNFS generally has lower error in the region north of Greenland

Comparison Against Ice-Bound Drifting Buoy Data

Region	Absolute Mean Error		Root Mean Square Error		Vector Correlation	
	GOFS 3.1	ACNFS	GOFS 3.1	ACNFS	GOFS 3.1	ACNFS
Pan Arctic	4.8	4.8	7.3	7.7	1.29	1.21
GIN Seas	7.0	7.6	11.1	13.1	1.03	0.92
Barents/Kara Seas	3.6	3.8	5.3	5.6	1.58	1.35
Laptev/E. Siberian Seas	3.7	3.9	5.3	5.5	1.43	1.36
Bering/Chukchi/Beaufort	4.7	4.5	7.0	6.8	1.26	1.23
Canadian Archipelago	6.1	5.5	8.9	9.0	0.89	0.86
Central Arctic	3.8	4.0	5.2	5.5	1.57	1.47
"wins"	4	2	6	1	7	0

- Model drift comparison was made in Arctic regions against International Arctic Buoy Program (IABP) ice-bound drifting buoys (254 buoys were used)
- 24-hour forecast over the July 2014 – June 2015 period at all ice concentrations
- Overall, GOFS 3.1 has lower absolute mean error and RMSE, and higher vector correlations with the observations

Operational Evaluation Results from USNIC

- USNIC supports the promotion of GOFS 3.1 into operations and has already begun the application of GOFS 3.1 nowcast and forecast parameters into daily operations
- The extension of GOFS 3.1 to cover the Southern Hemisphere adds significant value to USNIC applications. Existing ACNFS only forecasts ice conditions in the Northern Hemisphere.
- The largest improvement in GOFS 3.1 performance (over ACNFS) appears to be within the 48 hours ice edge forecasts