6th OCEAN EXPLORATION ADVISORY BOARD MEETING

14 September 2016

Dr. Frank Herr

Dr. Scott Harper

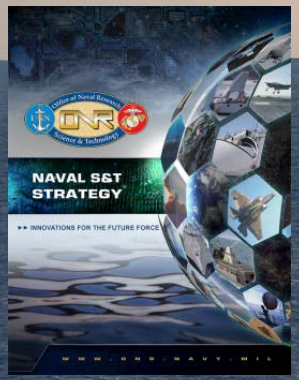
Office of Naval Research

Ocean Battlespace Sensing Department

The Office of Naval Research

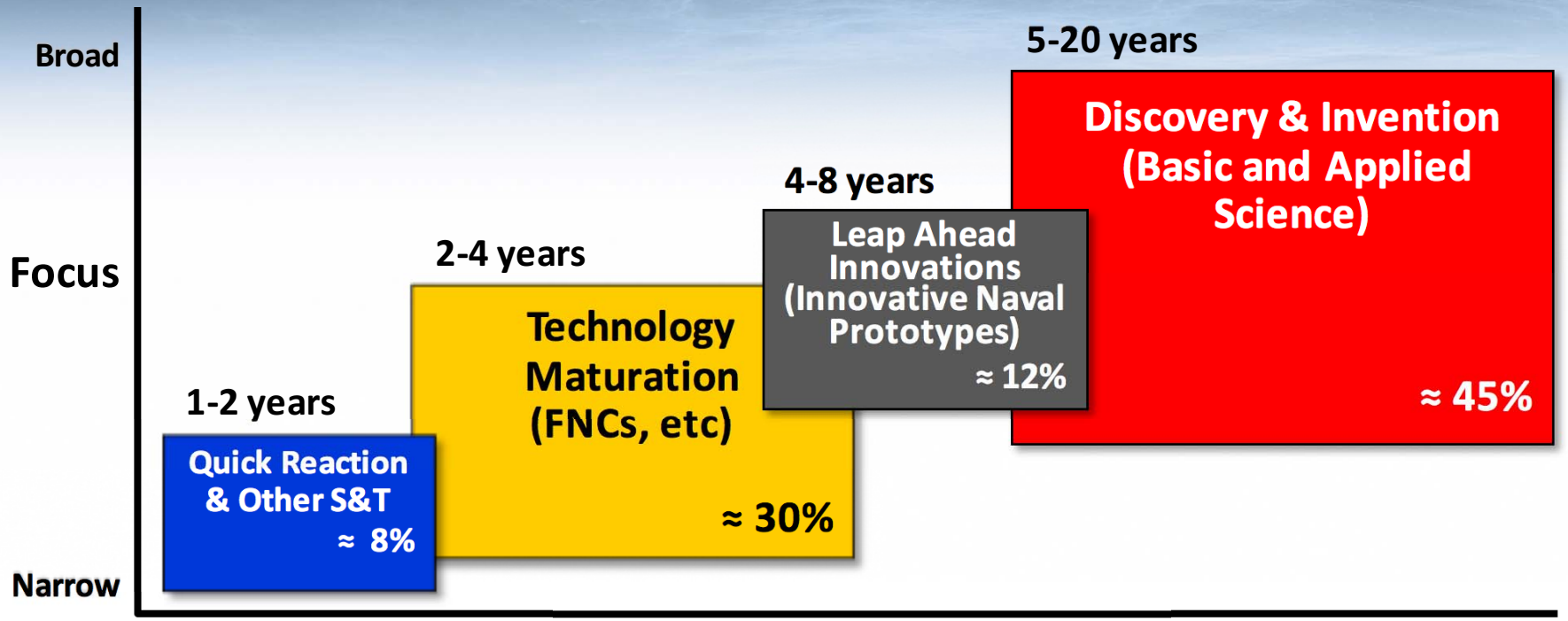
The S&T Provider for the Navy *and* Marine Corps

- 4,000+ People
- 23 Locations
- $2.1B / year
- >1,000 Partners



Discover → Develop → Deliver → Technological Advantage

Warfighting Capabilities Enabled by S&T Investments



Scientific Exploration:

Office of Naval Research supports hypothesis driven research

- Exploration as generally conceived – travel to unknown regions – is not part of the program.

However, we support:

Investigations in environmental processes to form a new state-of-the-art

- In specific regions after many years of scientific inattention
- Using new tools, analytical methods, and scientific perspective

Or, to address processes which have

- Previously been under sampled in space and time
- Seen their balance of importance and interactions altered significantly

These conditions may lead to a conclusion that what is understood is, in hindsight, less than previously thought.

Hypothesis driven research must be broadly fashioned, and it can take on some characteristics of exploration.

Research for a Purpose

- ONR adopts a "use inspired research" approach following Donald Stokes' formulation of the confluence of search for fundamental understanding with considerations of use.

- ONR seeks enduring problems within naval strategy, then addresses S&T deficiencies which underpin the larger problem

- Multiyear D&I efforts may be constructed as "challenges", perhaps "grand challenges" - these efforts may take on aspects of exploration

- Transition proceeds via technical demonstration of feasibility
  - Small Business Innovative Research
  - Future Naval Capabilities technology demonstrations (6.3)
  - Software demonstrations to acquisition offices

- Transition is a "contact sport" - intensive negotiations of risk, reward, DOTMLPF (Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities)

Geopolitical changes affect naval interests:

- Expansion of Chinese interests in S. and E. China Seas
- Resurgent Russia, particularly submarine building
- N. Korea, Iran
- ISIS activities
- Arctic opening to shipping

Antisubmarine warfare and mine countermeasures demand extensive knowledge of the environment as signatures are often very weak and confused with other environmental processes.

Ocean prediction is the primary means of codifying knowledge about the ocean/atmosphere/wave/cryosphere. Fully coupled system models constrained by in situ and remote data are developed for daily prediction by Commander, Navy Meteorology and Oceanography Command (CNMOC).

ONR Sponsored Research in Geophysical Modeling Supports Development and Improvement of 25+ Operational Prediction Systems at CNMOC

- **Major transitions:**

1) NAVGEM (Navy Global Environmental Model) next-generation global numerical weather prediction model; **FY14** replaced NOGAPS at FNMOC (Fleet Numerical Meteorology and Oceanography Center). Major resolution and physics increase in FY15. Transition to DSRC in FY16.

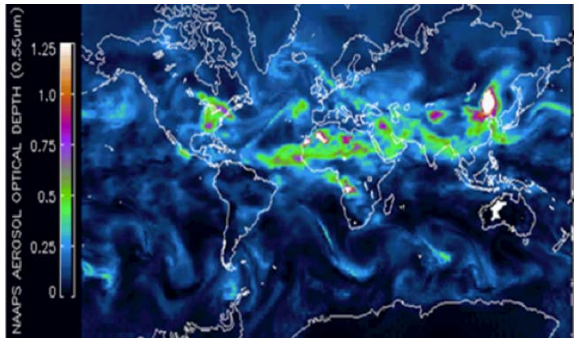
2) COAMPS-TC new mesoscale tropical cyclone model **FY14** operational at FNMOC. Predicts dynamically-driven TC intensity changes for the first time. Coupled version in FY15. Unified with COAMPS-OS in FY16. Ensemble version in FY18.

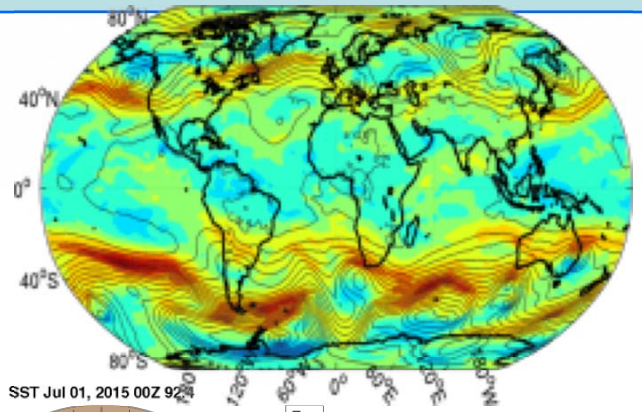
3) GOFS (Global Ocean Forecast System) Ver. 3.1 operational, transitioning to NAVGEM 1.3 forcing in FY16**.** [Includes CICE ice model and HyCOM ocean model with tides, 7km resolution]. Replaces Arctic Cap Forecast (ACFNS) in **FY15**.

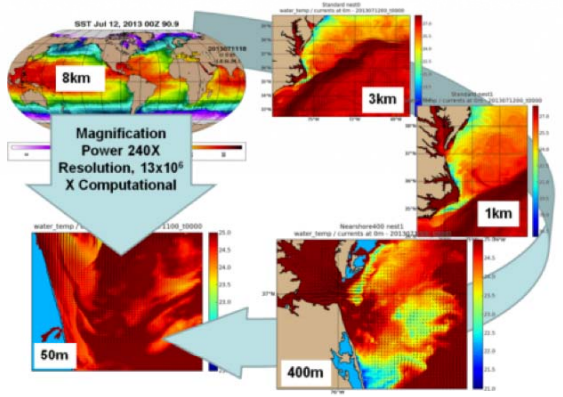
4) WaveWatch 3 (Global and Regional Wave Model) Transitioning version 5.03 in FY16. Coupled within ESPC in FY16.

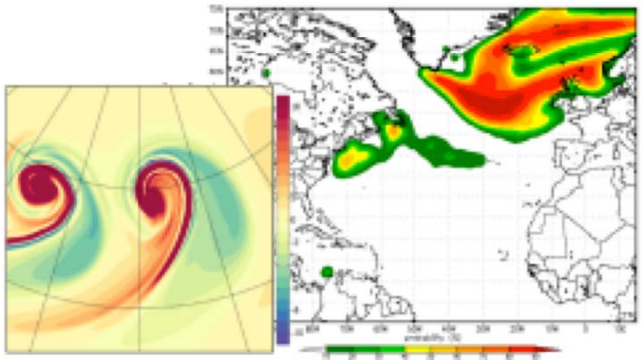
5) Regional Arctic Coupled Forecast System [Arctic COAMPS with HYCOM/CICE/WaveWatch3] tested by National Ice Center, operational in FY15 to provide improved predictions of ice fractures, leads, and polynyas for Arctic operations.

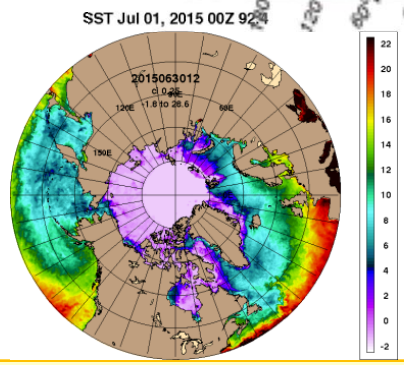
- **Future transitions: Coupled Air-Wave-Ocean COAMPS, Coupled NAVGEM/NAAPS/GOFS via ESPC, COAMPS Ensemble, GOFS 3.5**. [Requires ongoing acquisition of new High Performance Computing resources via the HPCMP]

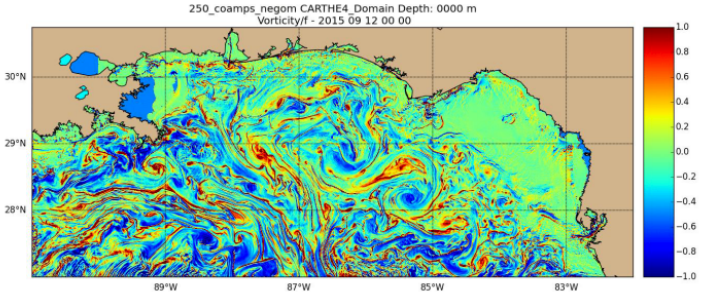






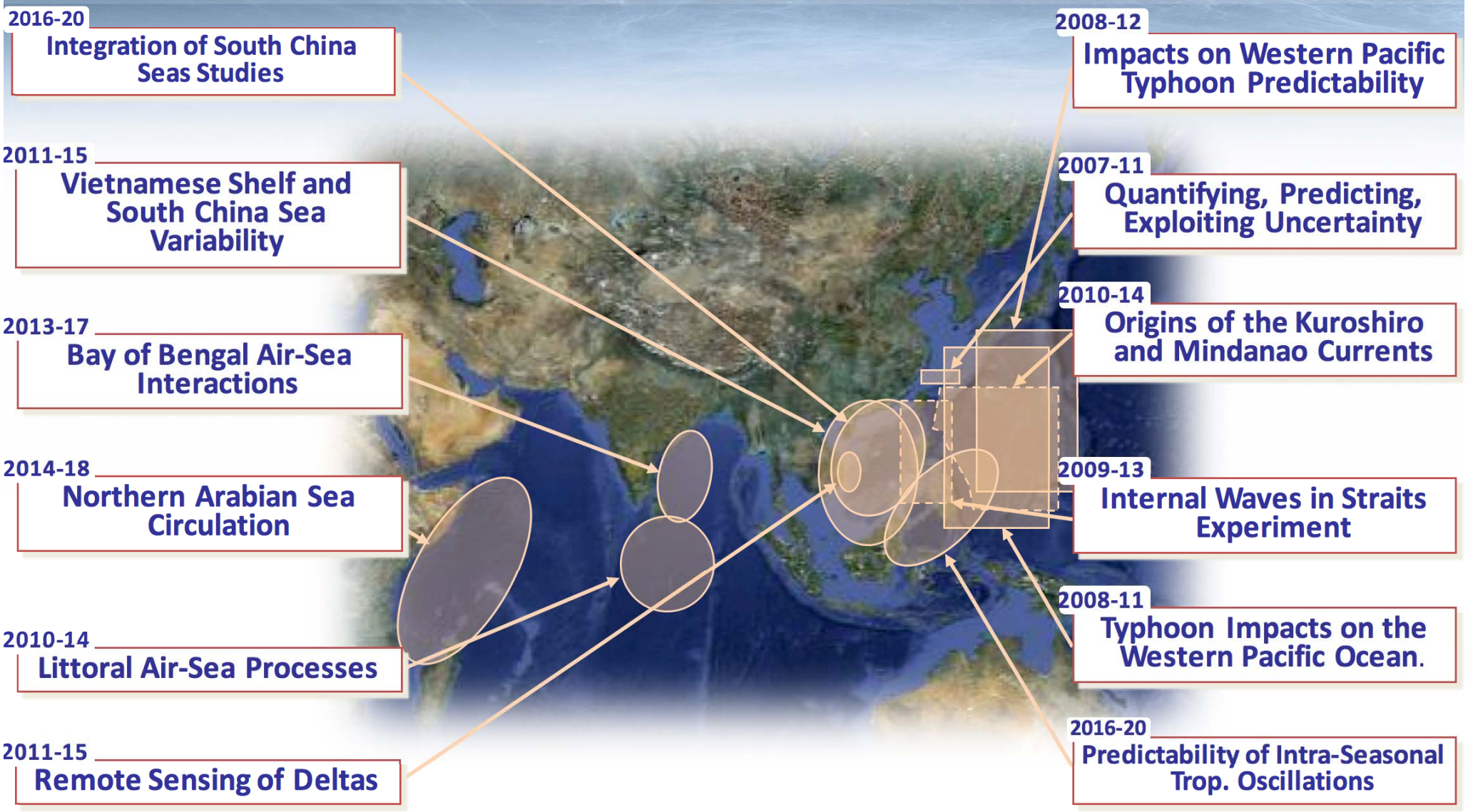






Predictions made by CNMOC Production Centers in Mississippi and California

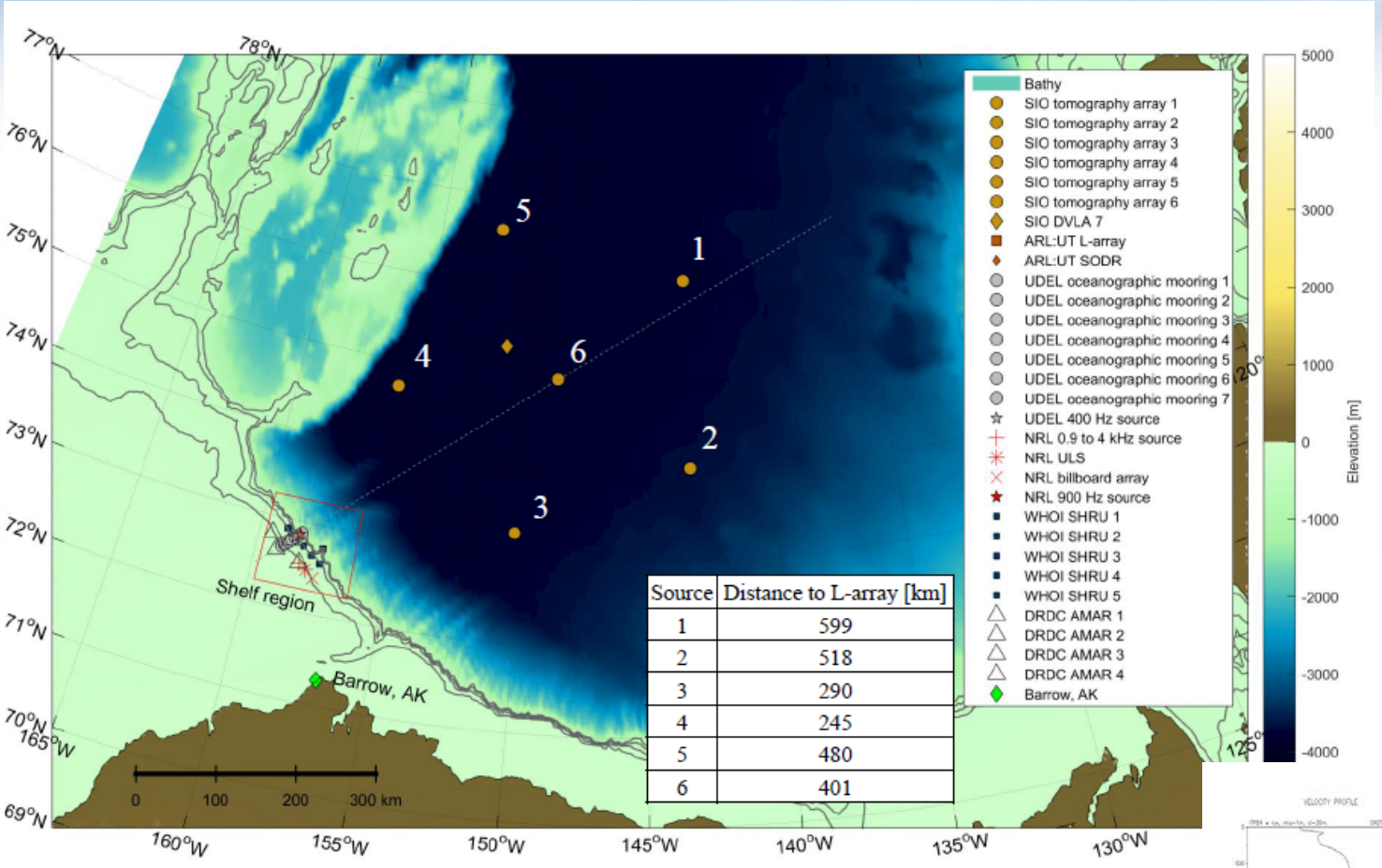
DRIs in the WESTPAC & IO Operational Environment



55 Five-Year Department Research Initiative (DRI) Studies Completed Since 1995 *(through end FY15)*

CANAPE: Canada Basin Acoustic Propagation Experiment, 2015 & 2016/17

ONR POC: Dr. Robert Headrick, Bob.Headrick@navy.mil



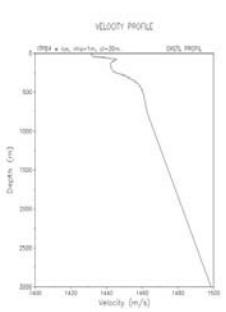
Source	Distance to L-array [km]
1	599
2	518
3	290
4	245
5	480
6	401

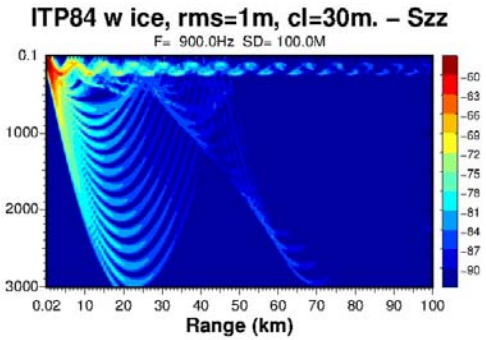
Goals

1. **Acoustic propagation:** Understand the impacts of changing sea ice and oceanographic conditions on acoustic (200-900 Hz) propagation and fluctuations.

2. **Ambient noise:** Characterize the depth dependence and temporal variability of the ambient noise field.

3. **Physical oceanography:** Can space/time acoustic methods with ice/ocean modeling yield estimates of the time-evolving ocean state.



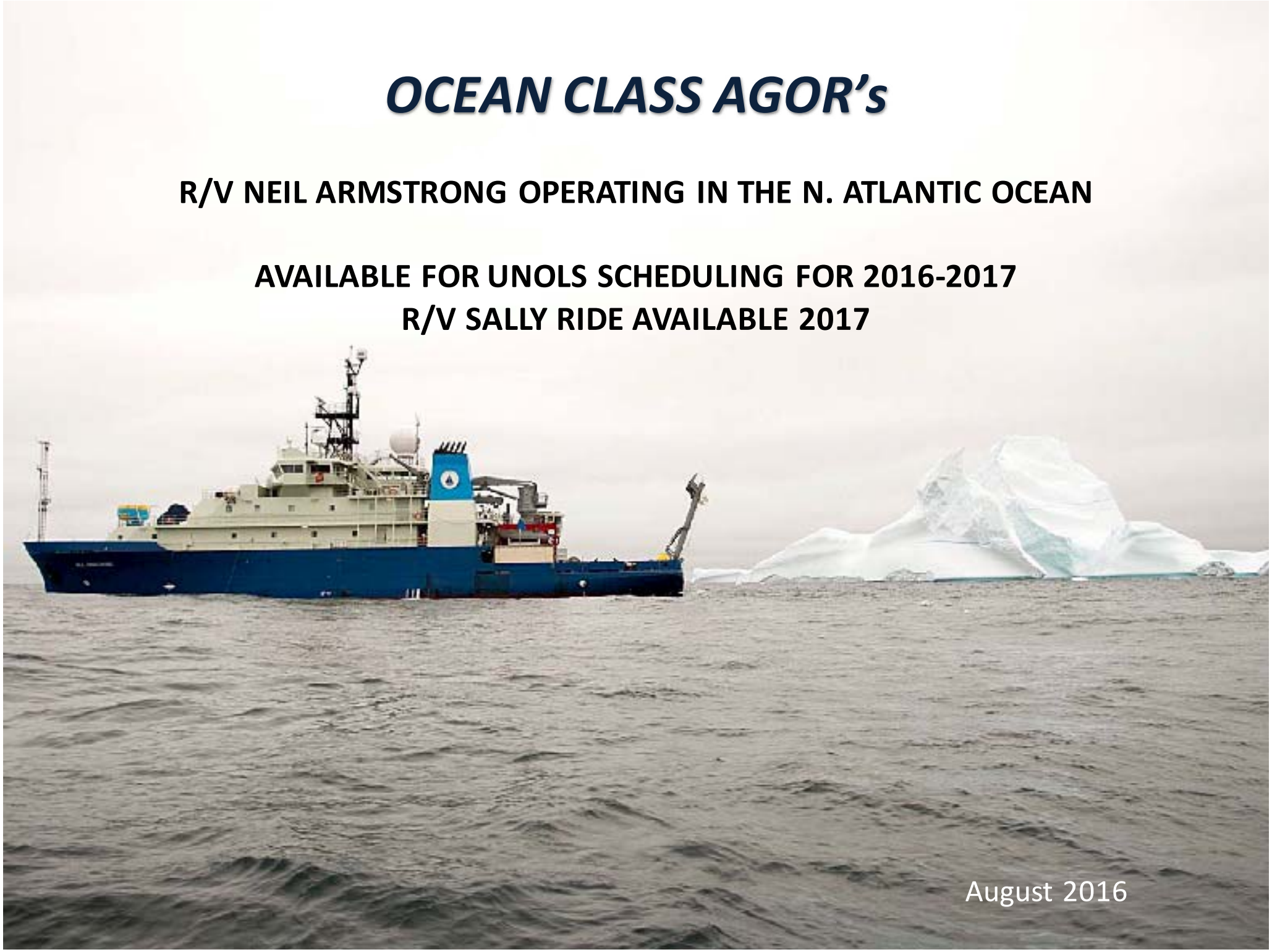


Arctic climatic changes have implications for the soundscape by changing the dominant ambient noise mechanisms, the distance sound travels in the water, how it is scattered by the ice, etc.

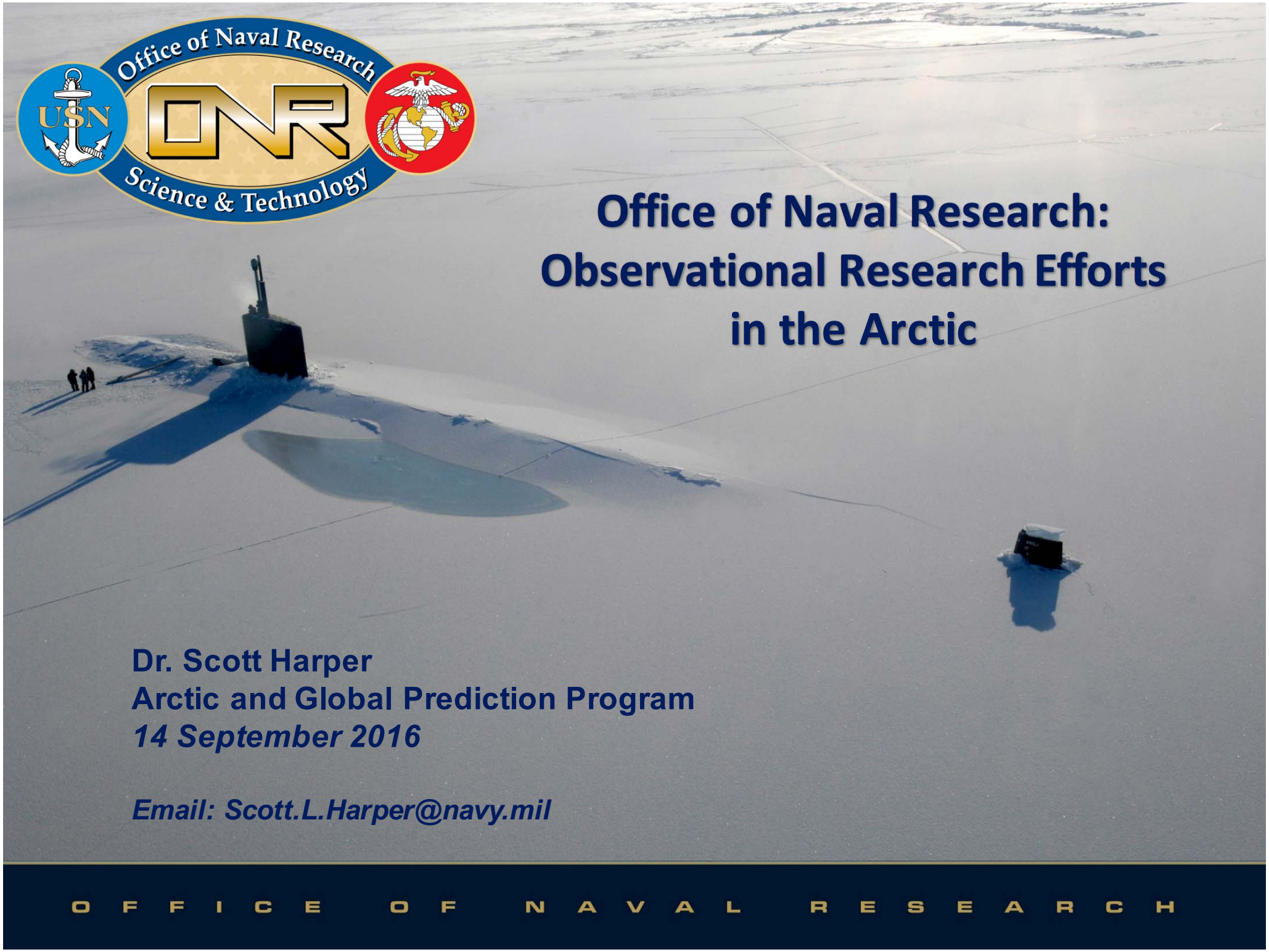
OCEAN CLASS AGOR's

R/V NEIL ARMSTRONG OPERATING IN THE N. ATLANTIC OCEAN

AVAILABLE FOR UNOLS SCHEDULING FOR 2016-2017
R/V SALLY RIDE AVAILABLE 2017



August 2016

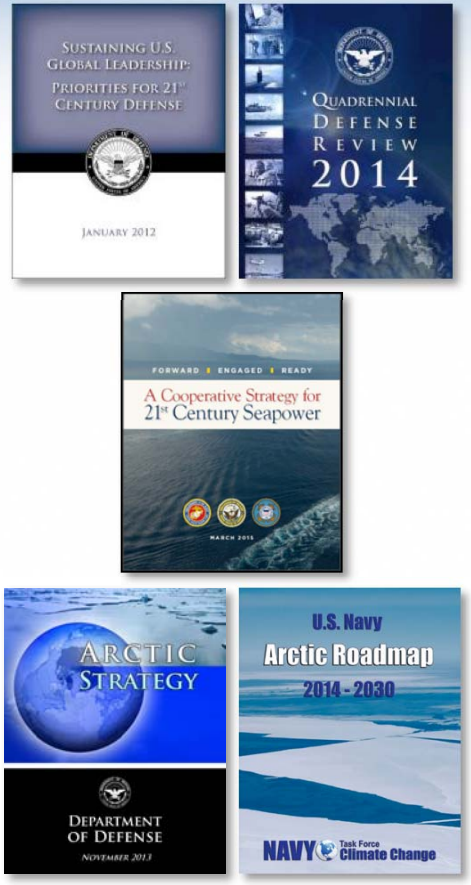


Office of Naval Research: Observational Research Efforts in the Arctic

Dr. Scott Harper
Arctic and Global Prediction Program
14 September 2016

Email: Scott.L.Harper@navy.mil

US Navy Arctic Guidance



U.S. Navy Arctic Roadmap 2014-2030
Updated Feb 2014

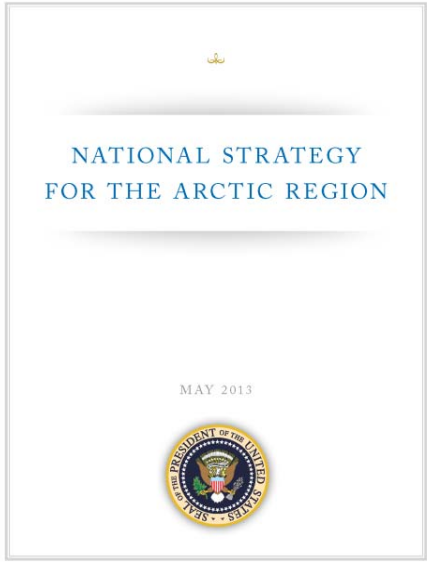
US Navy Strategic Objectives for the Arctic

- Ensure U.S. Arctic sovereignty and provide homeland defense
- Provide ready naval forces to respond to crises and contingencies
- Preserve freedom of the seas
- Promote partnerships within the U.S. and with international allies

US Navy Implementation Plan includes:

- Strategy, Policy, Missions, and Plans
- Operate Safely and Proficiently
  - Science and Technology
  - Environmental Observation and Prediction
  - Platforms, Weapons, Equipment and Sensors
- Build Trust and Confidence with Allies and Partners

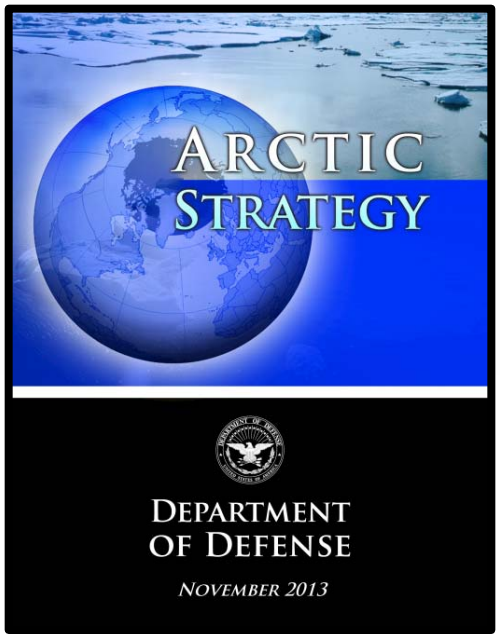
ONR's Arctic Guidance

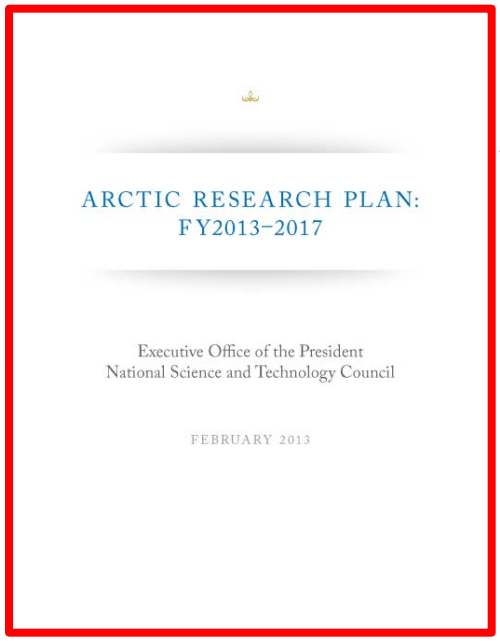


Develop a Framework of Observations and Modeling to Support Forecasting and Prediction of Sea Ice

Lead Agency: Department of Defense (Navy)

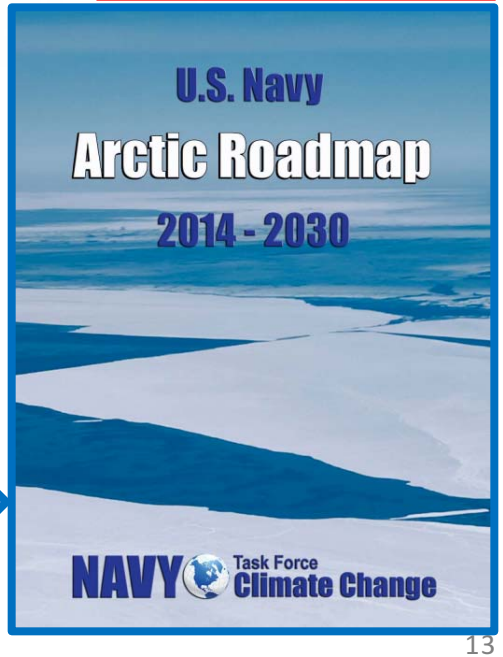
"increased certainty and accuracy of sea ice forecasts and predictions, and by showing improved understanding of feedback processes driving sea ice variability"





ONR co-leads two of the IARPC Collaboration Teams

- **Sea Ice**
- **Modeling**



Navy's Strategic Objectives for the Arctic Region

- **Ensure U.S. Arctic sovereignty and provide homeland defense**
- **Provide ready naval forces to respond to crises and contingencies**
- **Preserve freedom of the seas**
- **Promote partnerships within the U.S. Government and international allies**

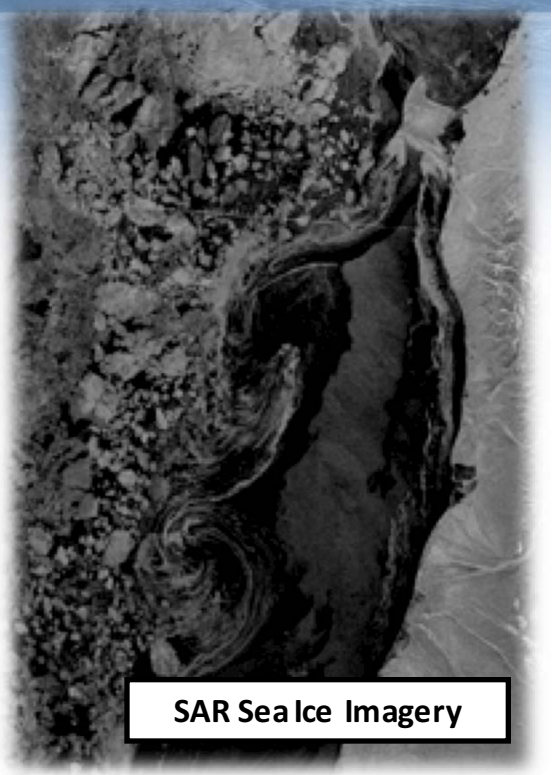
ONR's Arctic Objectives

- **Understand the physics and dynamics of the emerging Arctic Ocean environment**
  - Reduced ice cover during summer months
  - Thinner, more dynamic sea ice
  - Changes in Arctic Ocean stratification and circulation
- **Develop improved *in situ* and remote sensing capabilities**
  - Autonomous unattended platforms and sensors
  - Multi-sensor remote sensing algorithm development for sea ice
  - Real-time data availability for MDA and DA in forecast models
- **Improve predictive capabilities for the Arctic environment**
  - Develop high-resolution coupled Arctic System Models (ocean-ice-waves-atmosphere)
  - Improve assimilation of observed data (both *in situ* and remote sensing)
  - Research on extended prediction (not just days, but strategic – months to years)

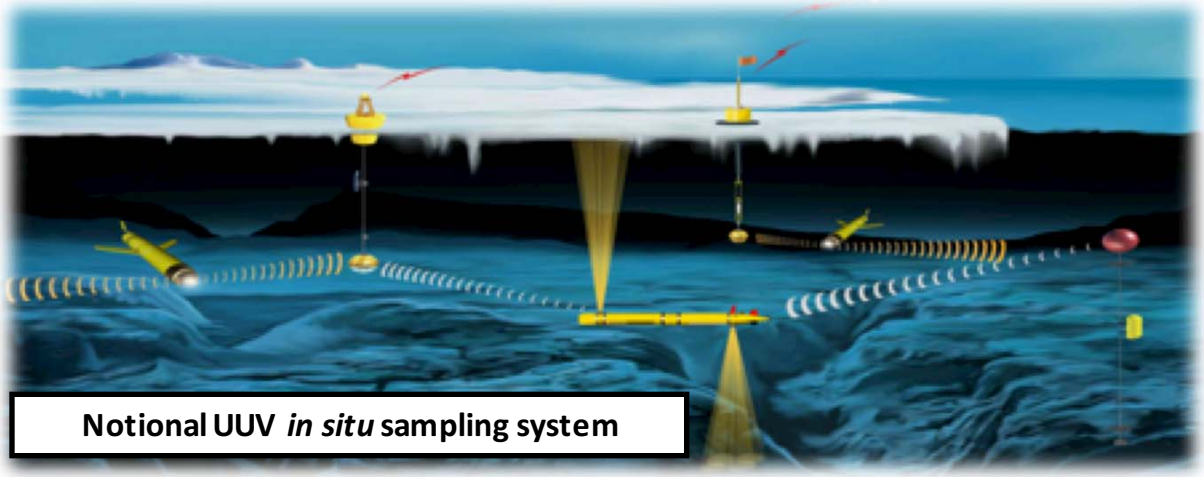
ONR Arctic Environmental Research

MAJOR THRUSTS:

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



SAR Sea Ice Imagery



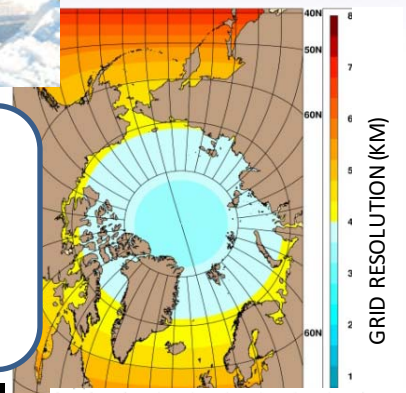
Notional UUV *in situ* sampling system

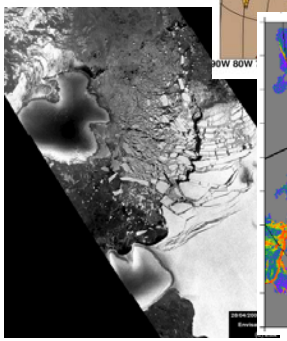
Advances in technology are required to enable an interagency and international **Arctic Observing Network** that will support scientific exploration and be able to initialize predictive models of the environment

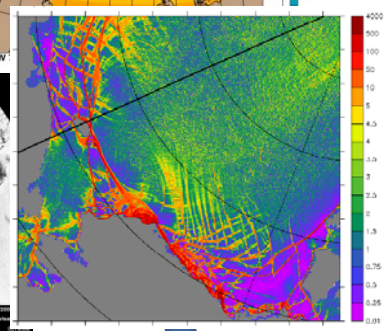
Development and Transition of Arctic Prediction Systems

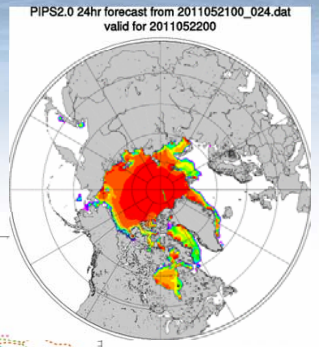
Fieldwork to better understand key physical processes

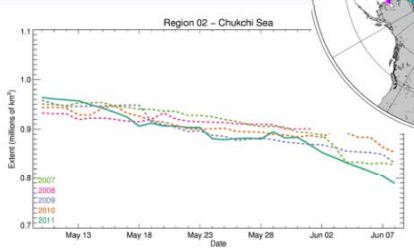
Improved physics built into data-assimilating integrated models

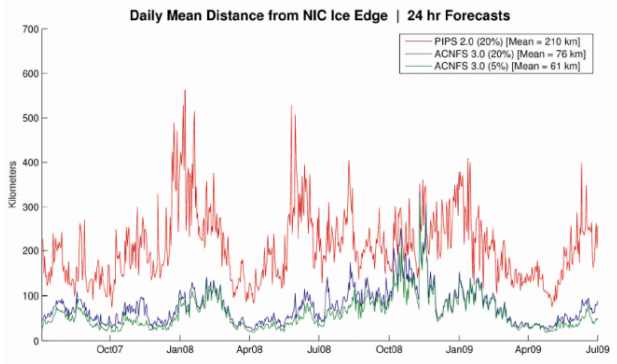












NAVAL METEOROLOGY AND OCEANOGRAPHY COMMAND

NATIONAL ICE CENTER
WASHINGTON D.C.

Arctic Prediction System Development

Observing System Development

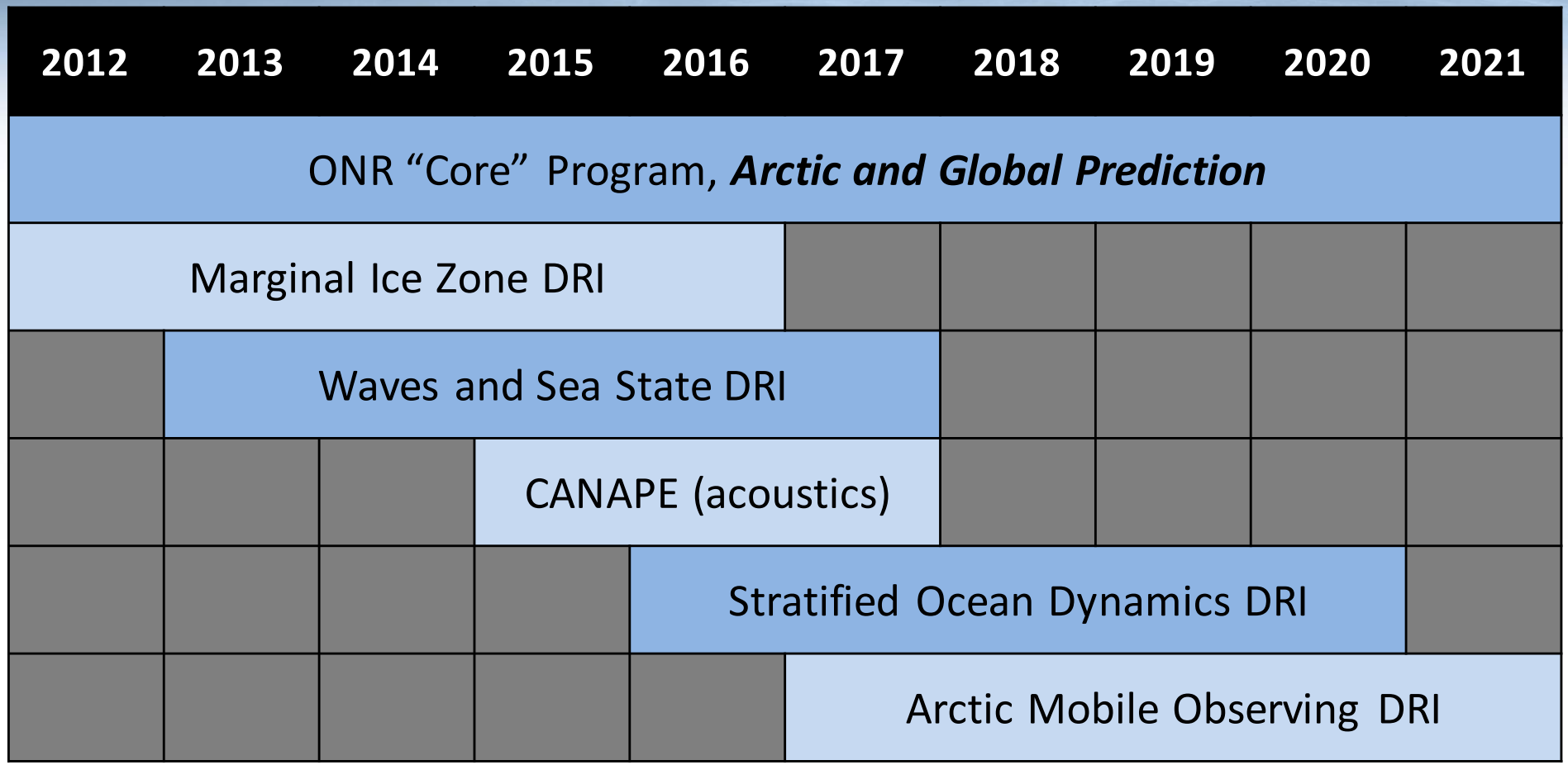
Validation and Verification

Testing, Prototyping and Experimentation

Transition to Operational Use

Transition to Operational Use

Timeline of Major ONR Arctic Efforts



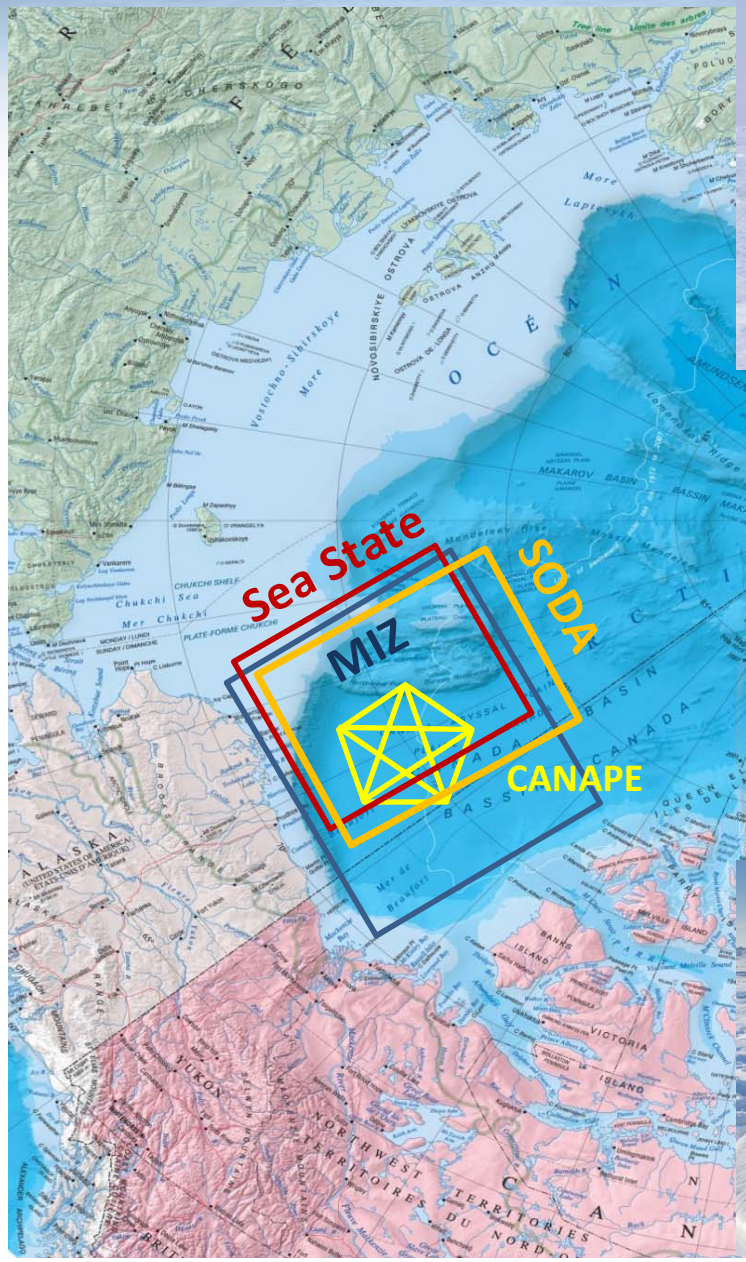
DRI = Department Research Initiative

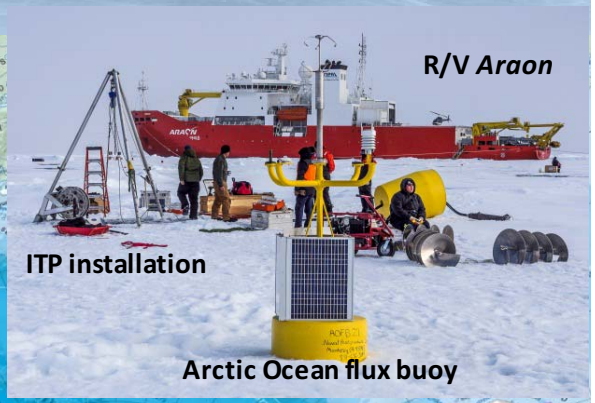
These are focused, five-year efforts to significantly advance our understanding in specific research areas using multi-disciplinary teams of scientists

ONR S&T Initiatives in the Arctic (2012-2020)

- **Arctic & Global Prediction Program**
- **Ocean Acoustics Program**

- **Marginal Ice Zone (MIZ) DRI (*2012-2016*)**
  2014 Field Program
- **Sea State & Boundary Layer Physics DRI (*2013-2017*)**
  2015 Field Program
- **Canada Basin Acoustic Propagation Experiment (CANAPE) (*2015-2017*)**
  2015, 2016-2017 Field Programs
- **Stratified Ocean Dynamics in the Arctic (SODA) (*2016-2020*)**
  2017-2019 Field Programs
- **Arctic Mobile Observing System (AMOS))*2017-2021*)**
  2018-2020 Field Programs

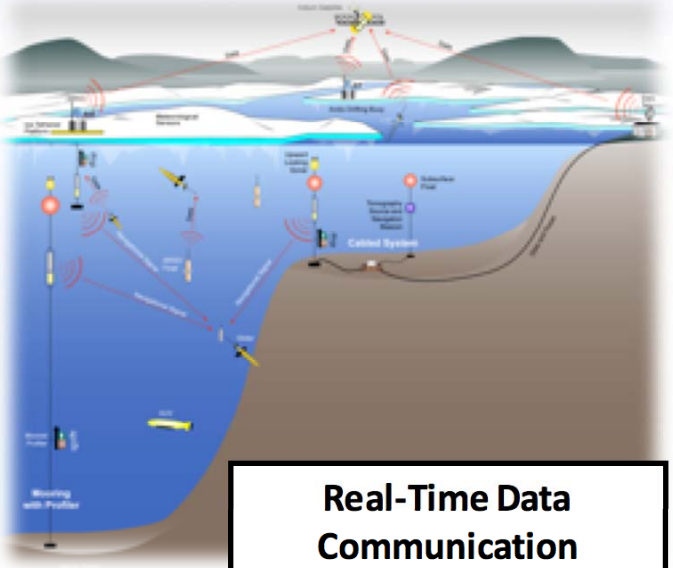


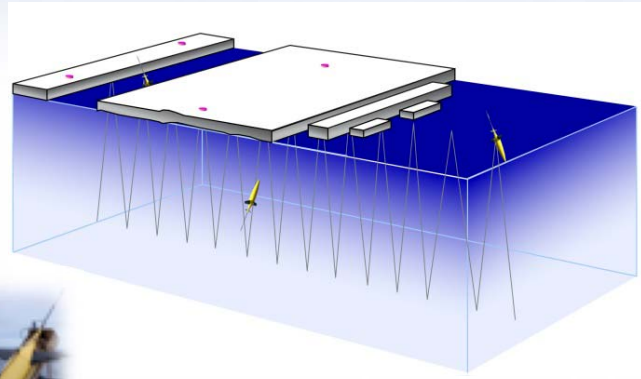


Technology Development

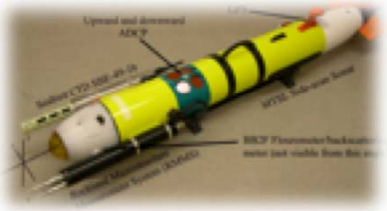
An Arctic sensing system must be developed to provide persistent observations that can further scientific understanding, provide long-term monitoring, and help constrain the predictive numerical models.

Autonomous platforms – Robust Sensors – Real-time Data Delivery – Key Environmental Variables

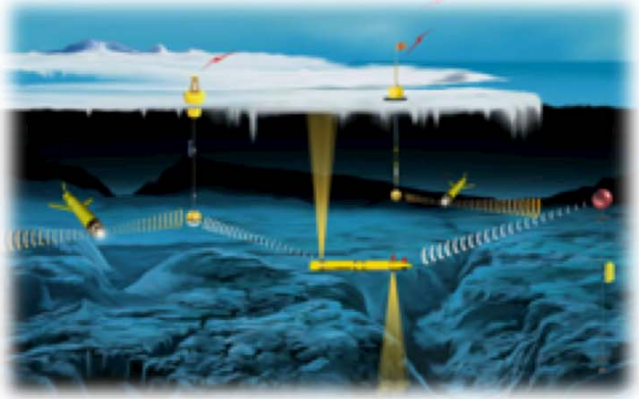


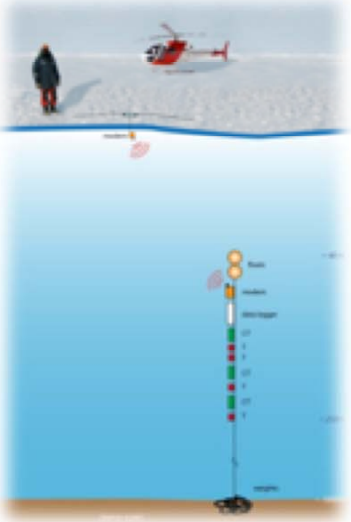


Novel Sensing Systems

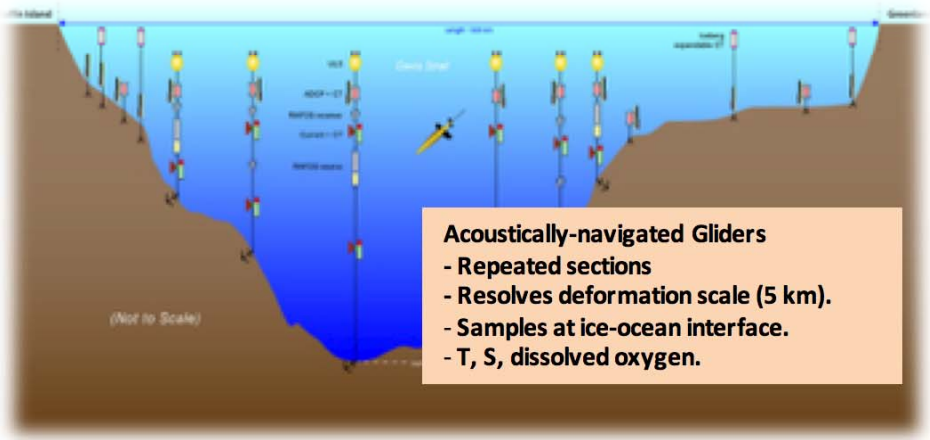


Real-Time Data Communication

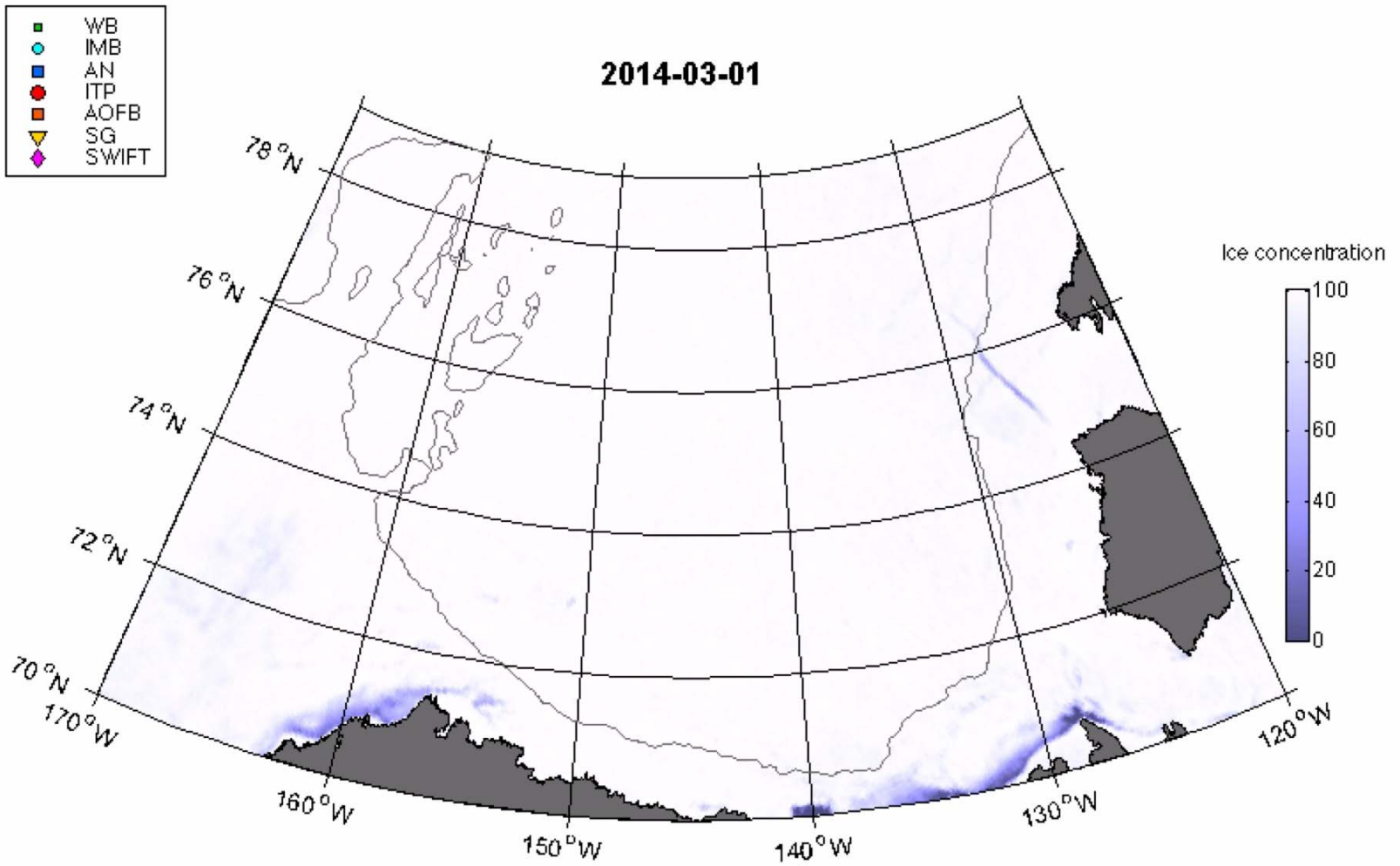


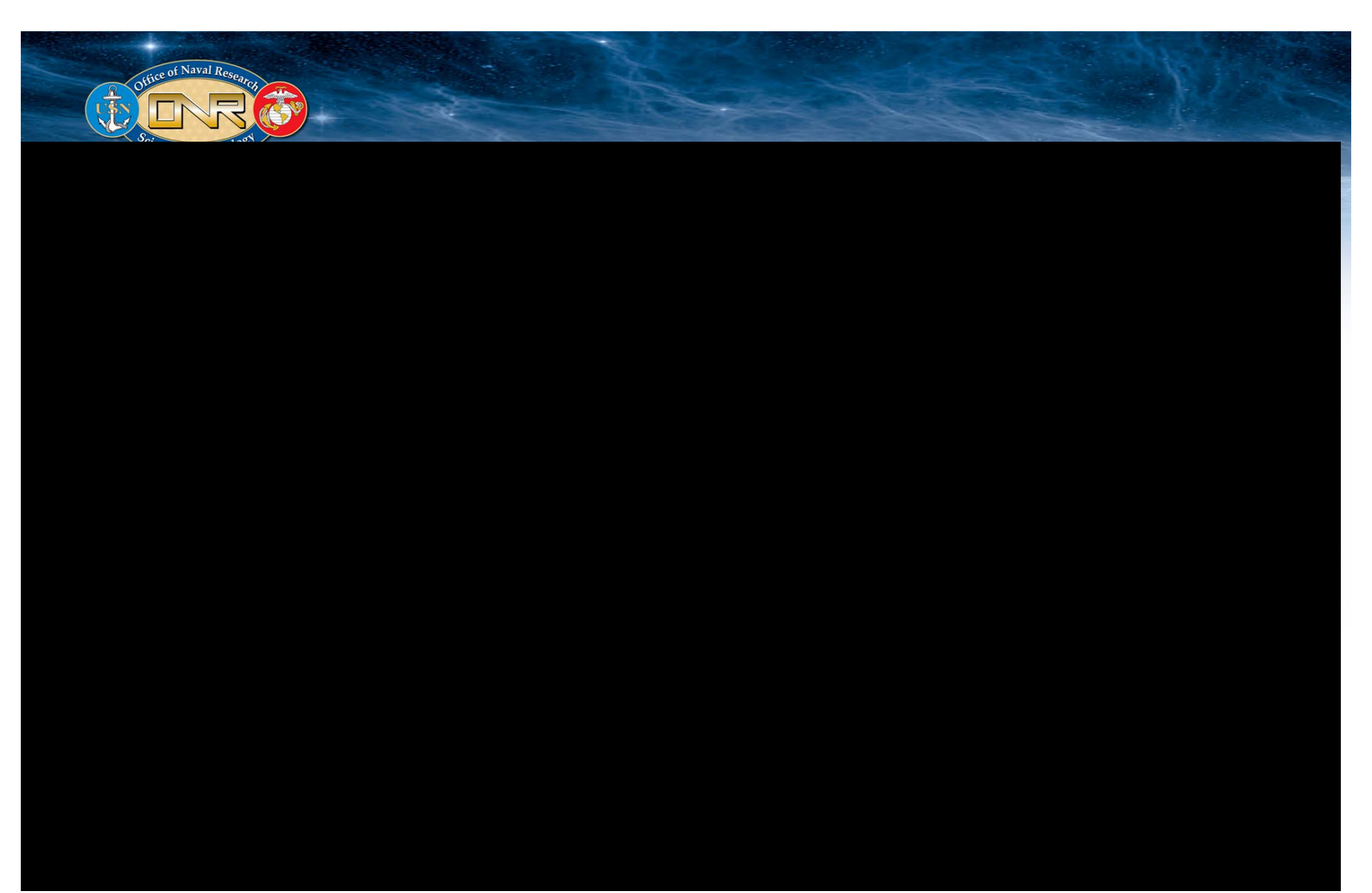


Autonomous Platforms and Enabling Technologies



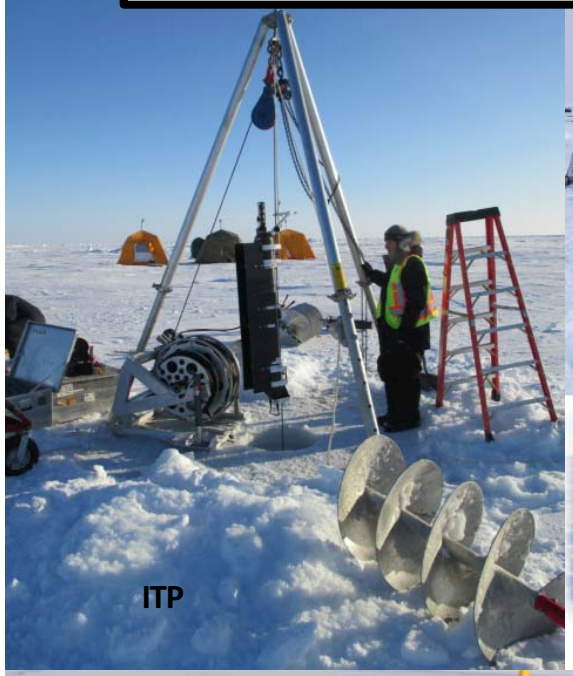
Sensor network deployed on ice via aircraft/helo, March 2014
Ship-deployed assets join field program in July and August

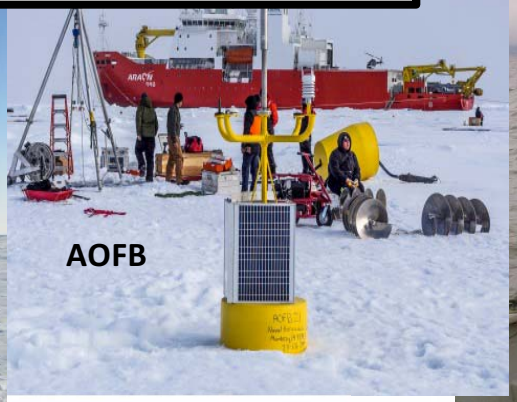


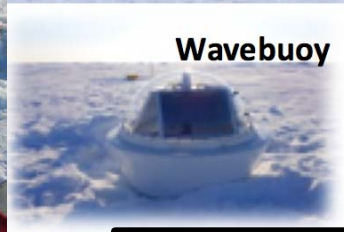


ONR Arctic Experimentation

Autonomous drifting sensor networks

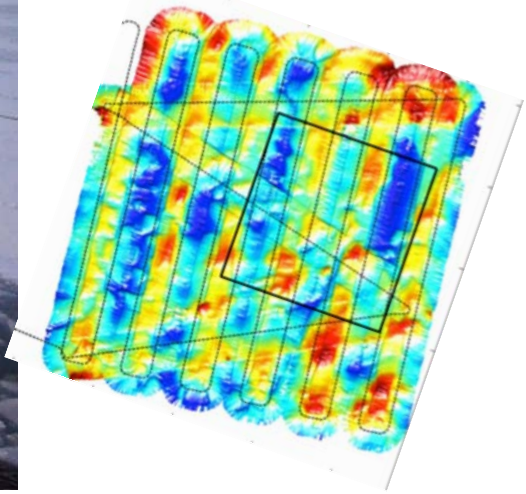


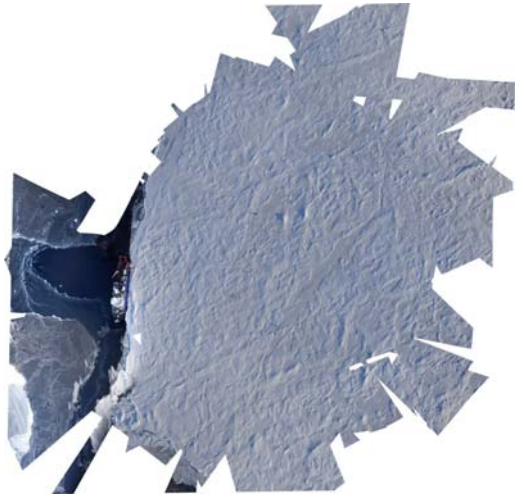




Under-ice acoustic navigation

UUV mapping and other sensing





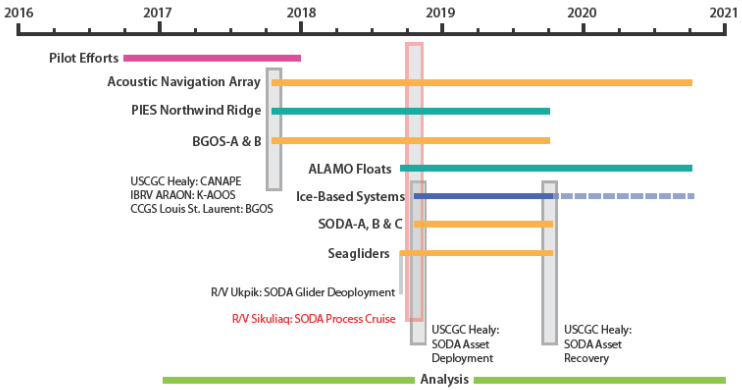
Stratified Ocean Dynamics in the Arctic
2018 – 2019 Field Efforts

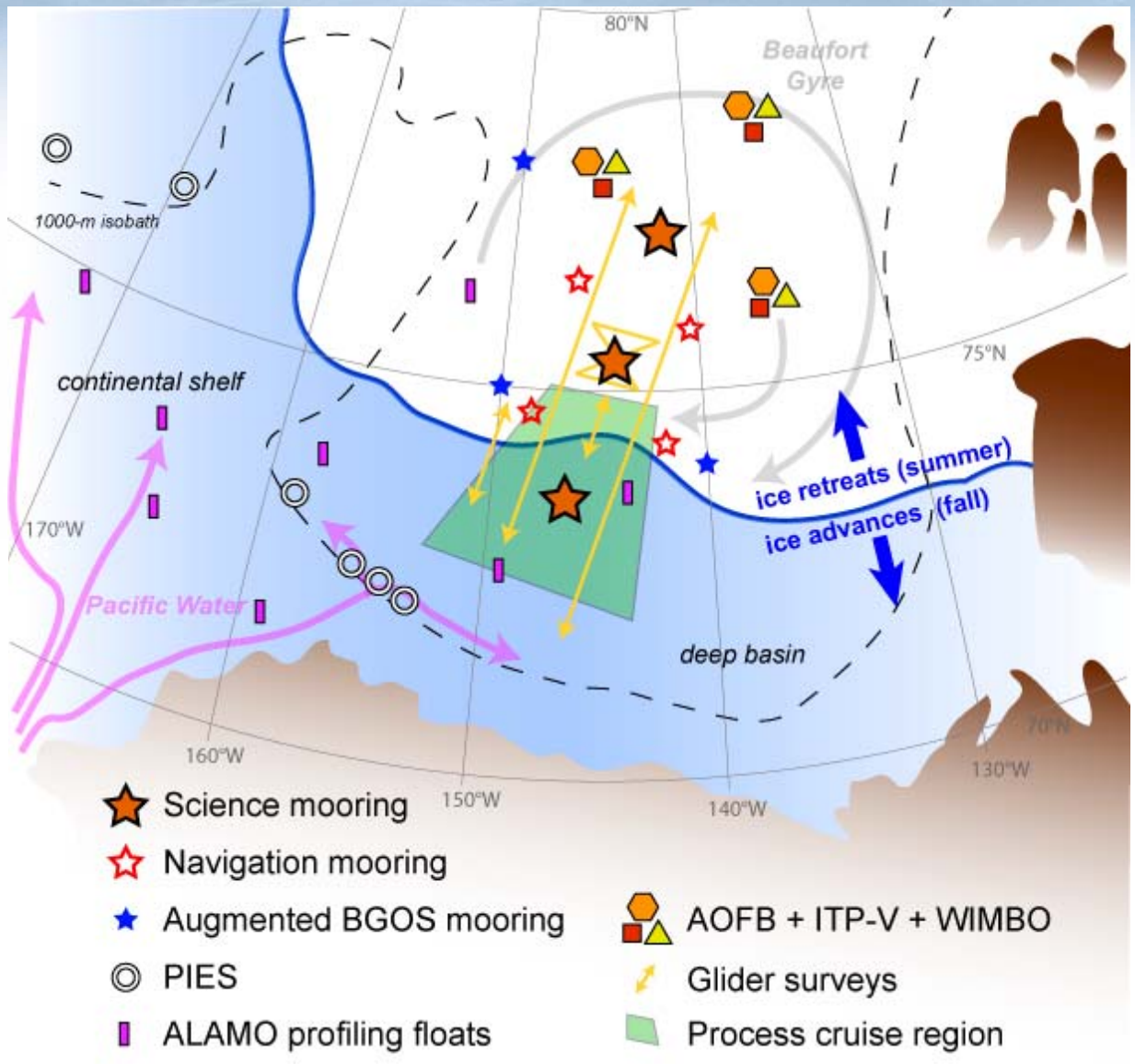
SODA Objective

SODA is a process study to better understand the response of the upper Arctic Ocean to changes in oceanic inflow and surface forcing over ice-free waters or areas of reduced sea ice cover.

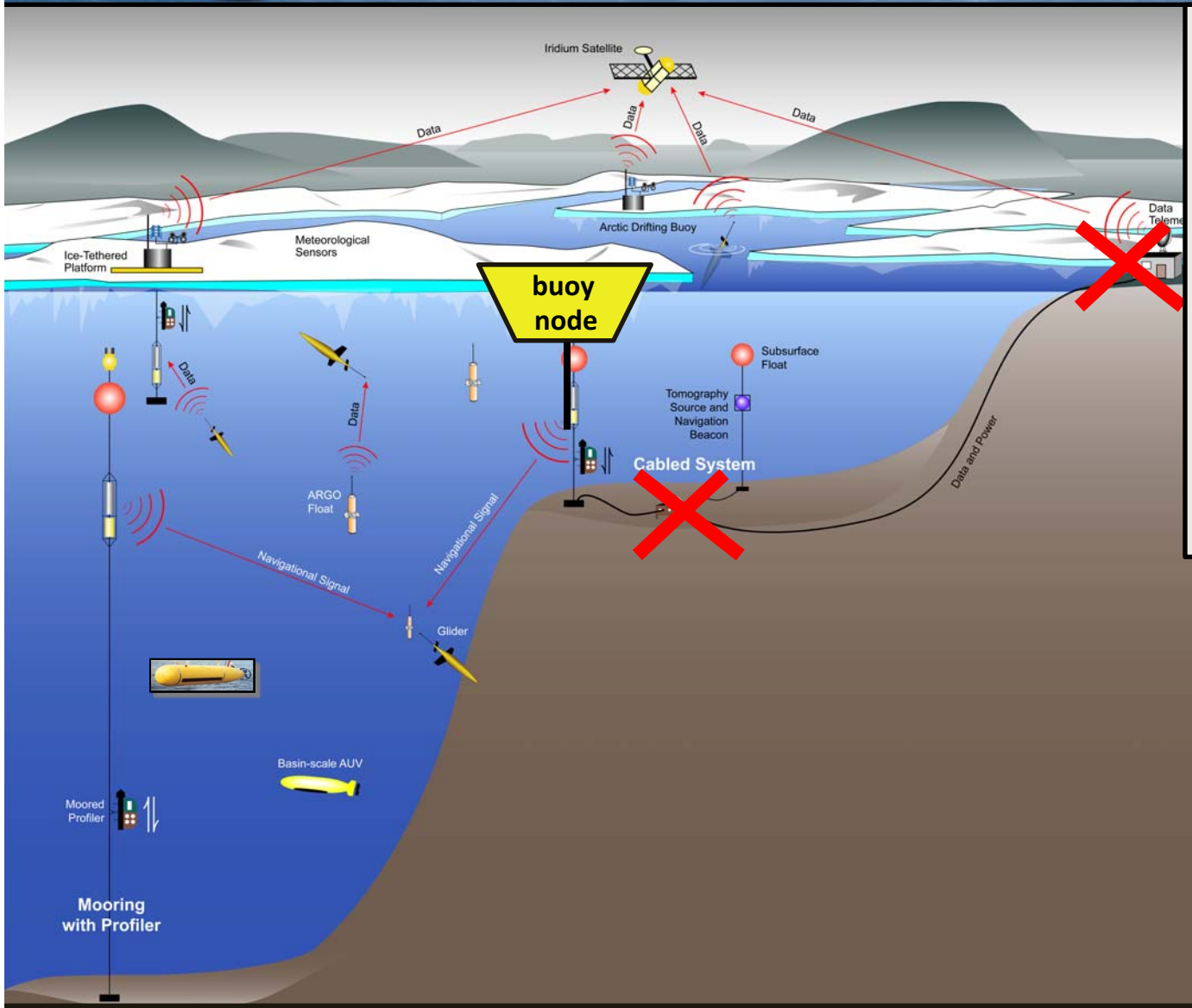
The program will include extended autonomous observations as well as intensive ship-based data collection during several cruises.

SODA Program Timeline





Arctic Mobile Observing System DRI



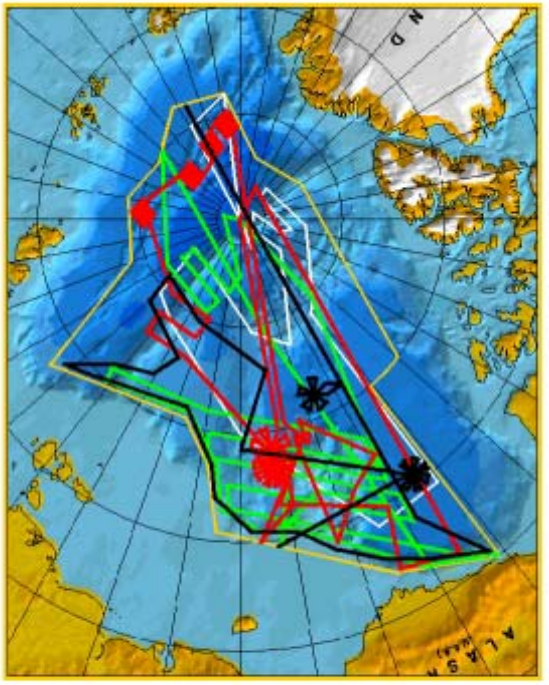
Enable a mobile maritime observing system that can be deployed anywhere in the Arctic using floating or ice-tethered buoy nodes that will provide persistent observational capabilities with sustained power and communications, and without the need for a cabled system.

A variety of mobile unmanned autonomous platforms operating from each node will provide an extensive footprint of oceanographic and cryospheric observing capability

SCICEX (and ICEX)

Coordinated efforts between the research community and operational Navy to take scientific-quality observations in the Arctic from submarines

- **SCICEX Phase I: Dedicated Science Missions**
  - Vital role measuring Arctic bathymetry, ice, ocean
  - Dedicated science cruises ended in 1999
- **SCICEX Advisory Committees**
  - Science Advisory Committee (SAC)
  - Inter-Agency Committee (IAC)
    - Currently only ONR, NSF, USARC, ASL
    - **Would like to add agencies (NOAA, NASA, DOE) to the mix**
- **SCICEX Phase II: Science Plan developed in 2010**
  - US Navy is currently running "Science Accommodation Missions"
  - SAC recommends a "menu" of preferred measurements to be taken in desired locations during submarine transits, time permitting
  - Most major efforts occur during biennial **ICEX**s (Navy **IC**e **EX**ercises)
  - Both 2014 and 2016 **ICEX** ice camp sites broke up early – better environmental guidance and prediction is needed for future on-ice activities



Naval Support to Arctic Science

"Today's force is powered by naval research, and current investments will ensure the next generation of Sailors and Marines are equally dominant when called upon." – *Naval S&T Strategy*