ONR Arctic Environmental Research

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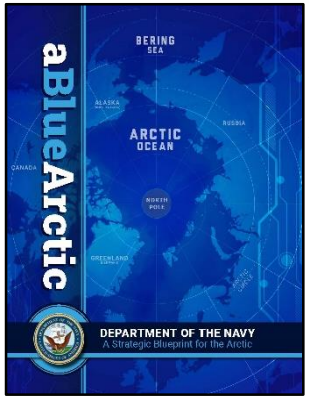
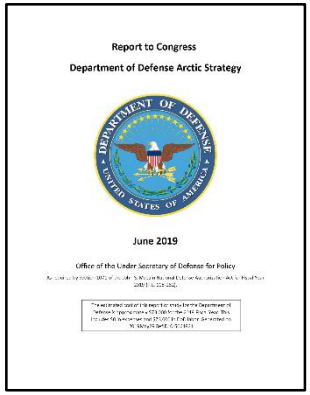
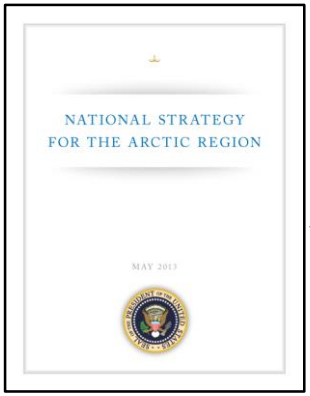
Responding to Evolving Navy, DoD, and National Strategic Arctic Guidance with S&T Investments




Report to Congress
Department of Defense Arctic Strategy
June 2019
Office of the Under Secretary of Defense for Policy


NATIONAL STRATEGY
FOR THE ARCTIC REGION
MAY 2013

Latest: US Navy's "Strategic Blueprint for the Arctic" (2021)

- **Maintain Enhanced Presence**
- **Strengthen Cooperative Partnerships**
- **Build a More Capable Arctic Naval Force**

SOURCES

- First US Navy Arctic Roadmap, Task Force Climate Change, October 2009
- COMSUBLANT/COMSUBPAC Arctic Requirements Letter, Ser N3/0644, 04 SEP 2013
- US National Strategy for the Arctic Region Implementation Plan, January 2014
- The United States Navy Arctic Roadmap for 2014 to 2030, February 2014
- NORAD-USNORTHCOM FY18-22 S&T Integrated Priority List (STIPL)
- N52 Arctic Engagement Plan Memo, 02 APR 2015
- NORAD-USNORTHCOM Arctic Maritime Capability Requirements Study:
  - Phase 1 Final Technical Report, 15 OCT 2015
  - Appendix E, Non-releasable Material, 31 JUL 2015
- NORAD-NORTHCOM Arctic Capabilities Based Assessment, May 2017
- Department of Defense Arctic Strategy, June 2019
- US Navy's "Strategic Outlook for the Arctic", January 2020
- US Navy's "a Blue Arctic: Strategic Blueprint for the Arctic", January 2021

Develop a Framework of Observations and Modeling to Support Forecasting and Prediction of Sea Ice

Lead Agency: Department of Defense (Navy)

"increased certainty and accuracy of sea ice forecasts and predictions, and by showing improved understanding of feedback processes driving sea ice variability"

Naval Operations in the Arctic

The Arctic is a novel, challenging operational environment

- Surface conditions are far more hazardous (sea ice, low temperatures)
- Subsurface ocean stratification is unique, and changing with the changing climate
- Numerical prediction requires full system models (ice-ocean-atmosphere-waves)
- Insufficient observations to characterize the environment
- Climatology is not a good indicator of future operational conditions

We must be able to observe and predict the Arctic environment in order to support operations (short-term forecasts) and investment and policy decisions (long-term).

ONR Arctic Environmental Research Thrusts

To Better Understand and Predict the Arctic Environment

Program Initiated in FY2012 in response to Navy Task Force Climate Change's "Arctic Roadmap"

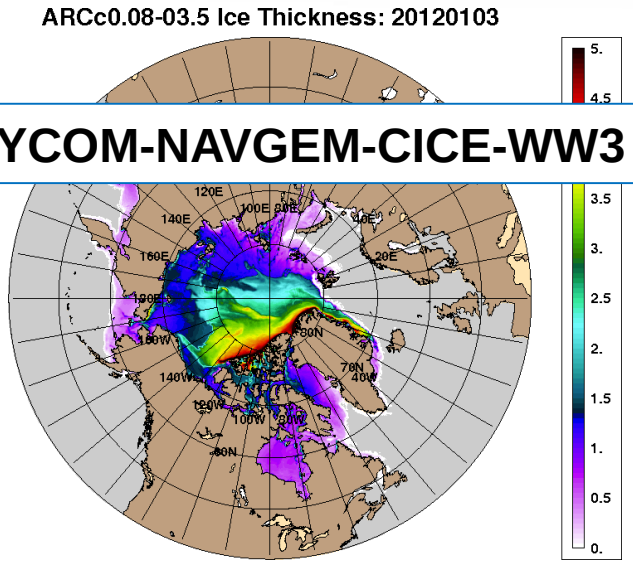
1. Generation of **new observing technologies and methods** (platforms, sensors, communications) that will enable persistent observational capabilities in the Arctic
2. **Improved basic physical understanding** of the Arctic environment and the important coupled processes that drive evolution and predictability in the Arctic region
3. Development of **fully-integrated Arctic System Models** incorporating the ocean, sea ice, waves and atmosphere for **improved prediction at longer lead times**, including the use of satellite SAR data for assimilation into integrated models

In the Beaufort and Chukchi Sea, the presence or absence of Arctic Sea Ice is *the* critical operational parameter

Cooperative Model Development

ONR is working the Arctic prediction problem on a variety of space and time scales, with NRL expertise and investment in model development with the academic performer community, including NPS, UW/APL and many others

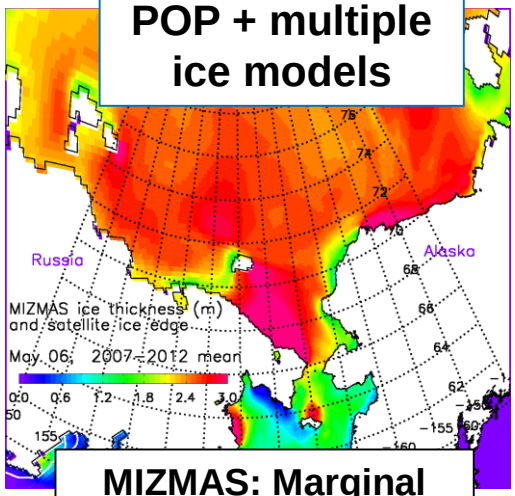
HYCOM-NAVGEM-CICE-WW3



Model grid resolution ~ 3.5 km

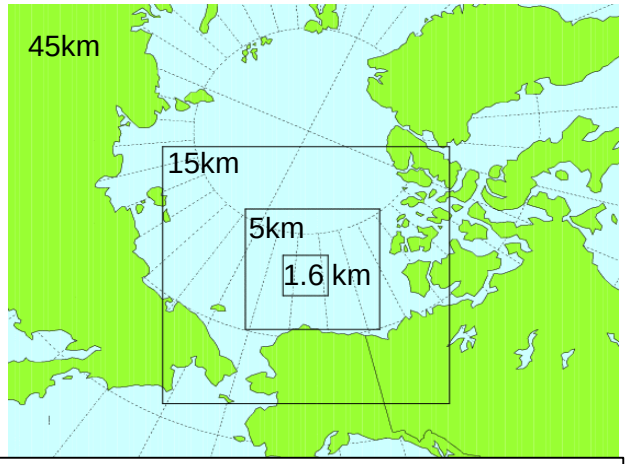
Black line is the independent ice edge location (NIC)

POP + multiple ice models



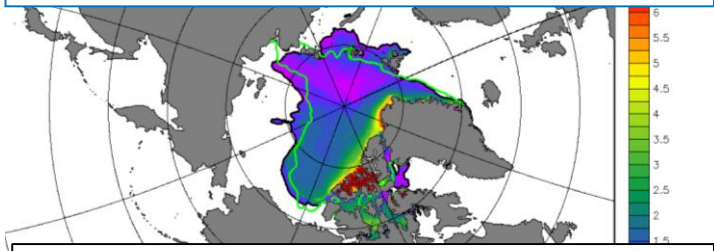
MIZMAS: Marginal Ice Zone Modeling and Assimilation system (UW/APL)

NCOM-COAMPS-CICE-WW3



Future Regional Arctic System (RAS)
Flexible Coupled Relocatable Model Domain

POP-Polar WRF-CICE

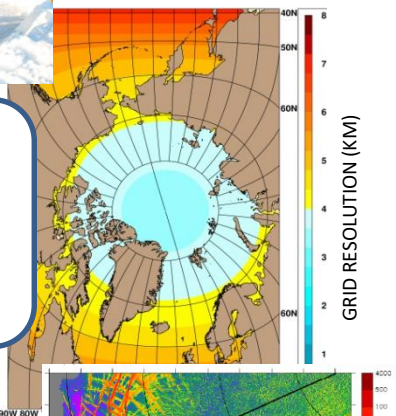


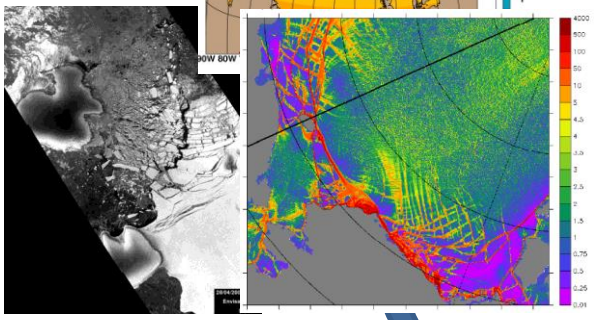
RASM: Regional Arctic System Model (NPS)

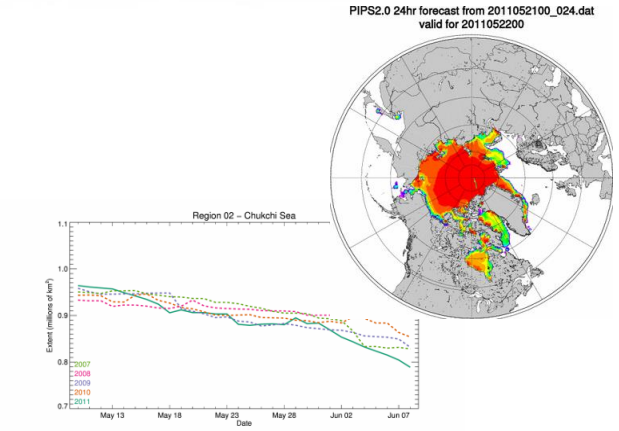
Development and Transition of New Arctic Prediction Capabilities

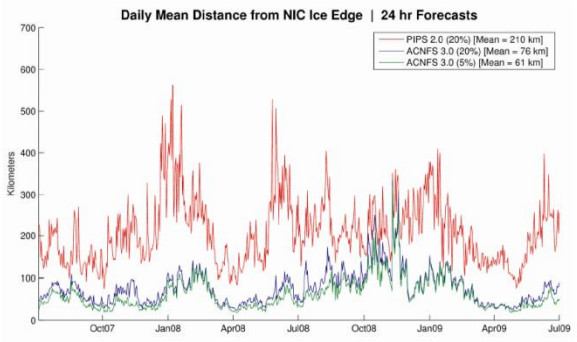
Fieldwork to better understand key physical processes

Improved physics built into data-assimilating integrated models









NAVAL METEOROLOGY AND OCEANOGRAPHY COMMAND

NATIONAL ICE CENTER
WASHINGTON D.C.

Arctic Prediction System Development

Observing System Development

Validation and Verification

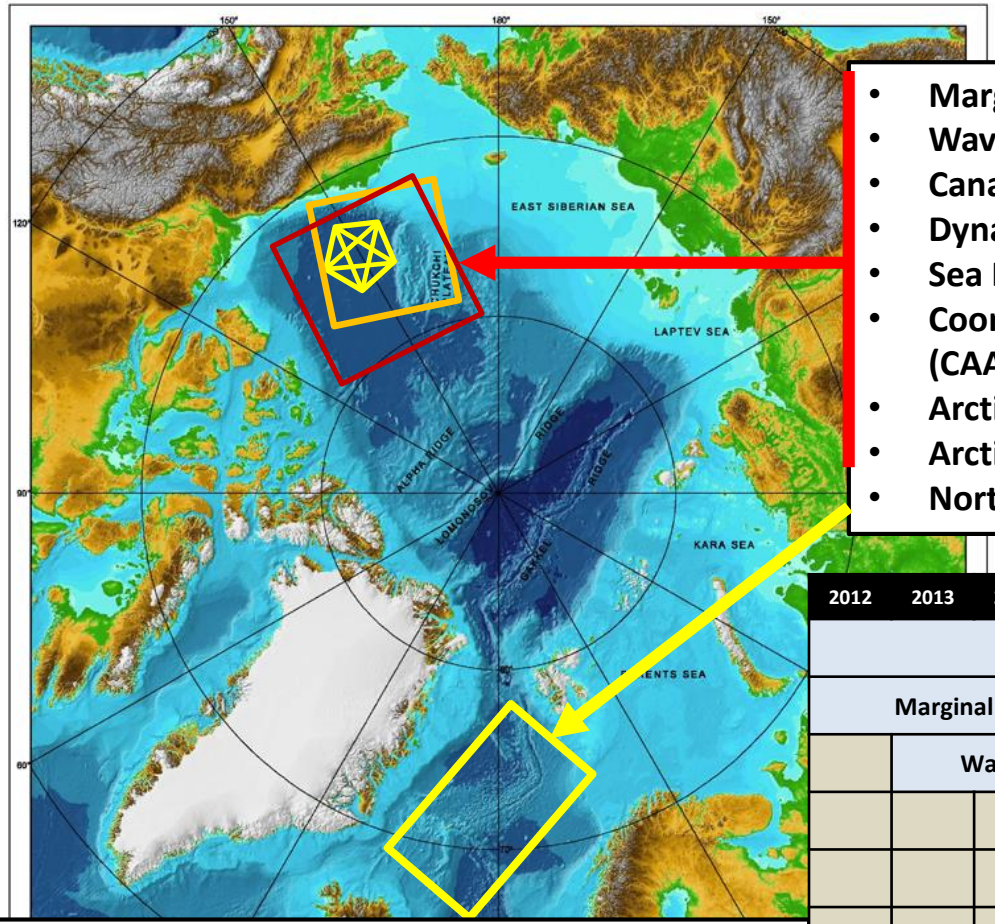
Testing, Prototyping and Experimentation

Transition to Operational Use

Transition to Operational Use

Timeline of Major ONR Arctic Research Initiatives

Arctic Program re-started in 2011



- Marginal Ice Zone (MIZ) Initiative
- Waves and Sea State Initiative
- Canada Basin Acoustic Propagation Experiment (CANAPE)
- Dynamics in the Arctic (SODA)
- Sea Ice Dynamics Experiment (SIDEx)
- Coordinated Arctic Acoustic Thermometry Experiment (CAATEx)
- Arctic Cyclone Predictability
- Arctic Mobile Observing System (AMOS) INP
- Northern Ocean Rapid Surface Evolution (NORSE)

Important Operational Parameters:

- Seasonal Cycle of Sea Ice
- Surface Weather: Winds, Waves, and Swell
- Ocean Stratification
- Sea Ice Dynamics

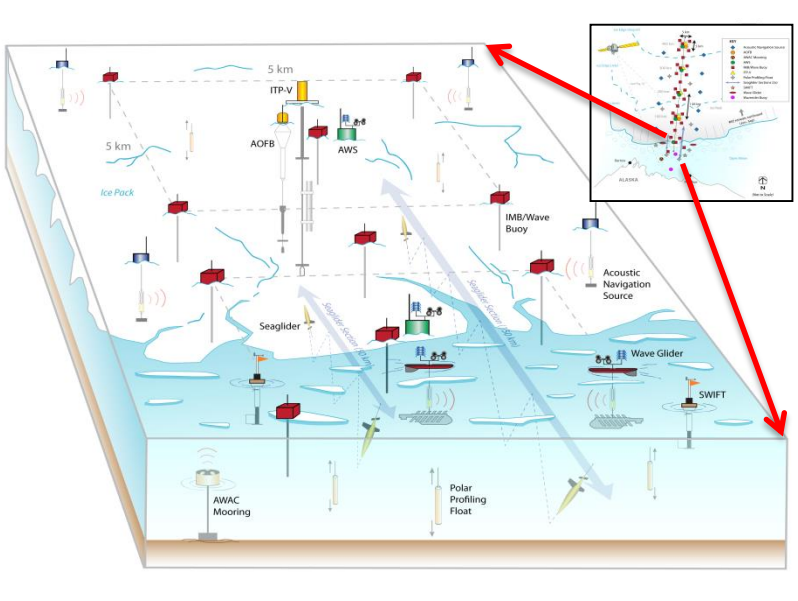
2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
ONR Code 32 Core Program Arctic Research Efforts												
Marginal Ice Zone DRI												
	Waves and Sea State DRI											
			CANAPE (acoustics)									
				Stratified Ocean Dynamics DRI								
					Sea Ice Dynamics Experiment DRI							
						CAATEX (acoustics)						
						Arctic Cyclone Predictability DRI						
							Arctic Mobile Observing System INP					
								NORSE DRI				

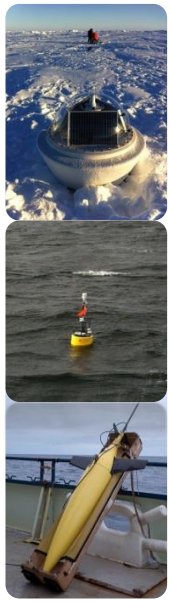
ONR Research on the Seasonal Cycle of Sea Ice

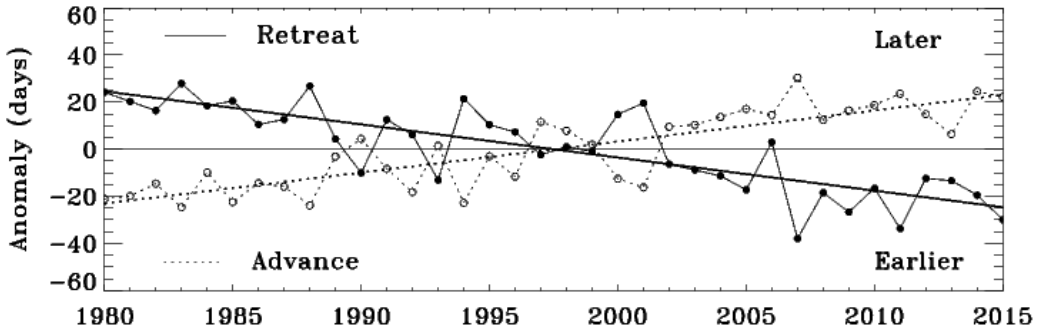
Department Research Initiatives (DRIs)

Marginal Ice Zone DRI

Thermodynamic Melting of Sea Ice

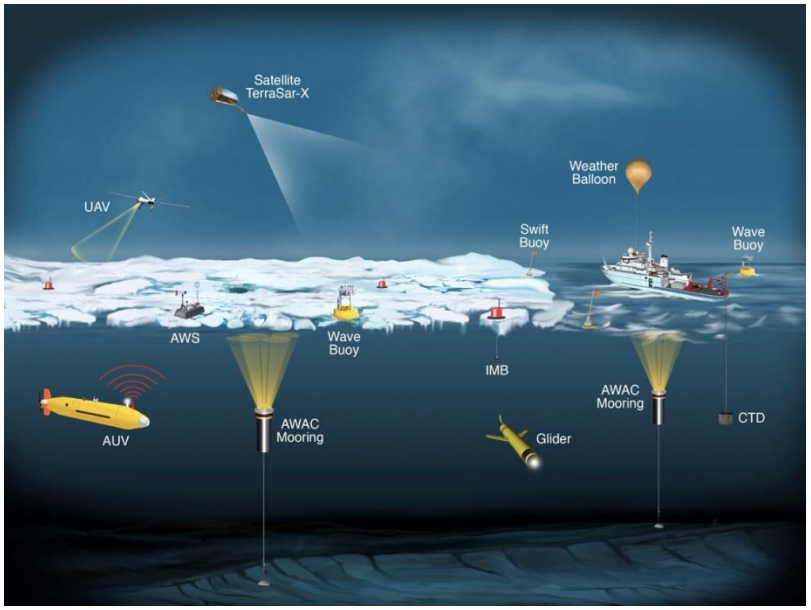






Sea State DRI

Impact of Waves and Swell on Freeze-Up

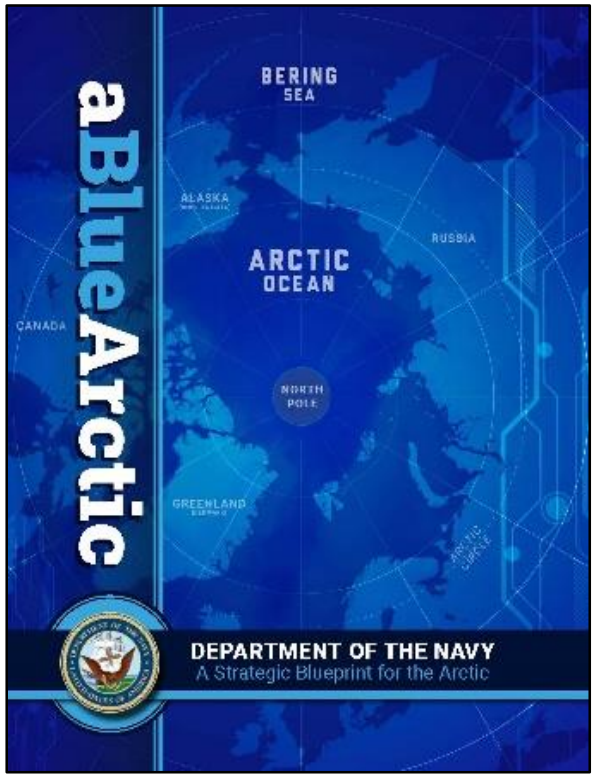


Three additional months of low-ice conditions in the Arctic since 1980

- **Sea ice retreat occurs 6 weeks earlier**
- **Sea ice advance occurs 6 weeks later**

"A Strategic Blueprint for the Arctic"

January 2021



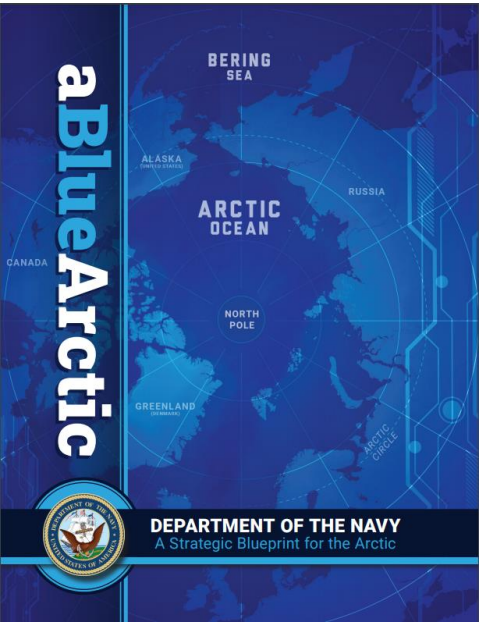
What is it?

A 25-page document with lots of pictures, outlining the US Navy's expected approach to the Arctic over the next two decades.

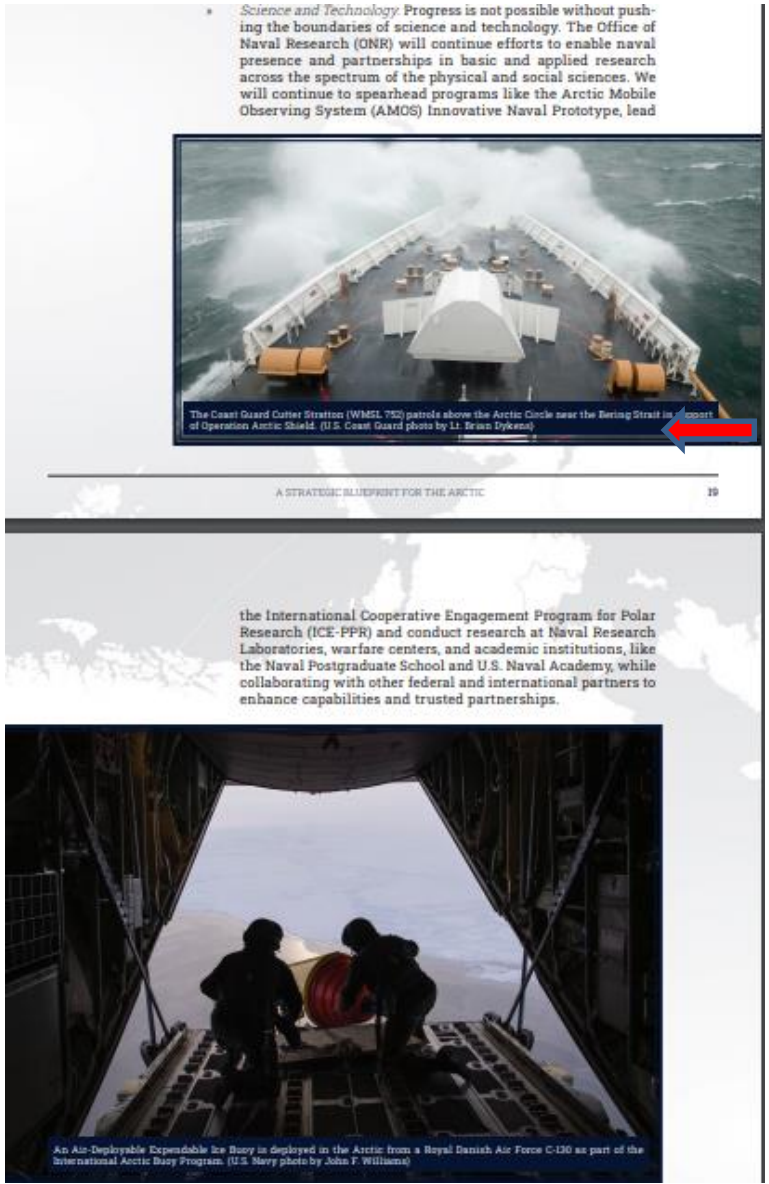
Some personal observations…

- ***Recognizes that the Arctic is gradually turning from "White" to "Blue" as sea ice continues to decline***
- ***Recognizes the Arctic as a strategic region of growing geo-political and global importance***
- ***Suggests the US Navy will need to operate above, on, and under the Arctic Ocean more frequently as the sea ice continues to diminish and activity in the Arctic increases***
- ***The US Navy places high value on working with many partners in the Arctic, both international as well as US federal partners, state, local, and indigenous communities***

"Strategic Blueprint" for Science and Technology



Naval forces will preserve peace and build confidence among nations through collective deterrence and security efforts that focus on common threats and mutual interests in a Blue Arctic. ***This requires an unprecedented level of critical thinking, planning, integration, and interoperability among our joint forces and international partners****, along with greater cooperation among U.S. interagency, state, local, and indigenous communities*



Science and Technology Progress is not possible without pushing the boundaries of science and technology. The Office of Naval Research (ONR) will continue efforts to enable naval presence and partnerships in basic and applied research across the spectrum of the physical and social sciences. We will continue to spearhead programs like the Arctic Mobile Observing System (AMOS) Innovative Naval Prototype, lead

The Coast Guard Cutter Stratton (WMSL 752) patrols above the Arctic Circle near the Bering Strait in support of Operation Arctic Shield. (U.S. Coast Guard photo by Lt. Brian Dykens)

A STRATEGIC BLUEPRINT FOR THE ARCTIC 19

the International Cooperative Engagement Program for Polar Research (ICE-PPR) and conduct research at Naval Research Laboratories, warfare centers, and academic institutions, like the Naval Postgraduate School and U.S. Naval Academy, while collaborating with other federal and international partners to enhance capabilities and trusted partnerships.

An Air-Deployable Expendable Ice Buoy is deployed in the Arctic from a Royal Danish Air Force C-130 as part of the International Arctic Buoy Program. (U.S. Navy photo by John F. Williams)

The *Strategic Blueprint* calls on ONR to "***continue efforts to enable naval presence and partnerships in basic and applied research***" and specifically calls out:

- **Arctic Mobile Observing System (AMOS) INP**
- **International Collaborative Engagement Program for Polar Research (ICE-PPR)**

✓ Participants: US, Canada, Denmark, Finland, New Zealand, Norway and Sweden

✓ Working groups: Environmental, Human Performance, Platforms and Situational Awareness

Arctic Mobile Observing System (AMOS)
ONR Innovative Naval Prototype (FY19-FY24)

Develop and field a prototype distributed observing system that will enable the persistent collection and communication of critical Arctic environmental variables above, within, and below the sea ice of the Arctic Ocean in near-real time.

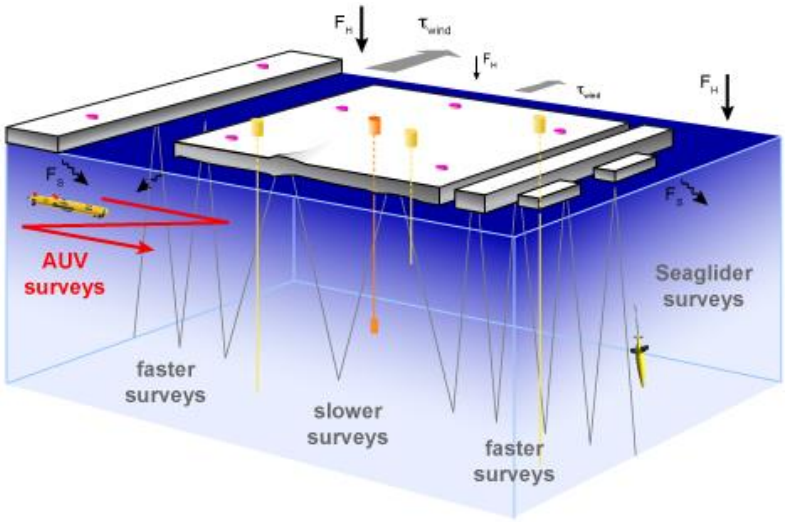
Technology:

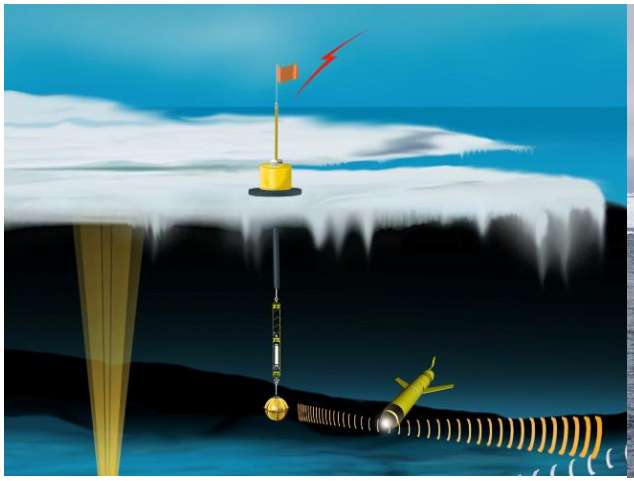
Domain-Specific Engineering Development

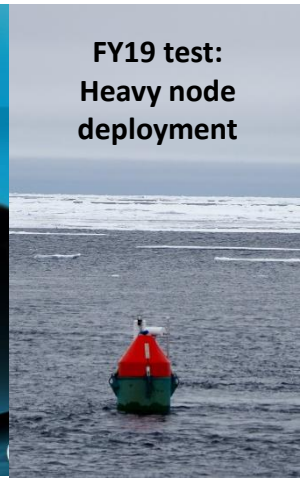
- Upgraded UUV platforms hardened for the Arctic environment
- Cold-weather power/comms housed in survivable buoy node
- Develop and integrate mature and maturing UUV sensing capabilities suitable for Arctic operations

Develop Under-ice CONOPS for Autonomous UUV Network

- Build on capabilities developed under previous efforts for vehicle autonomy, re-charging, sensing, communication, and C4I
- Develop, test, and demo capabilities for operating under sea ice
- Deploy and demo an under-ice acoustic navigation system for unmanned platforms, suitable for use in any GPS-denied area







FY19 test: Heavy node deployment

AMOS intended to demonstrate and provide:

- **Mobile Sensing System for Arctic Observation and Prediction**
- **Multiple unmanned platforms with under-ice capabilities – UUVs/buoys/floats will collect data around a central buoy node drifting with the sea ice that provides power/comms**
- **Bi-directional data transfer and mission adaptability with autonomy improvements**
- **Designed to characterize the Arctic environment & prototype CONOPs for persistent robotic observing systems in the Arctic**

Arctic Mobile Observing System INP Motivation:
Limited *in situ* Arctic sensing capabilities

Problem:

The Navy lacks a persistent capability to collect observations in support of MDA and forecasts of the maritime Arctic to support of Fleet Operations

- Operational capability of surface ships in summer months is marginal due to weather and sea ice
- US Navy presence in winter and spring is limited to submarines and ice surface at biennial ice camps
- Arctic observations are needed for improved forecasts to enable safer maritime operations

Arctic Domain (Beaufort/Chukchi Seas):

- Harsh surface conditions; nine months of sea ice cover
- Difficult, remote operations drive need for an unmanned solution for Arctic domain awareness
- Requires alternate navigation solution for UUVs due to surface-denied environment (no GPS fix)
- Systems require domain-specific “Arctic-hardening”

Arctic Mobile Observing System (AMOS)

Ice Gateway Buoy - Heavy

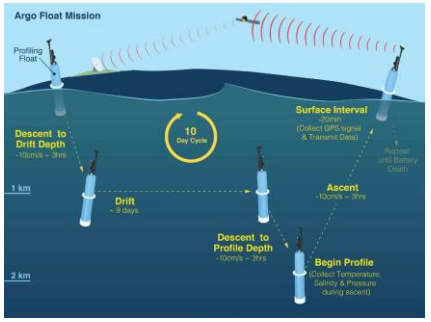
Ice Gateway Buoy - Light

Persistent, year-round Arctic monitoring and an event-driven sampling and response capability

- Data exfiltration and control for instruments operating under ice through 'gateway' buoys that bridge ice-ocean interface.
- Store and forward network of mobile instruments.
- Robust, broad acoustic navigation:
  - Long-range (trans-basin) very low frequency (35 Hz) beacons – 'underwater GPS.'
  - Range and bearing from single 900 Hz beacons on gateway buoys – expand utility of drifting systems.
- Persistent presence, multi-scale sampling – gliders, floats & fast UUVs operating with 'gateway' buoys.
- Situational awareness and control center – in situ environmental data, remote sensing, numerical predictions inform decisions.

Long-Endurance Gliders

Fast Unmanned Underwater Vehicles

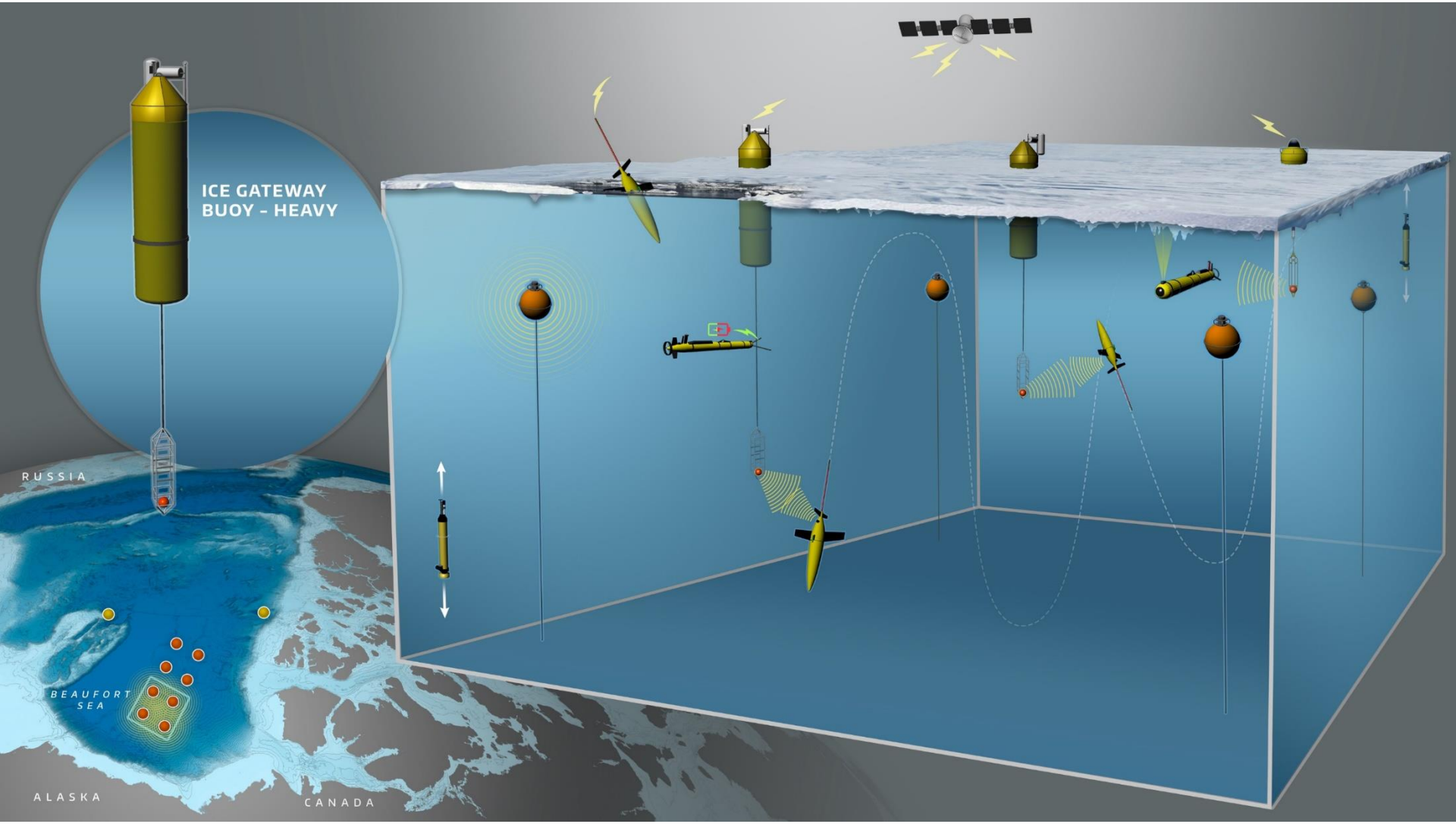


Free-drifting, Profiling Floats

Arctic Mobile Observing System (AMOS)

An ONR Innovative Naval Prototype component (FY19-FY24)

AMOS is a distributed autonomous network of sensor platforms for Arctic awareness



ONR Arctic Research Summary

ONR's Arctic program is investing in research that will enable the Navy to prepare for and respond to future Arctic missions and concerns in recognition of the emerging interest in the region.

Primary thrusts:

- Development and use of new observing tools, with an emphasis on Arctic-capable autonomous platforms and sensors
- Basic understanding of the emerging physical Arctic system
- Development of the Arctic component of Earth system numerical prediction models to enable improved forecasts