U.S. NAVAL RESEARCH LABORATORY

Development and Utilization of the Navy's Environmental Models to Support Polar Operations

David Hebert[a], Rick Allard[a], Pam Posey[a,b], E. Joseph Metzger[a], Alan Wallcraft[a,f], Ole Martin Smedstad[b], Julie Crout[b], Michael Phelps[c], Li Li[d], William Johnston[e], Neil Barton[g]

[a]Naval Research Laboratory, Stennis Space Center
[b]Vencore Service Solutions, Inc., Stennis Space Center
[c]Jacobs Technology Inc., Stennis Space Center
[d]Naval Research Laboratory, Washington, DC
[e]Computational Physics, Inc., Fairfax, VA
[f]Florida State University, Tallahassee, FL
[g]Naval Research Laboratory, Monterey, CA

Overview

- Model Systems
  - GOFS
  - NESM
- Recent Utilizations
  - ICEX 2018
  - SUBX – McMurdo Resupply
  - USCGC MAPLE 2017 Northwest Passage
- Model development
  - VIIRS
  - CryoSAT-2
- Future Plans
  - Landfast ice, tides
  - Regional, High Resoultion Arctic

Global Ocean Forecast System (GOFS 3.1)

Global two-way coupled OCEAN/ICE modeling system with data assimilation

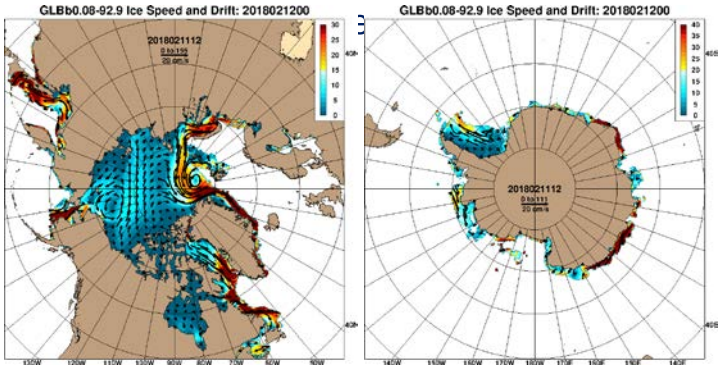
- **Ice Model**: Community Ice Code (CICE)
- **Ocean Model**: HYbrid Coordinate Ocean Model (HYCOM)
- **Data Assimilation**: Navy Coupled Ocean Data Assimilation (NCODA)

Resolution 1/12º (3.5 km at the pole)

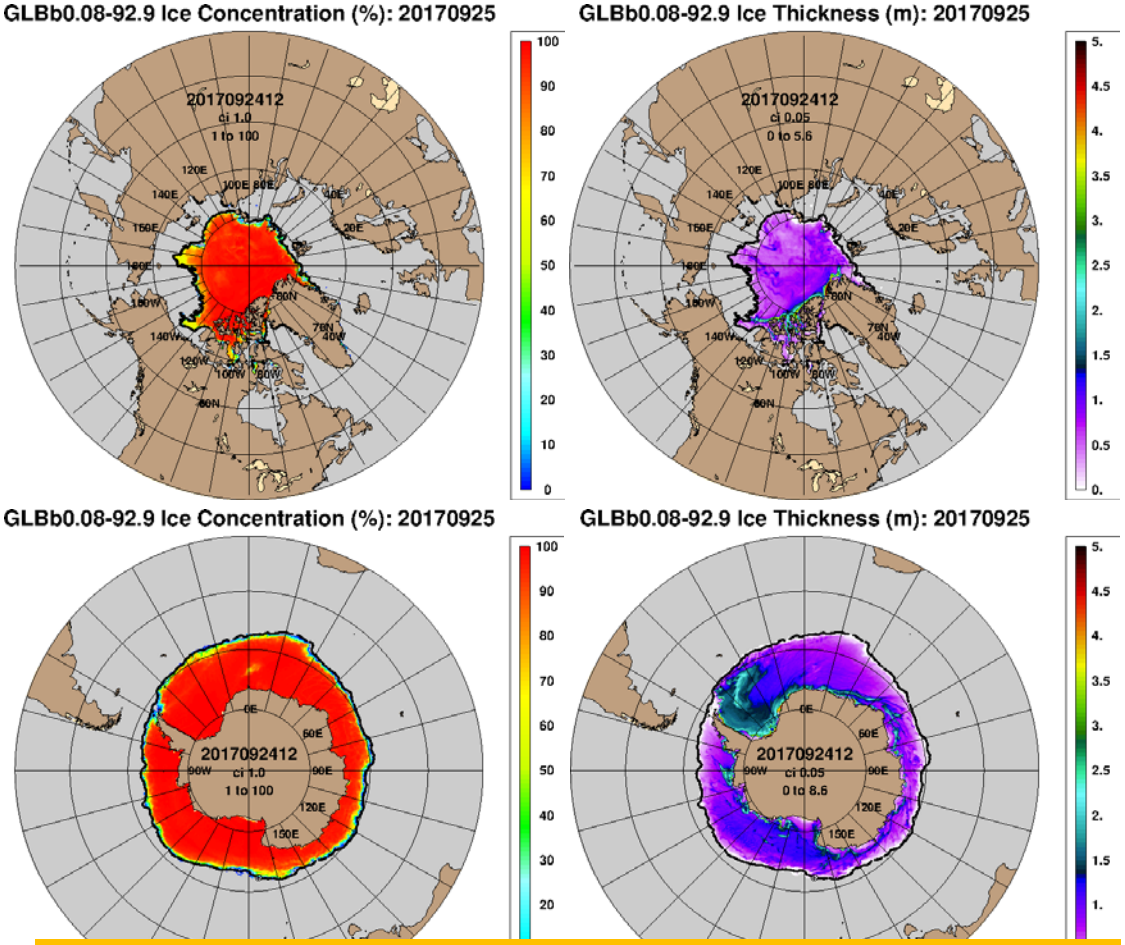
Forced with NAVy Global Environmental Model (NAVGEM) atmospheric products

GOFS 3.1 produces nowcast/7-day forecasts of ice concentration, ice thickness, ice drift, SST, SSS and ocean currents for *Full Globe*

Products pushed daily to NOAA and the U.S. National Ice Center (NIC)

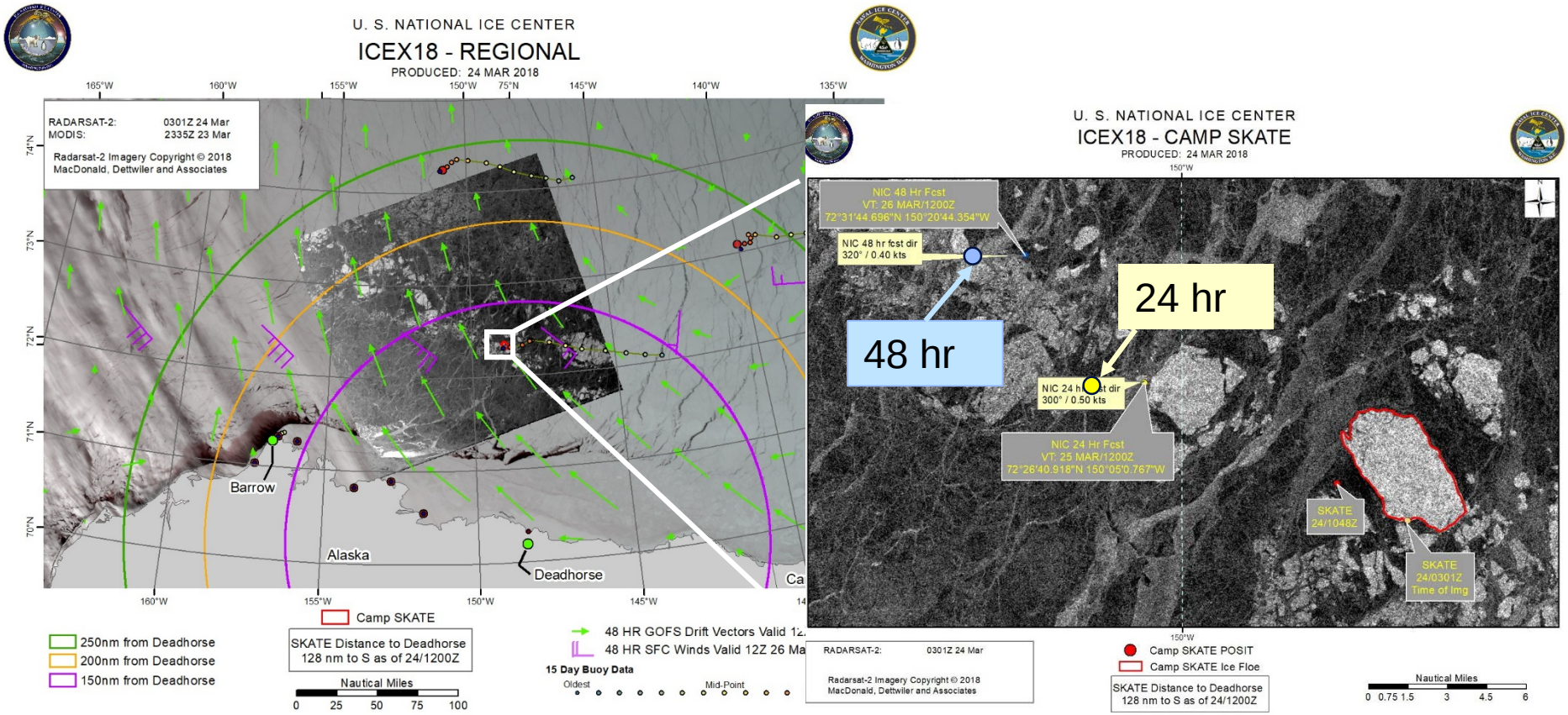


Daily Graphics/Animations at:
https://www7320.nrlssc.navy.mil/GLBhycomcice1-12/skill.html



Black dots: NIC Ice Edge Location (Not assimilated)

ICEX 2018 – Camp SKATE Drift



- Green arrows are GOFS 48 HR ice drift
- Used to help predict future camp drift

ICEX 2018 – Camp SKATE Fracture

U.S. NATIONAL ICE CENTER

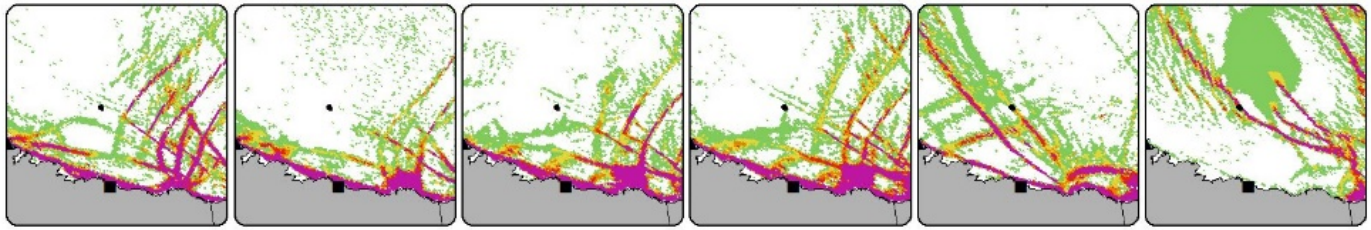
ICEX-18: REGIONAL ICE STRAIN AND FRACTURING RISK

PRODUCED: 23 MAR 2018

Regional Fracturing Risk Code

03/24 00 UTC 03/23 16 AKST	03/25 00 UTC 03/24 16 AKST	03/26 00 UTC 03/25 16 AKST	03/27 00 UTC 03/26 16 AKST	03/28 00 UTC 03/27 16 AKST	03/29 00 UTC 03/28 16 AKST
HIGH	MODERATE	MODERATE	MODERATE	MODERATE	HIGH

Ice Strain



GOFS Ice Openings Strain Rate
Model Run: 23 Mar 2018

Low Ice Strain — High Ice Strain

● Floe Position 23 Mar
Alaska/Canadian Coast
▲ Barrow, Alaska
■ Deadhorse/Prudhoe, Alaska

Nautical Miles
0 125 250 375 500

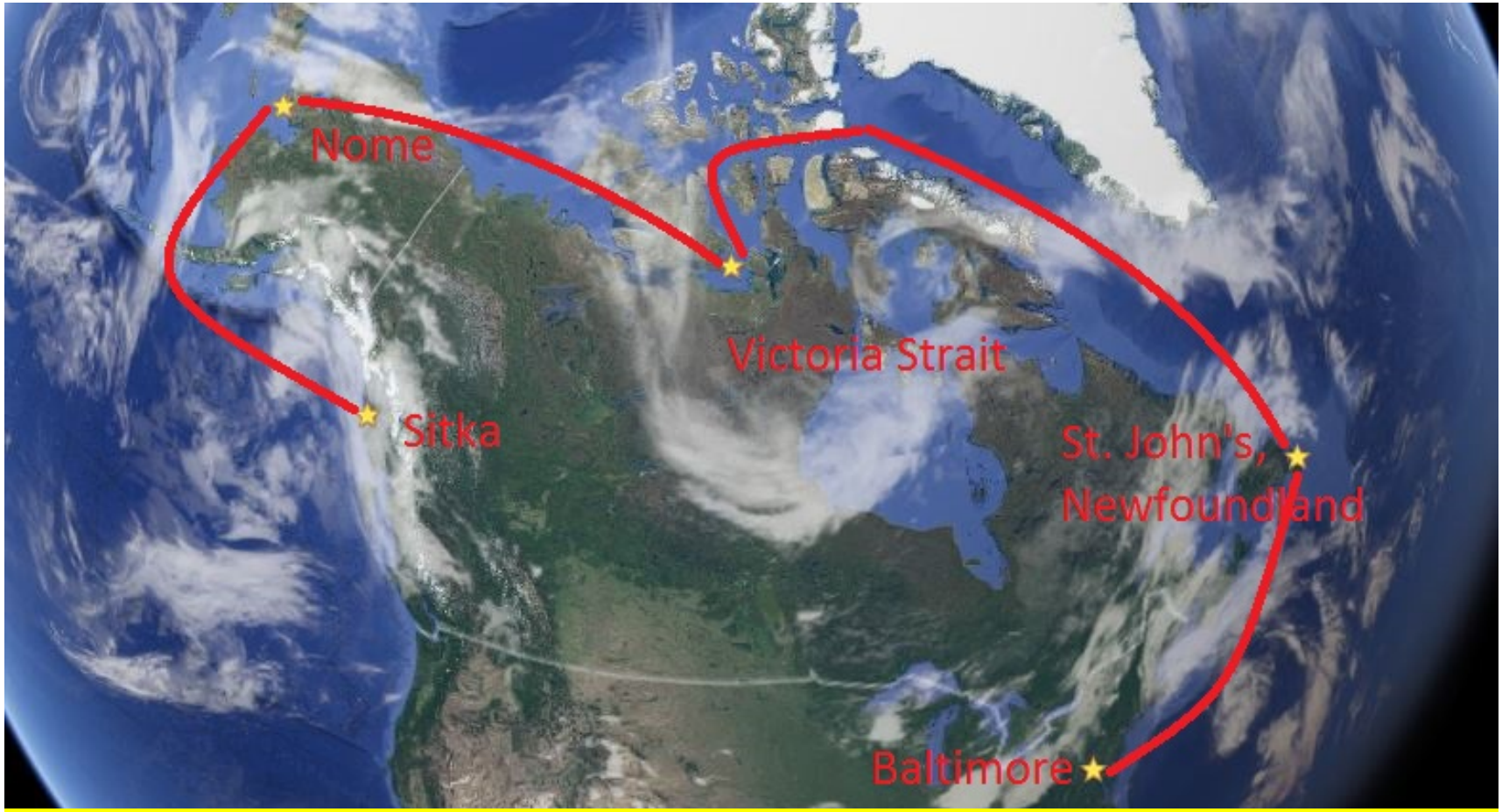
Regional Fracturing Risk Code Guide

LOW	Low risk of new fractures: No sign of ice strain in environmental conditions AND model data.
MODERATE	Moderate risk of new fractures: Environmental conditions indicate ice strain developing OR model data suggests elevated ice strain.
HIGH	High risk of new fractures: Environmental conditions AND model data indicate high ice strain.
ACTIVE FRACTURING	Fracturing imminent or underway: Environmental conditions AND model data indicate fracturing OR fracturing has been observed.

Analyst Notes

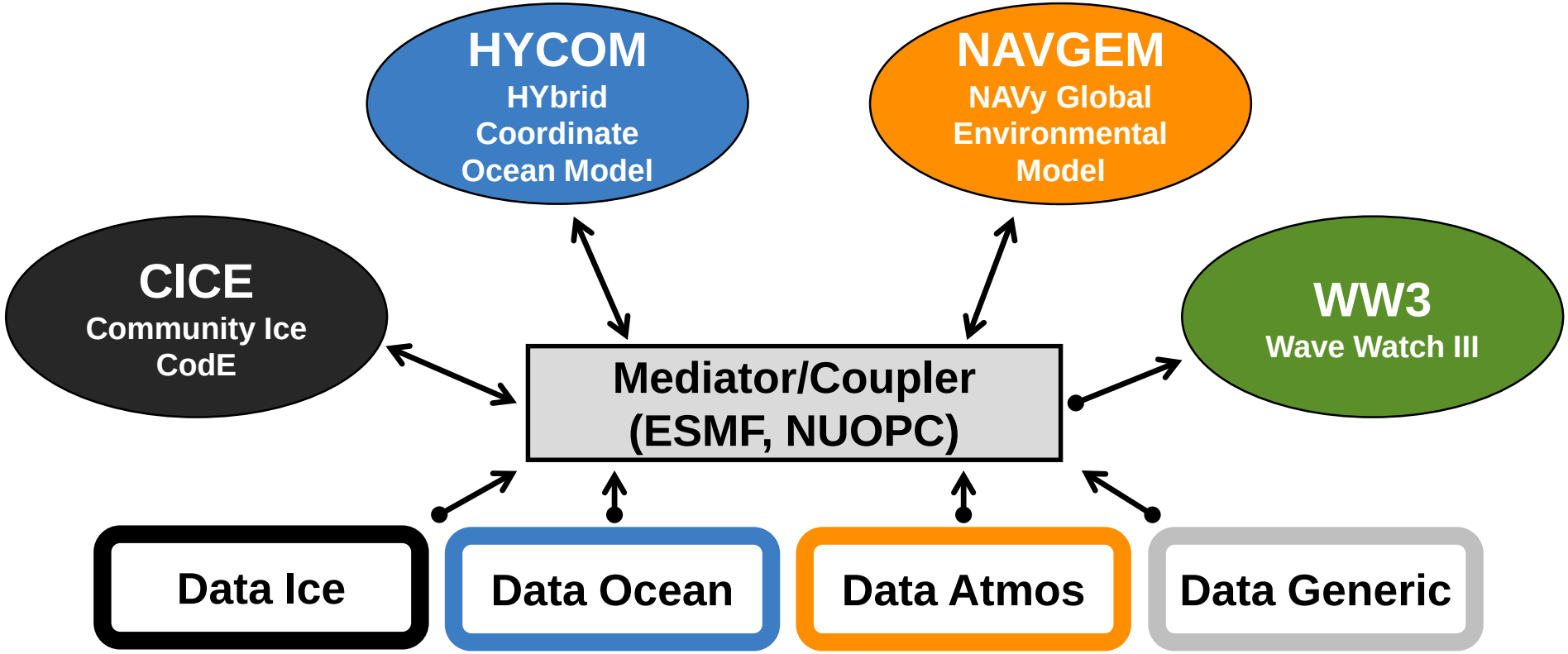
Current imagery is showing numerous leads in the vicinity of SKATE. Winds are strong breeze to near gale out of the east as this will continue to cause more fracturing in the region. From the 03/25 at 00 UTC through 03/28 at 00 UTC things should settle into a consistent rhythm of easterly winds and drift. The strain rate model is only showing moderate risk through the region due the many leads and cracks in the region that already exist and will re-activate within this dynamic environment.

USCGC MAPLE NORTHWEST PASSAGE



https://kcaw-org.s3.amazonaws.com/wp-content/uploads/2017/07/NWPassage_Edit.jpg

Navy Earth System Model (NESM)

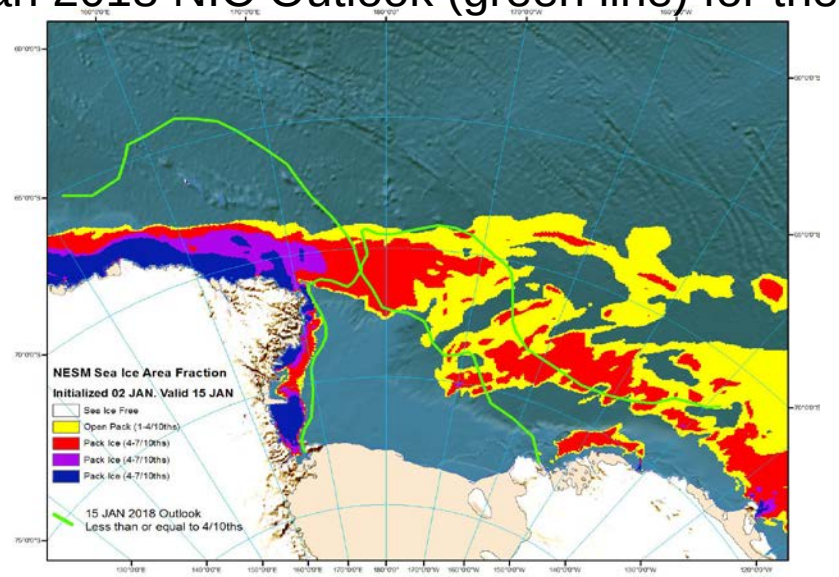


NMME-SubX

Leveraging NMME-SubX Forecasts

NESM real time forecasts were leveraged to provide the NIC with 45-day forecasts of sea ice concentration, thickness and drift for long-range planning guidance for 2018 Operation Deep Freeze (McMurdo resupply mission) and ICEX (Beaufort Sea) field campaign support.

15 Jan 2018 NRL NESM 15-day sea ice fraction forecast (color shading) compared to 15 Jan 2018 NIC Outlook (green line) for the Ross Sea, Antarctica



Model Development

Ice Concnetration - VIIRS

VIIRS (Visible Infrared Imaging Radiometer Suite) currently not assimilated into operational GOFS

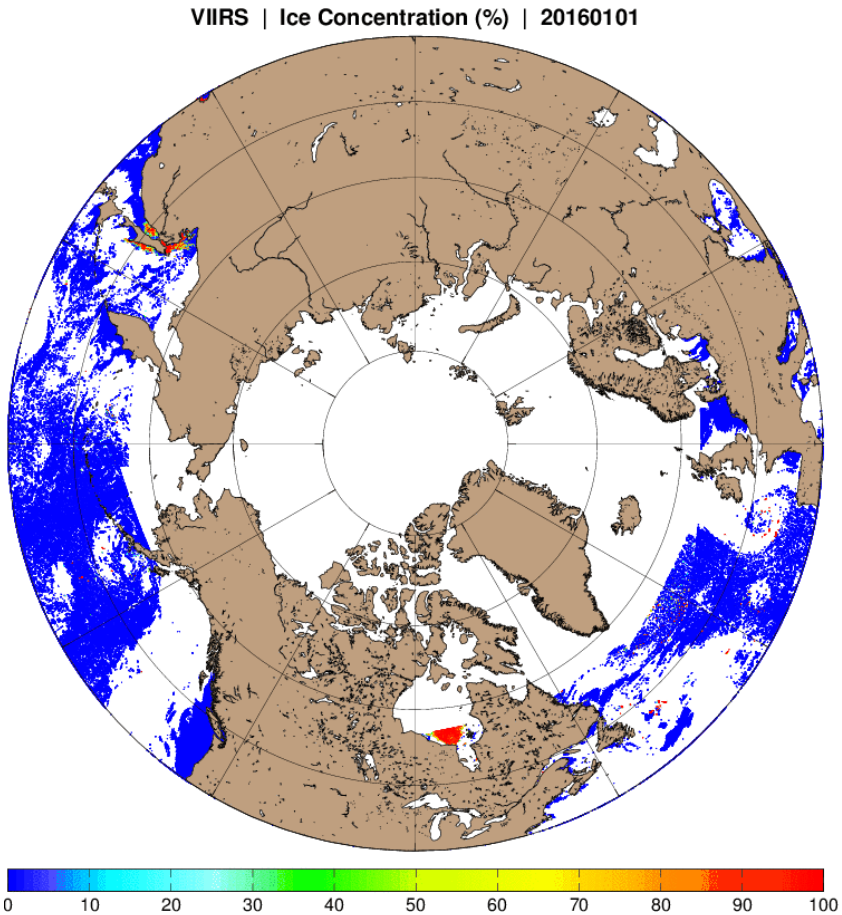
Pros

- High Resolution (375-750 meter)
- Available near real time
- No issues with low concentration in summer

Cons

- Data only when visible light available (i.e., not in winter months)
- Cannot see through clouds

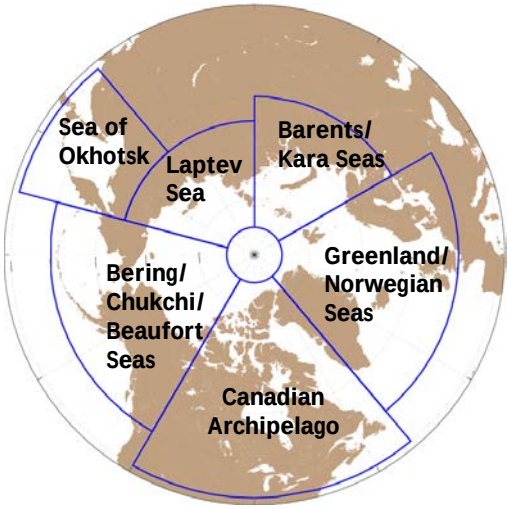
Can we utilize this satellite data in our model?



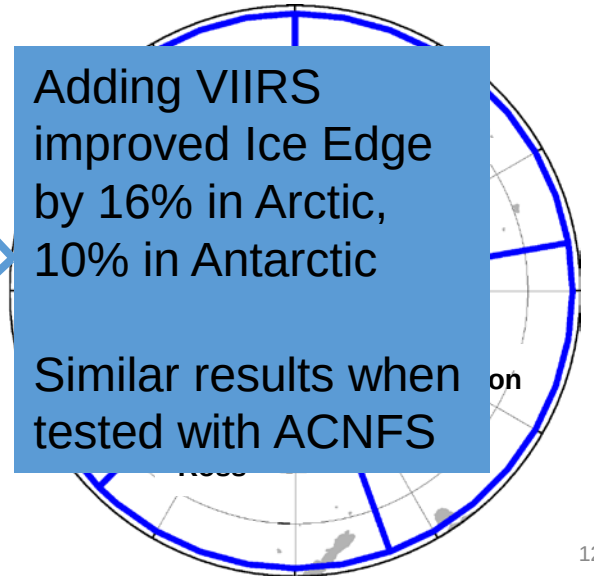
Ice Edge Analysis - VIIRS

Arctic	Pre-operational GOFS 3.1 SSMI/AMSR2	GOFS 3.1 SSMI/AMSR2/ VIIRS	Total improvement over pre-operational GOFS 3.1
Greenland	30.9	21.2	31%
Barents	24.3	22.4	8%
Laptev	27.6	23.2	16%
Sea of Okhotsk	19.8	18.3	8%
Bering/Beaufort	23.7	21.6	9%
Can Arch	31.2	24.6	21%
Average improvement over GOFS 3.1			**16%**

Antarctic	Pre-operational GOFS 3.1 SSMI/AMSR2	GOFS 3.1 SSMI/AMSR2/ VIIRS	Total improvement over pre-operational GOFS 3.1
Amery	38.5	32.9	15%
Shackleton	31.7	29.1	8%
Ross	41.9	38.3	9%
Amundsen	37.2	33.8	9%
Bellingshausen	27.6	25.2	9%
Weddell	46.2	40.9	12%
Average improvement over GOFS 3.1			**10%**



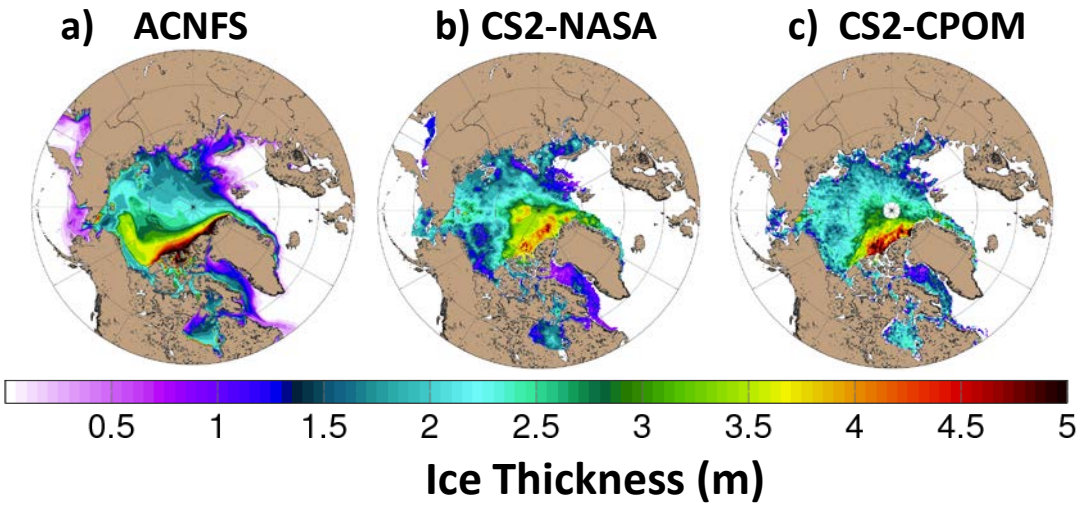
1 year test Nov 2016-Oct 2017

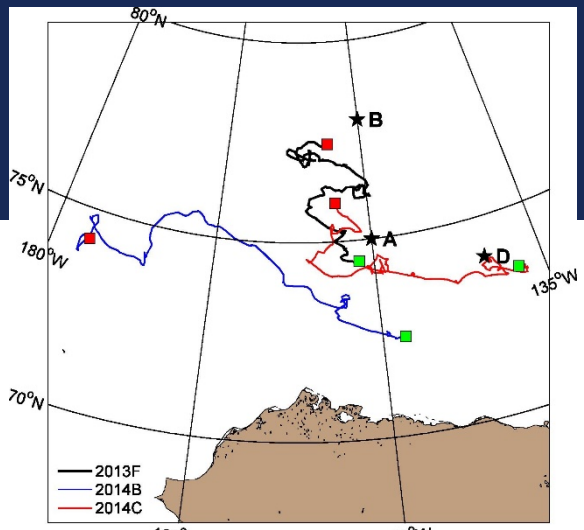


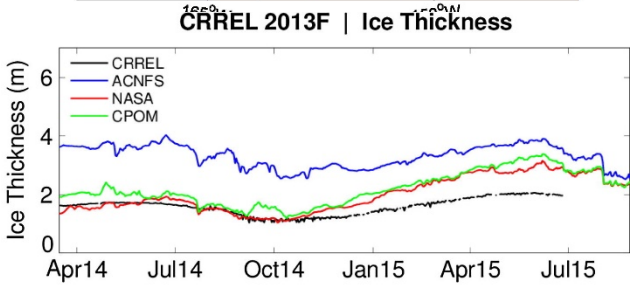
Adding VIIRS improved Ice Edge by 16% in Arctic, 10% in Antarctic

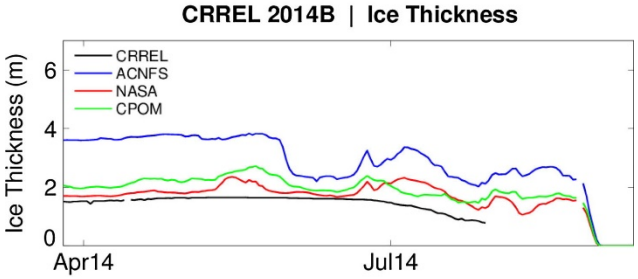
Similar results when tested with ACNFS

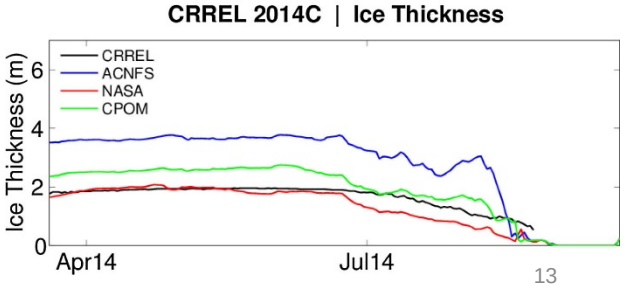
Reinitialize Ice Thickness









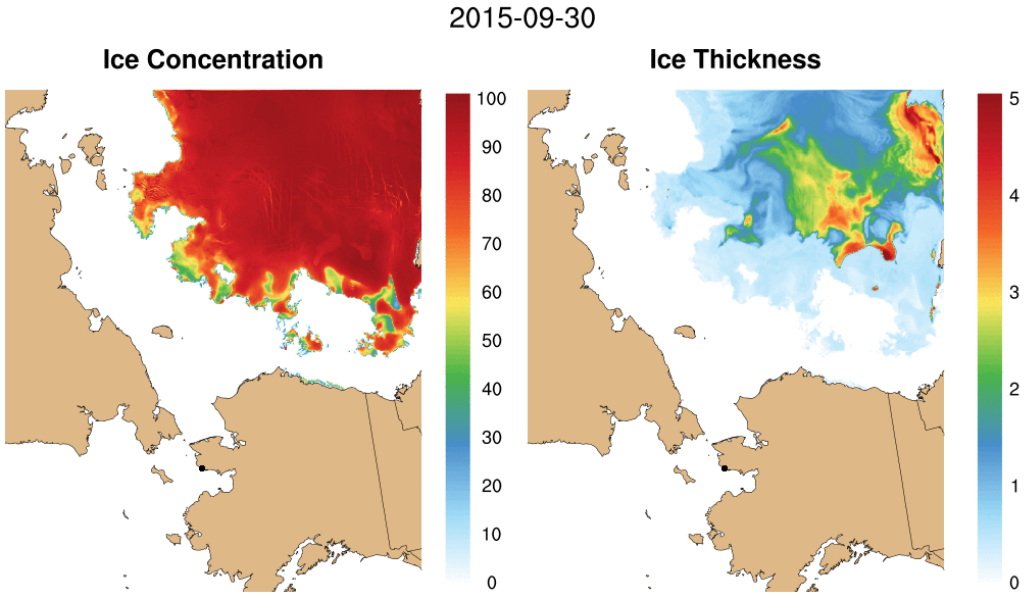


- Model Ice Thickness re-initialized with March Monthly Ice Thickness from CryoSat-2.
  - Thickness available by NASA and CPOM
- Comparison to CRREL IMBB show improvement lasts for almost full season, regardless of CryoSat-2 Source
- Used to initialize spin-up of next update to GOFS 3.5

Future plans

High Regional Modeling

- 2 km regional model used to support USCGC Healy and ONR Sea State DRI 2015
- Working to test sub-km, fully coupled regional arctic



Black dots are R/V Sikuliaq track for ONR Sea State DRI

Landfast Ice, Tides

- New implementation of CICE code will have landfast ice parameterization.
- New version of GOFS 3.5 includes tides (1.75 km resolution at the pole)

U.S. NAVAL RESEARCH LABORATORY

Summary

GOFS 3.1 provides modeled polar condition forecasts to NIC daily.

- Utilized for ICEX March 2018, USCGC Maple Northwest Passage August 2018.

Navy Earth System Model (NESM) fully coupled global model in initial testing stages

- Provides sub-seasonal (45 day) forecasts of polar conditions.
- Used for long range planning to McMurdo Resupply

Model development by adding new arctic data sources for assimilation

- Adding VIIRS ice concentration improved modeled Ice Edge by 16%-20%
- Re-initializing with CryoSat-2 ice thickness improved modeled ice thickness throughout the summer season.
- High resolution ice models being tested now.
- Investigate adding landfast ice.
- Next Generation GOFS 3.5 will have tides

U.S. NAVAL RESEARCH LABORATORY

Thank you!