Office of Naval Research Arctic Observing Activities

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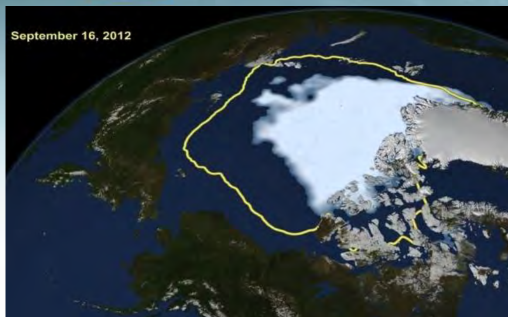
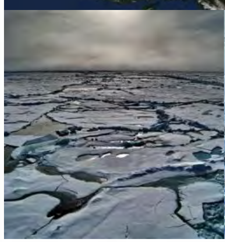
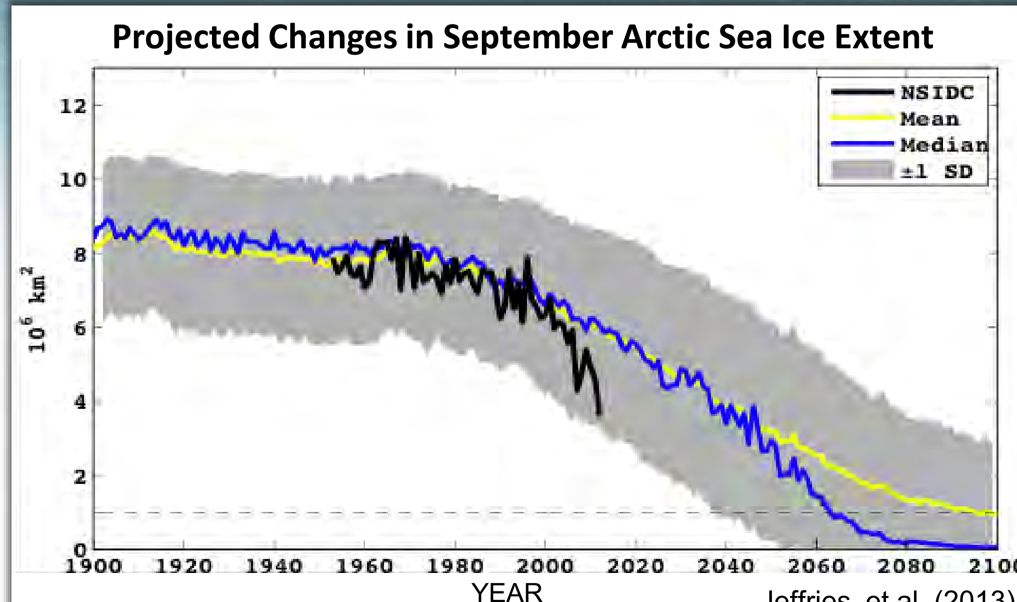
The Changing Arctic







Jeffries, et al. (2013)

- ❑ How little sea ice will there be, and when will the key changes occur?
  - Need better prediction capability underpinned by basic research.
- ❑ How is the Arctic region as a whole going to be different?
  - Need research into how the entire Arctic environmental system functions.
- ❑ What does the Navy need to know to operate in the Arctic?
  - Need sustained observations and improved predictions of the state of the Arctic.
- ❑ How will the changing Arctic affect the rest of the earth, and vice-versa?
  - Need an Arctic environmental system model integrated within global prediction models

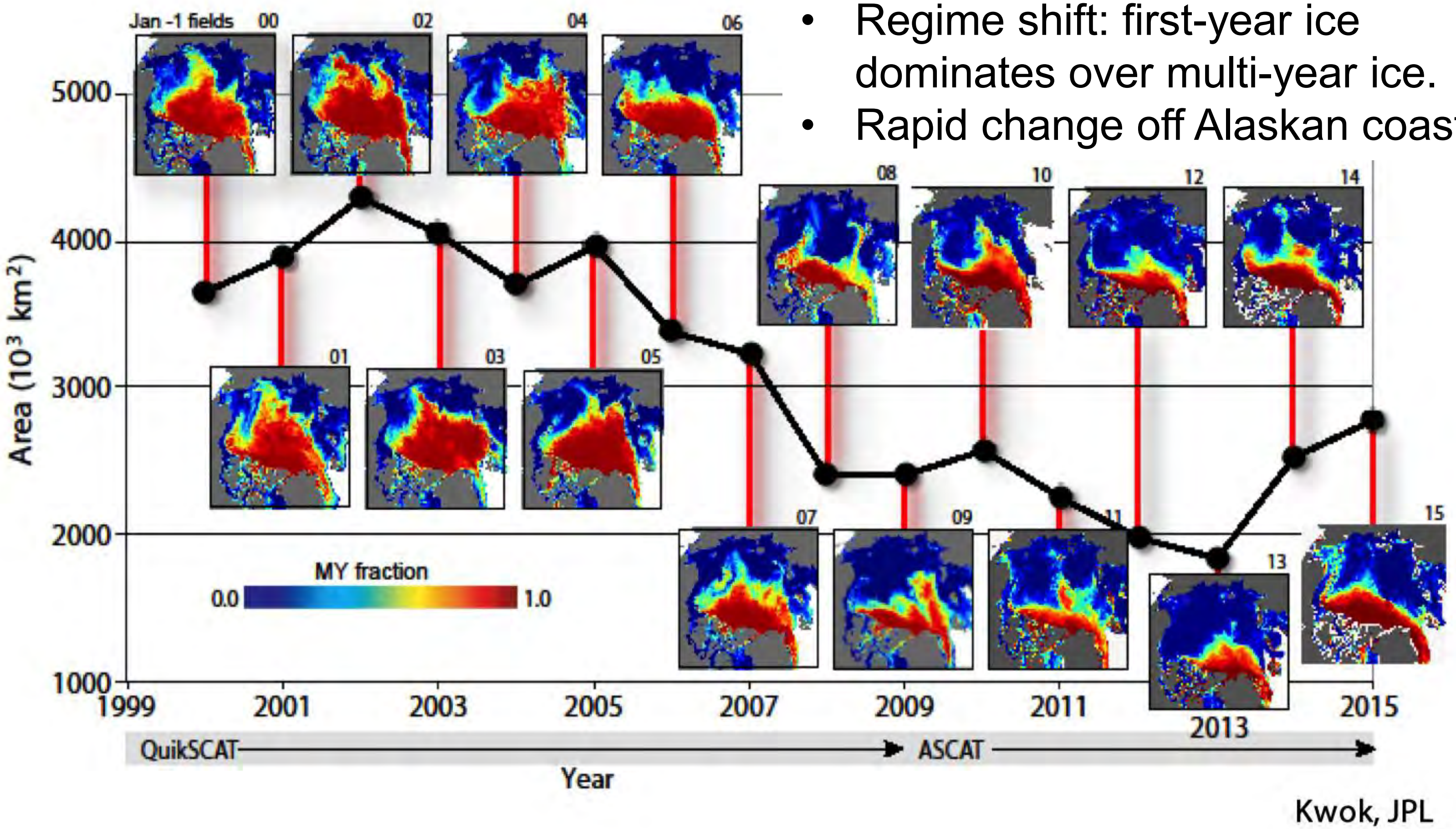
ONR Arctic Research Program

To Better Understand and Predict the Arctic Environment
Program Initiated in FY2012

Major Program Thrusts:

- Improved **Basic Physical Understanding** of the Arctic Environment
- **New technologies** to enable persistent Arctic observations
- Development of new fully-integrated **Arctic System Models**
- **Exploitation of Remote Sensing** for both Basic Understanding and to constrain the new Arctic System Models

Changing Sea Ice

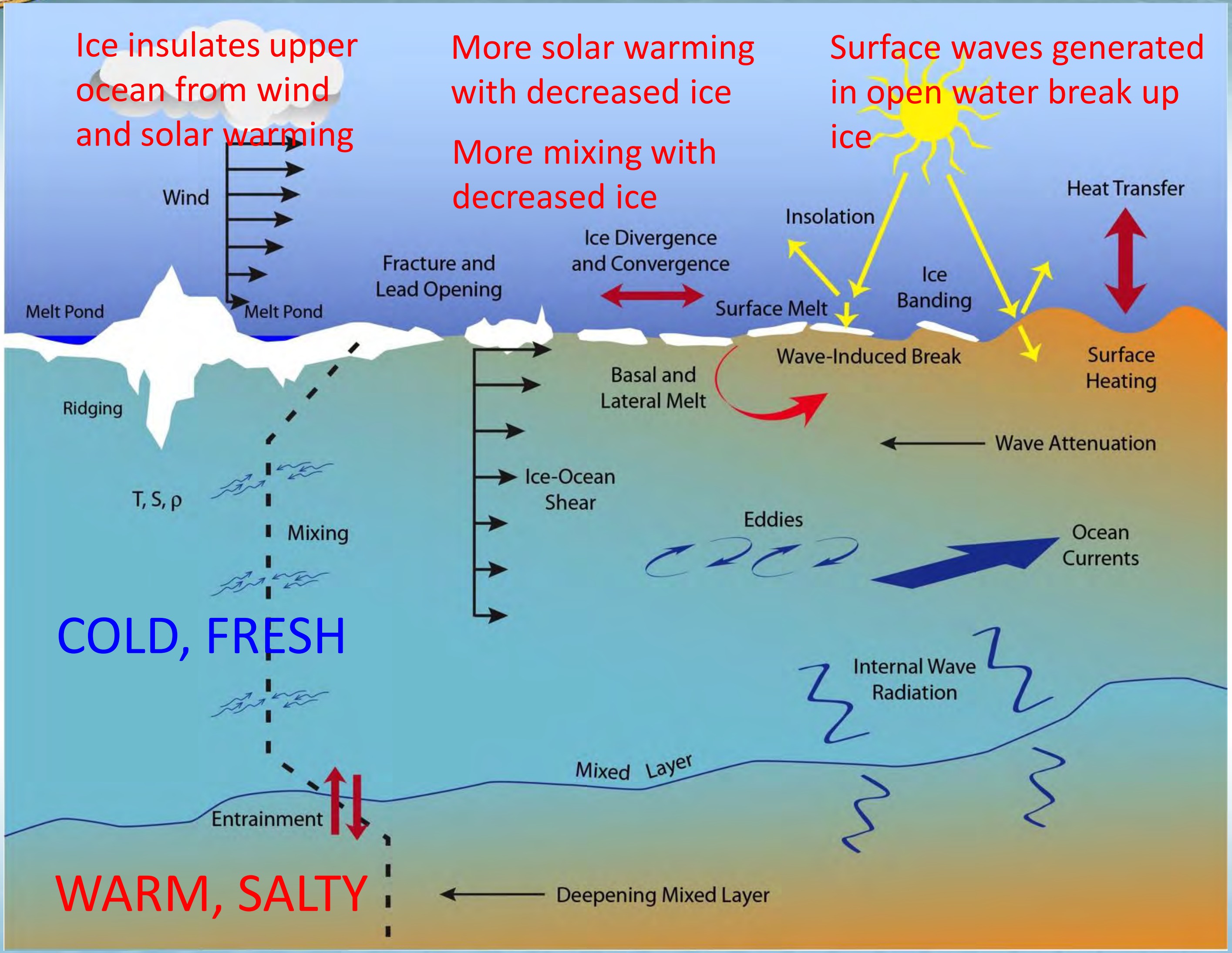


- Regime shift: first-year ice dominates over multi-year ice.
- Rapid change off Alaskan coast.

⇓ Extent + ⇓ Thickness = ⇓ sea ice volume

Quantity *and* quality of sea ice impact processes and feedbacks.

What Controls Sea Ice Melt?



Research Objectives

Enhance forecast capability- Improve numerical models

Science

1. Understand the physics that control sea ice breakup and melt.
2. Characterize changes in physics associated with decreasing ice/increasing open water.
3. Explore feedbacks that might impact the speed of sea ice decline.
4. Collect a public, benchmark dataset for refining and testing models.

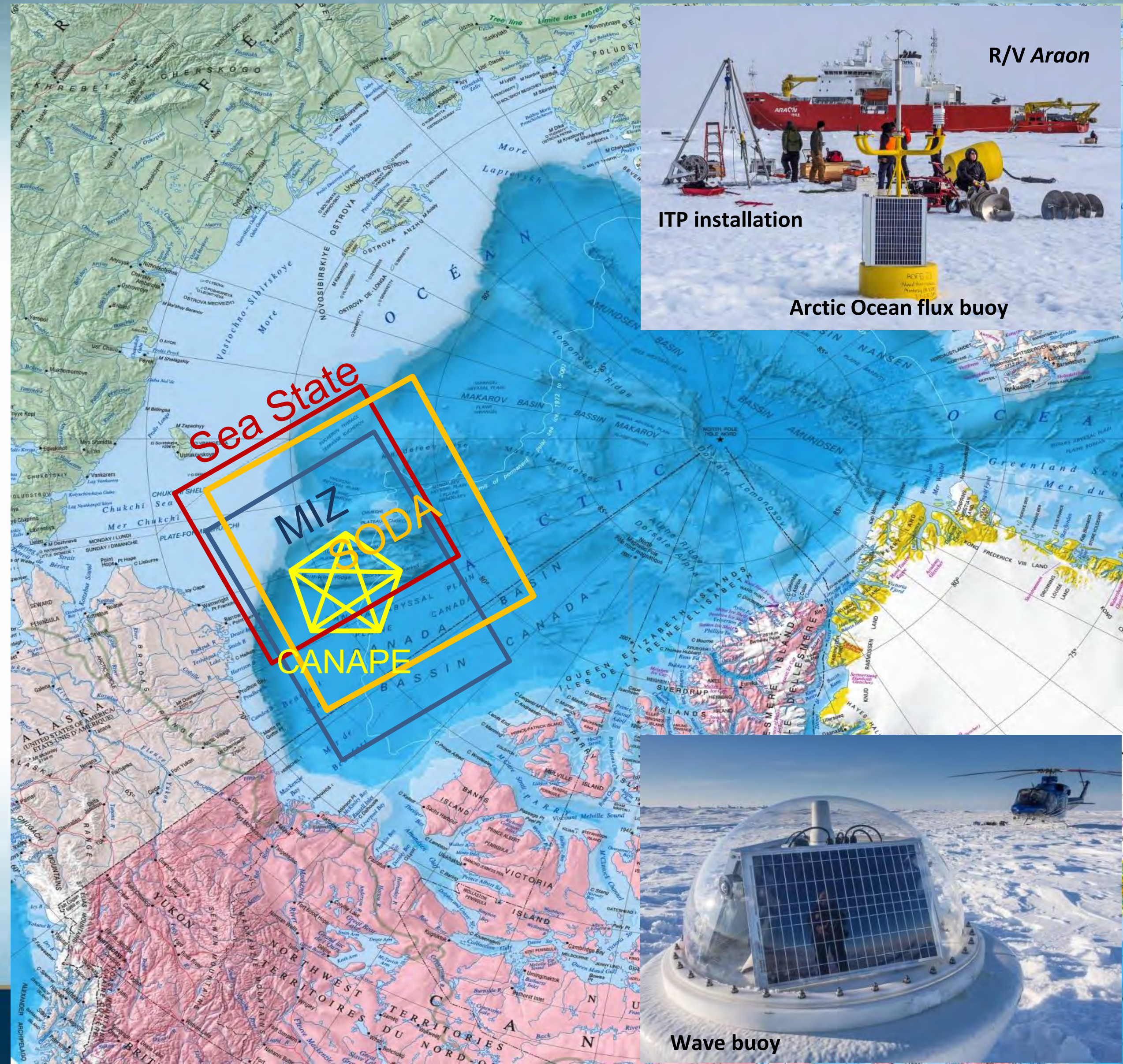
Technical

1. Develop and demonstrate new robotic networks for collecting observations in, under and around sea ice.
2. Improve interpretation of satellite imagery.

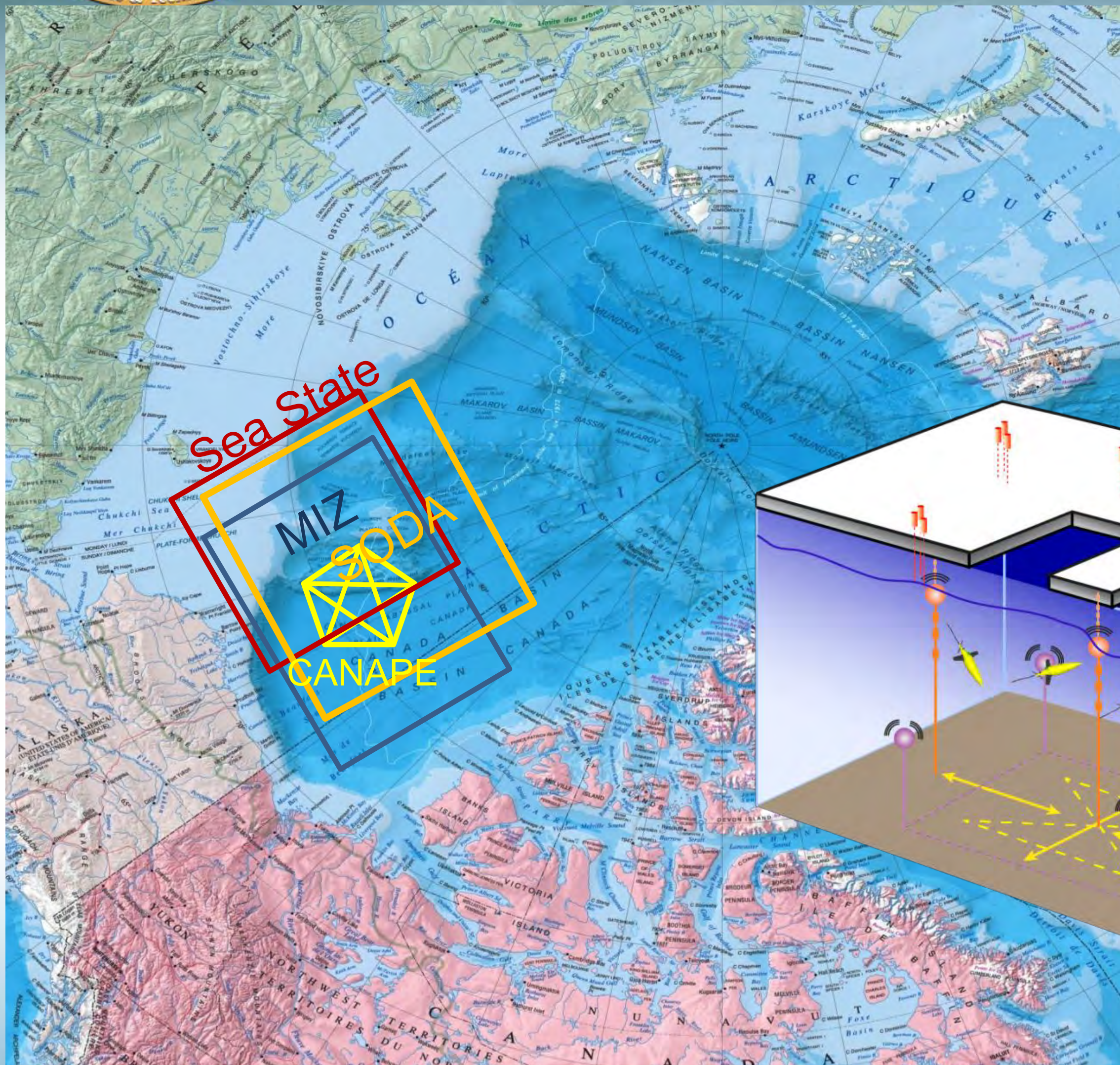
Arctic Research Initiatives (2012-2020)

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

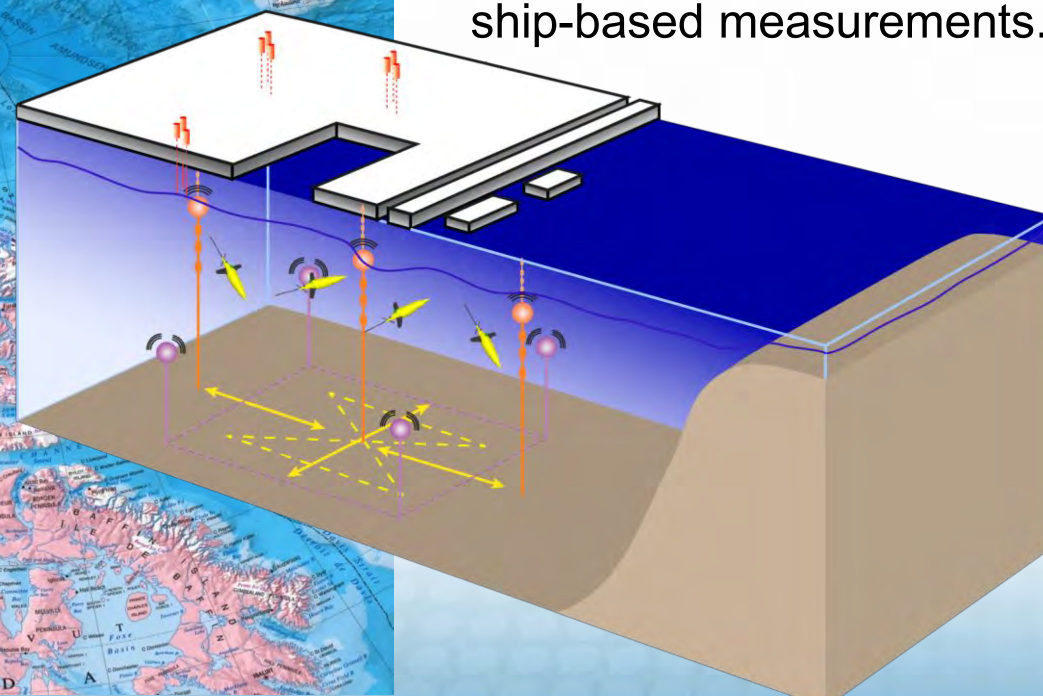
- **Marginal Ice Zone (MIZ) DRI**
  2012-2016 (2014 Experiment)
- **Sea State & Boundary Layer Physics DRI**
  2013-2017 (2015 Experiment)
- **Canada Basin Acoustic Propagation Experiment (CANAPE)**
  2015-2017
- **Stratified Ocean Dynamics in the Arctic (SODA)**
  2016 -2020 (2018 Experiment)



Stratified Ocean Dynamics in the Arctic (SODA)



- 2018-2019.
- Central Beaufort Sea.
- One year of autonomous sampling (moorings, gliders, ice-tethered sensors).
- Autumn service cruises, ship-based measurements.



SODA objectives

SODA focuses on understanding how the upper Beaufort Sea responds to changes in inflow and surface forcing. Specific science questions address three oceanographic properties: buoyancy, momentum, and heat.

Buoyancy. What are the causes and consequences of the changing upper ocean stratification (mixed layer and Pacific Water)?

• *Vertical*: What is the interplay among wind entrainment, convection, solar heating, and buoyancy input?

- On synoptic, seasonal, and year-long integral timescales?
- How does this balance vary with sea ice conditions?

• *Lateral*: What is the importance of heterogeneity in mesoscale and submesocale processes?

- On synoptic, seasonal, or year-long integral timescales?
- How spatially variable is this balance? (Is it more important at some locations, e.g., ice edge, mesoscale fronts, etc.?)

Momentum. How is the wind stress partitioned within the ice–ocean system? (depth and frequency; surface waves; ice motions; mixed layer and deeper acceleration; internal waves)

• How do sea ice properties affect this partition?
• How do the buoyancy flux and stratification affect the partition?
• How do lateral contrasts in forcing or ocean structure affect the partition and create secondary circulations?
• How does the phenology of the air–ice–ocean system affect the partition?

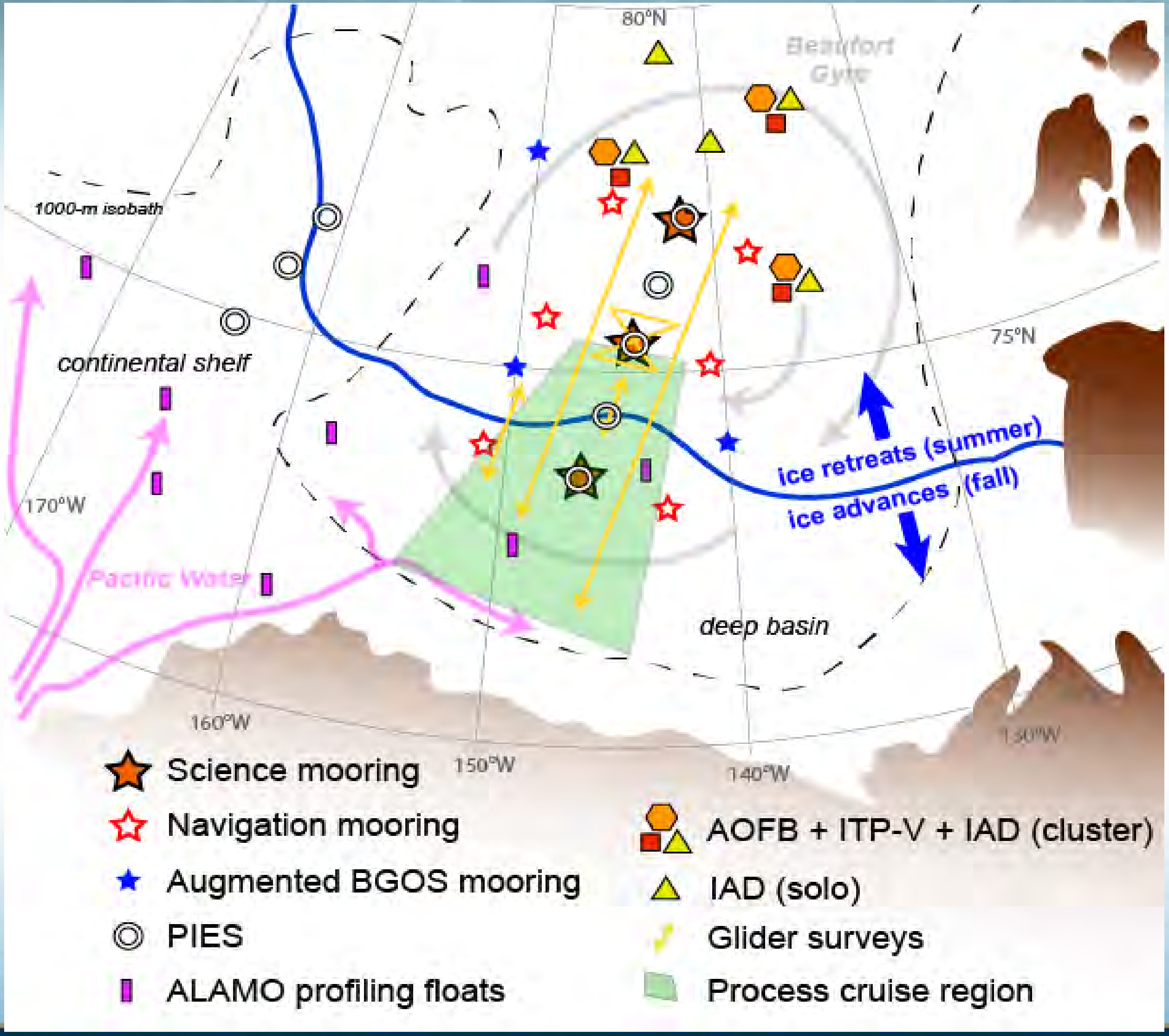
Heat. What is the fate and impact of the significant increase in upper ocean heat (and the associated sound channel)?

• What processes control the near surface temperature maximum formation and release?

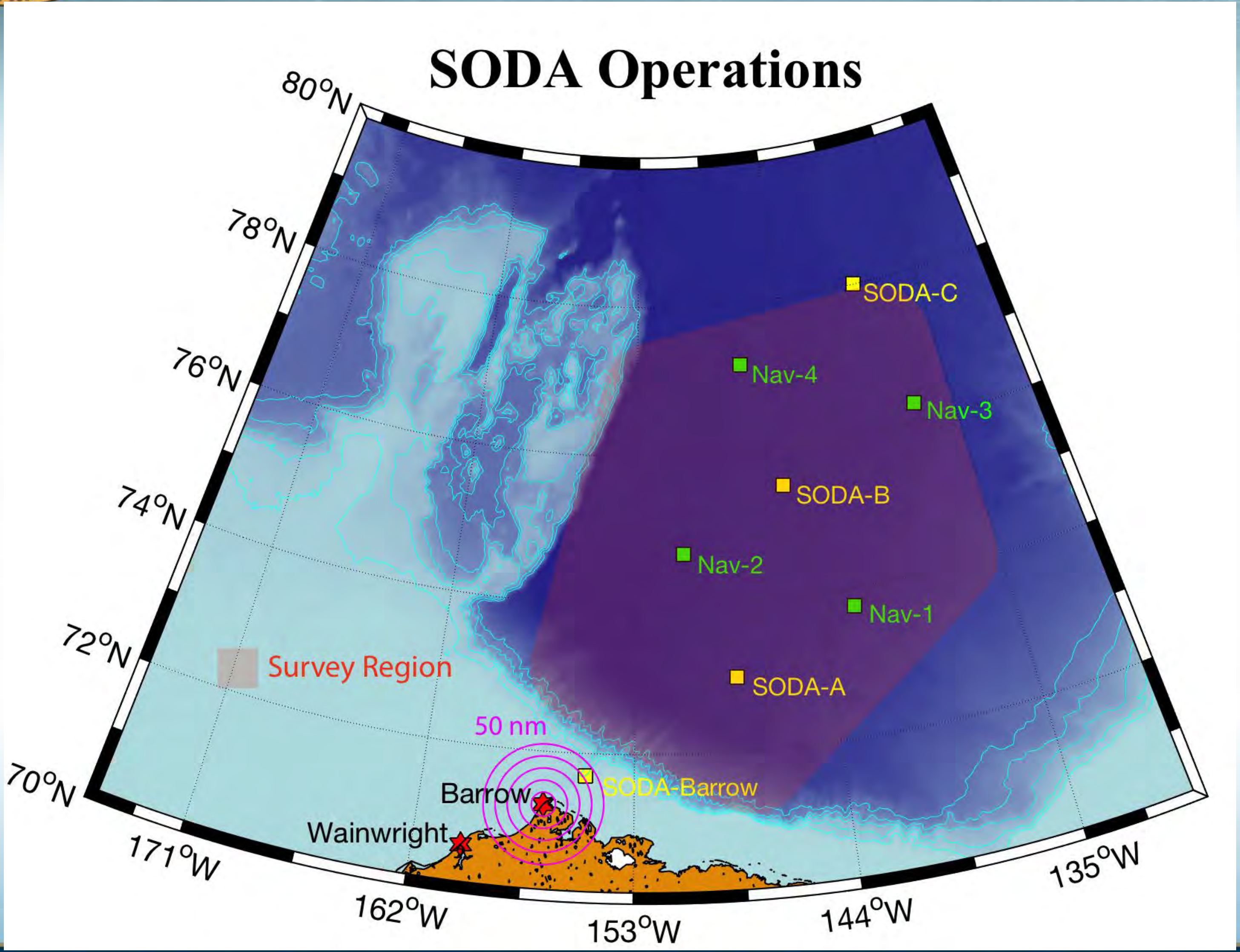
- How does it impact the fall sea ice freeze-up?
- How does it vary with sea ice conditions?

• How difficult is it for the mixed layer to entrain and access heat carried in the Pacific Water, and how does it vary with sea ice conditions?

SODA sampling



SODA region



SODA Operations
80°N
78°N
76°N
74°N
72°N
70°N
171°W
162°W
153°W
144°W
135°W
SODA-C
Nav-4
Nav-3
SODA-B
Nav-2
Nav-1
SODA-A
Survey Region
50 nm
SODA-Barrow
Barrow
Wainwright

Sikuliaq Cruise (Sept 2018)

Focus on process, in three modules:

1. Eddy survey
2. Mooring survey
3. Ice edge survey

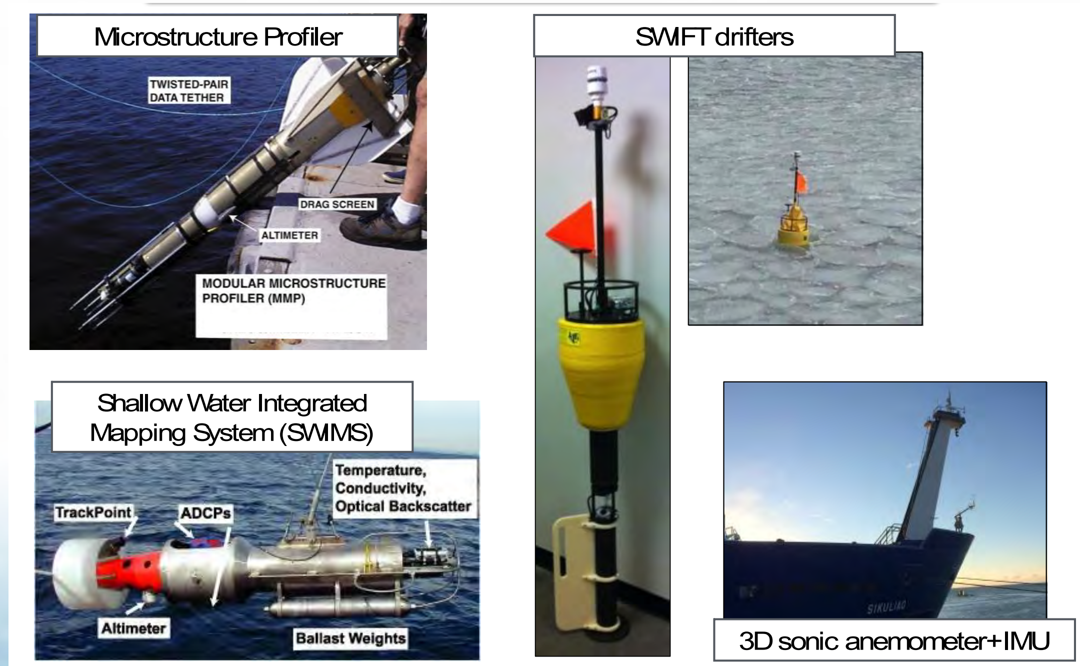
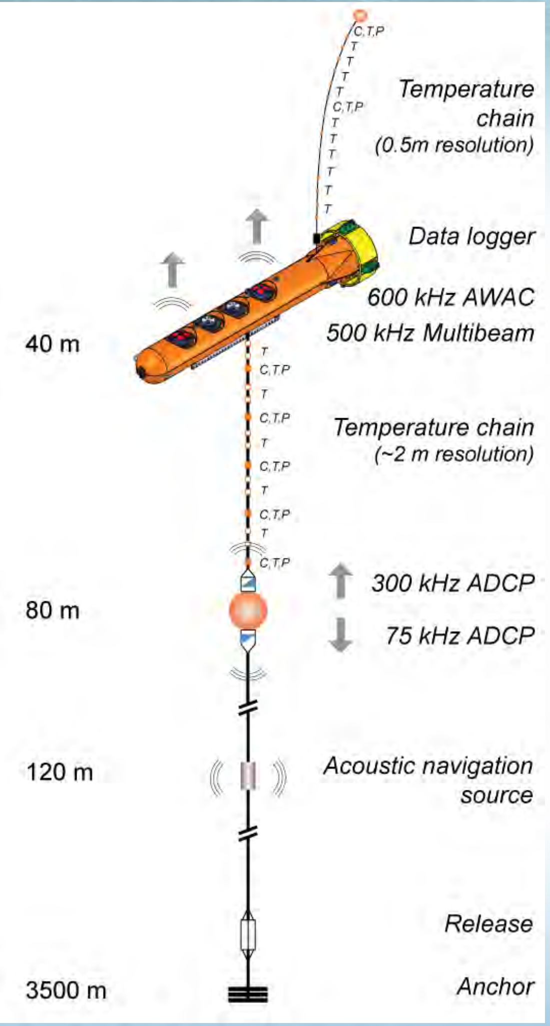


Figure 10. Proposed tools to be used during the process cruise. Clockwise from upper left: the Modular Microstructure Profiler (rapid tethered profiling down to 300 m), SWIFT drifters for short deployments from the ship (new versions have ADCPs and C-T chains), meteorological instrumentation on the mast, and the SWIMS towed body.

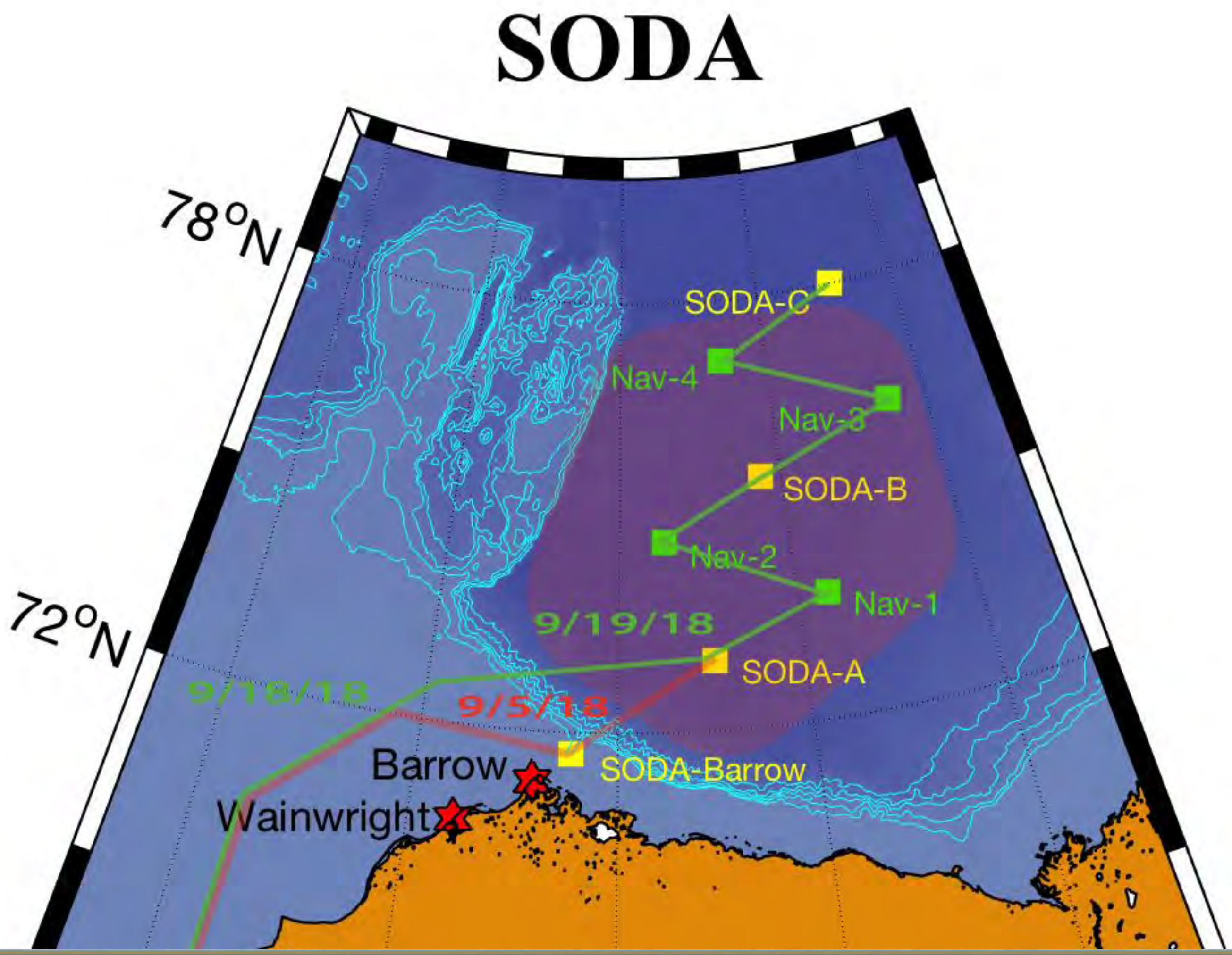
Healy cruise (Sept 2018)

Focus on mooring deployments:

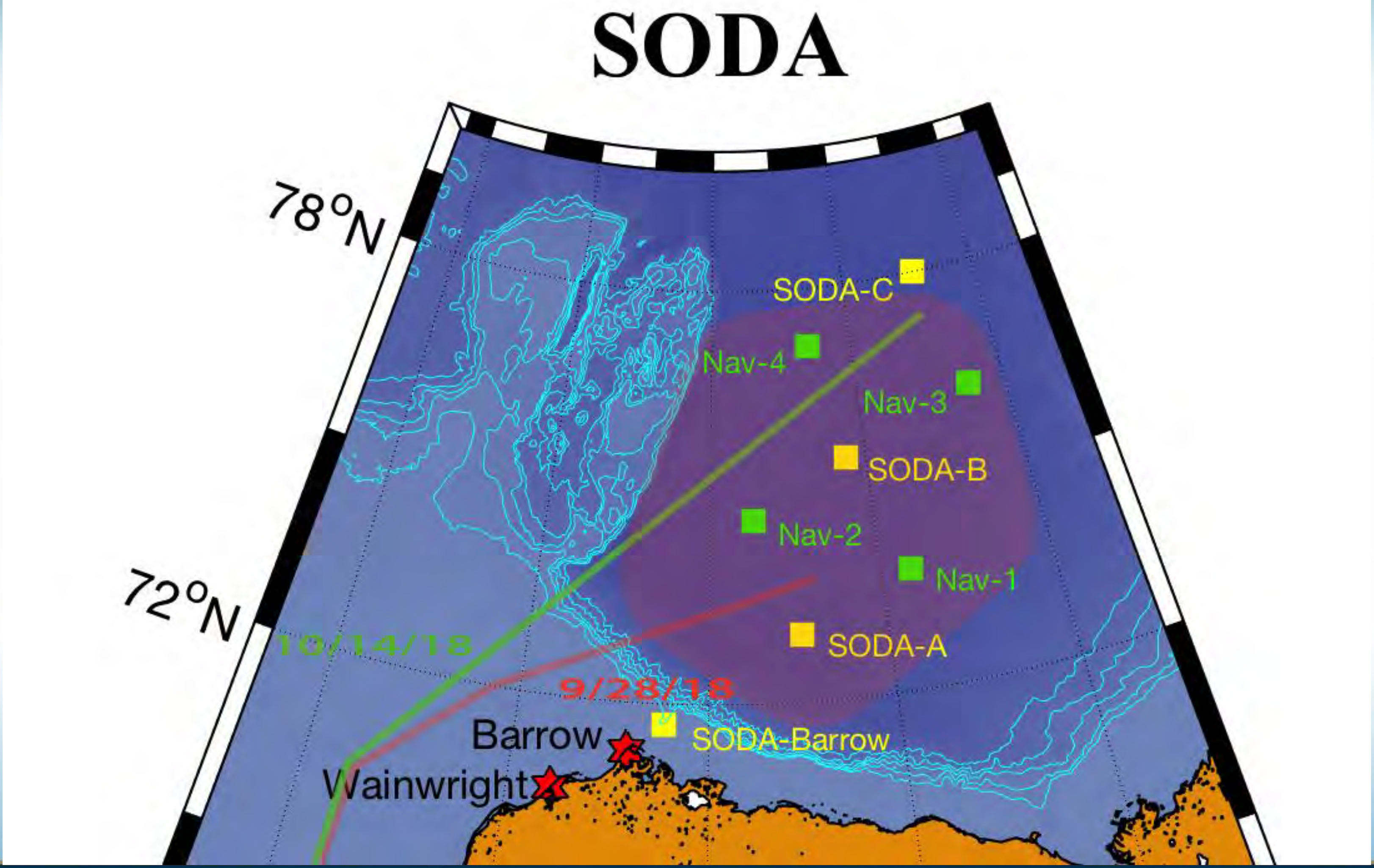
- SODA A, B, C
- Nav moorings
- Ice-based platforms
- surveys of oppurtunity



SODA sequence



SODA sequence

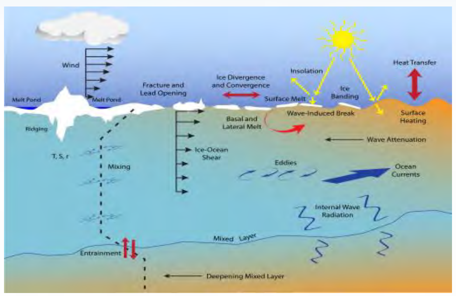


Other ONR Arctic programs

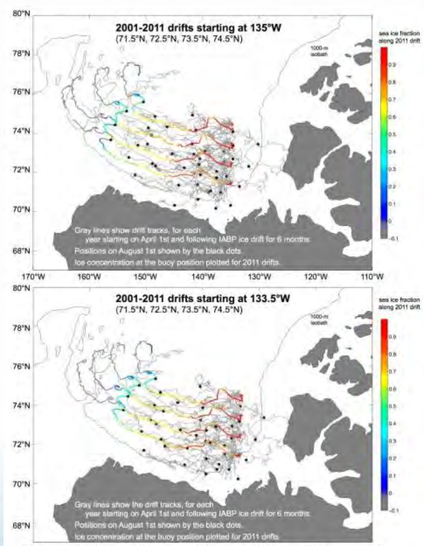
Marginal Ice Zone Program

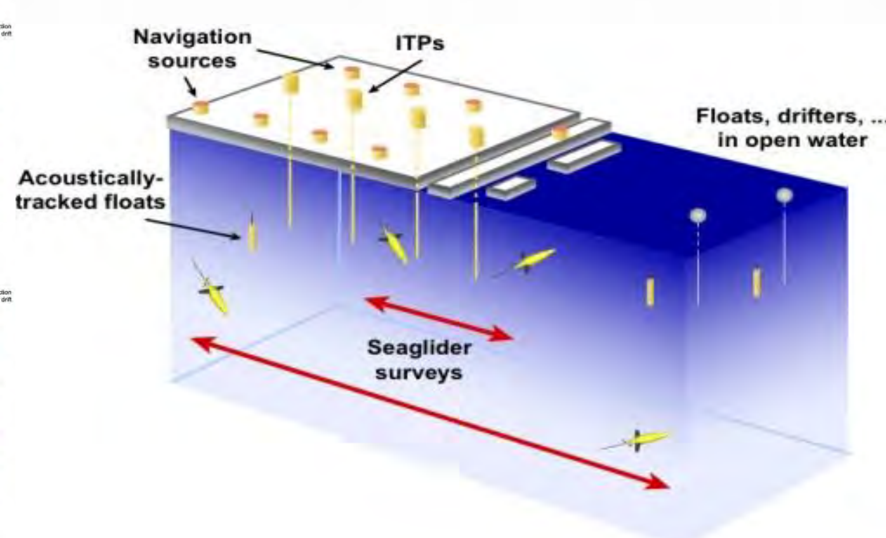
Marginal Ice Zone Initiative (FY12-FY16)

- A study of the emerging physics of the marginal ice zone during the summer melt-back period
- FY14: Major field experiment using buoys and UUVs with interagency and international cooperation



March 2014: Deploy sensor array along 135E, let sensors drift with ice
July 2014: Ukpik from Prudhoe Bay, deploy mobile sensing array in MIZ
September 2014: Recovery of observational assets





Better basic understanding of the dynamics of the Marginal Ice zone is needed to understand, model, and predict the ongoing decrease in ice coverage and volume in the Beaufort and Chukchi Seas

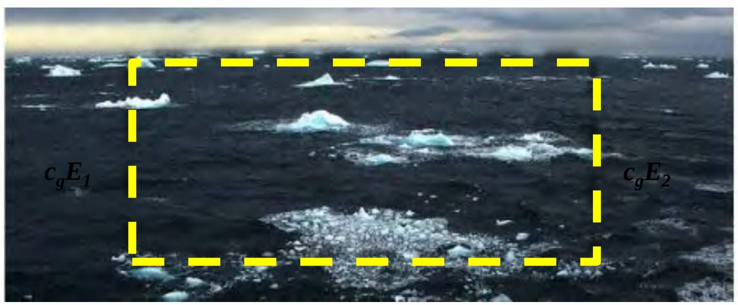
Arctic Sea State Program

Arctic Waves and Sea State DRI (FY13-FY17)

A study of ocean waves and swell in the Beaufort and Chukchi Seas, to better understand the impact of increasing open water on air-sea interaction and the remaining sea ice cover

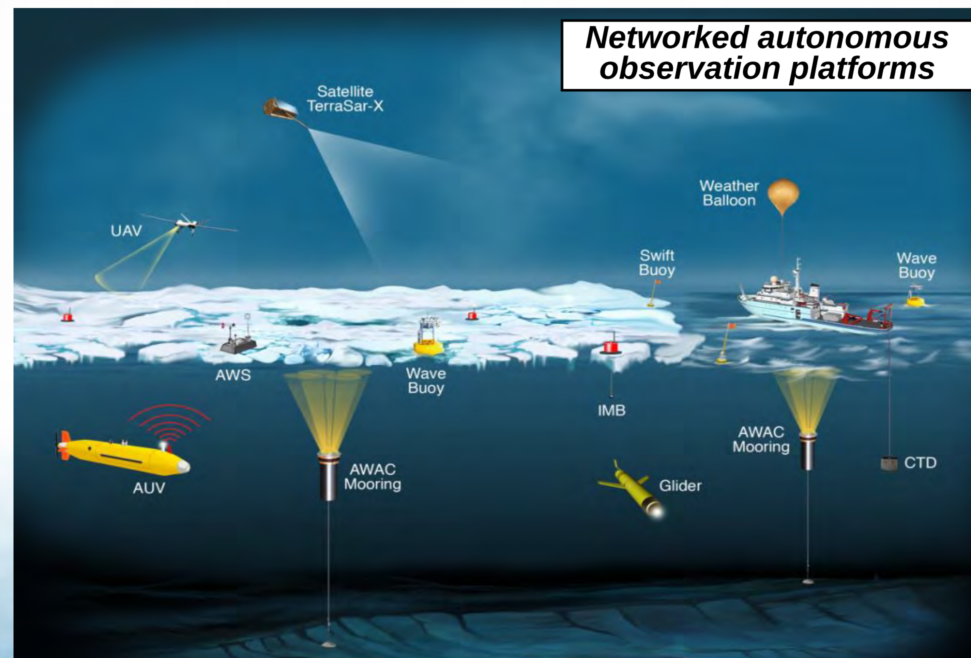
Sampling from the R/V Sikuliaq and autonomous sensors, October 2015

$$d/dt\,(E) + d/dx\,(c_g E) = S_{wind} - S_{brk} + S_{nl} + S_{ice}$$



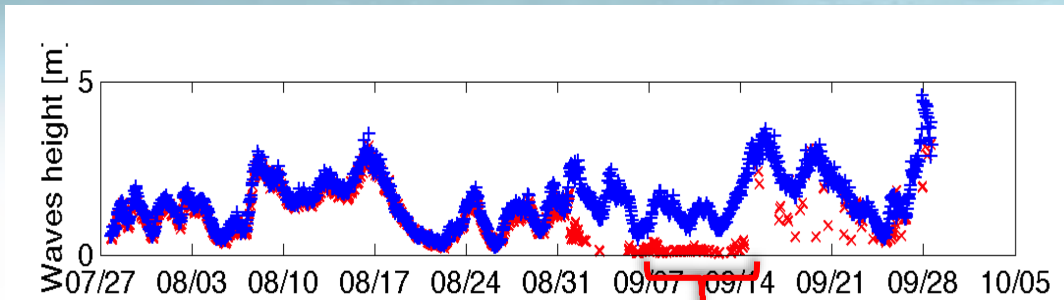
***Fetch**, x*

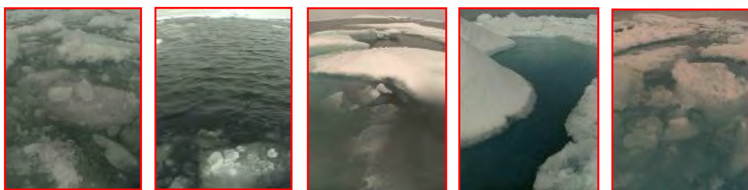
R/V SIKULIAQ



Surface Wave Impacts: Melt and Freeze-up

Melt: Waves Loose Energy Rapidly in Ice





Daily telemetry images from SWIFT 10

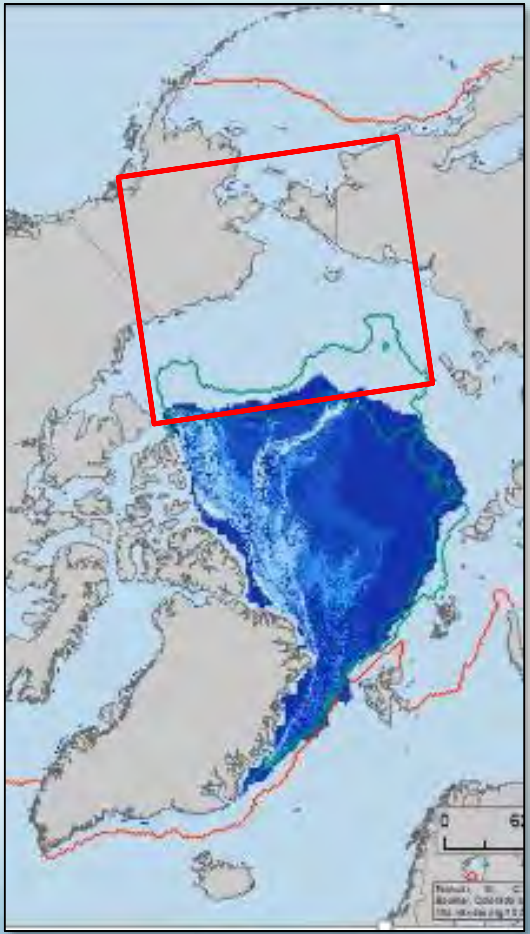
Freeze-up:
Less ice →
More waves →
More pancake ice

- Increasing open water leads to more, and larger, surface waves.
- These may impact freeze-up more than melt.

CANAPE

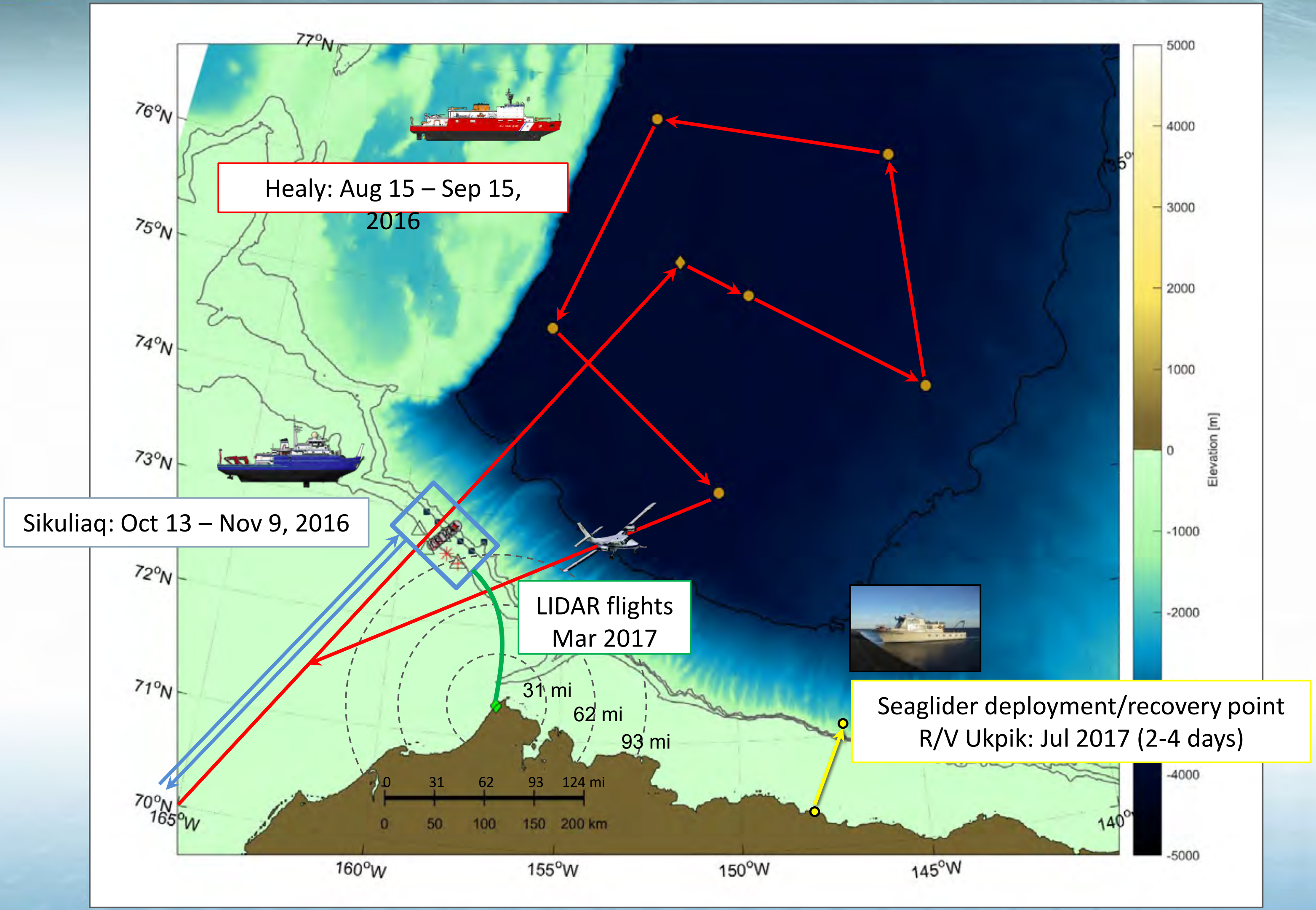
<u>Can</u>adian Basin <u>A</u>coustic <u>P</u>ropagation <u>E</u>xperiment

September 2012

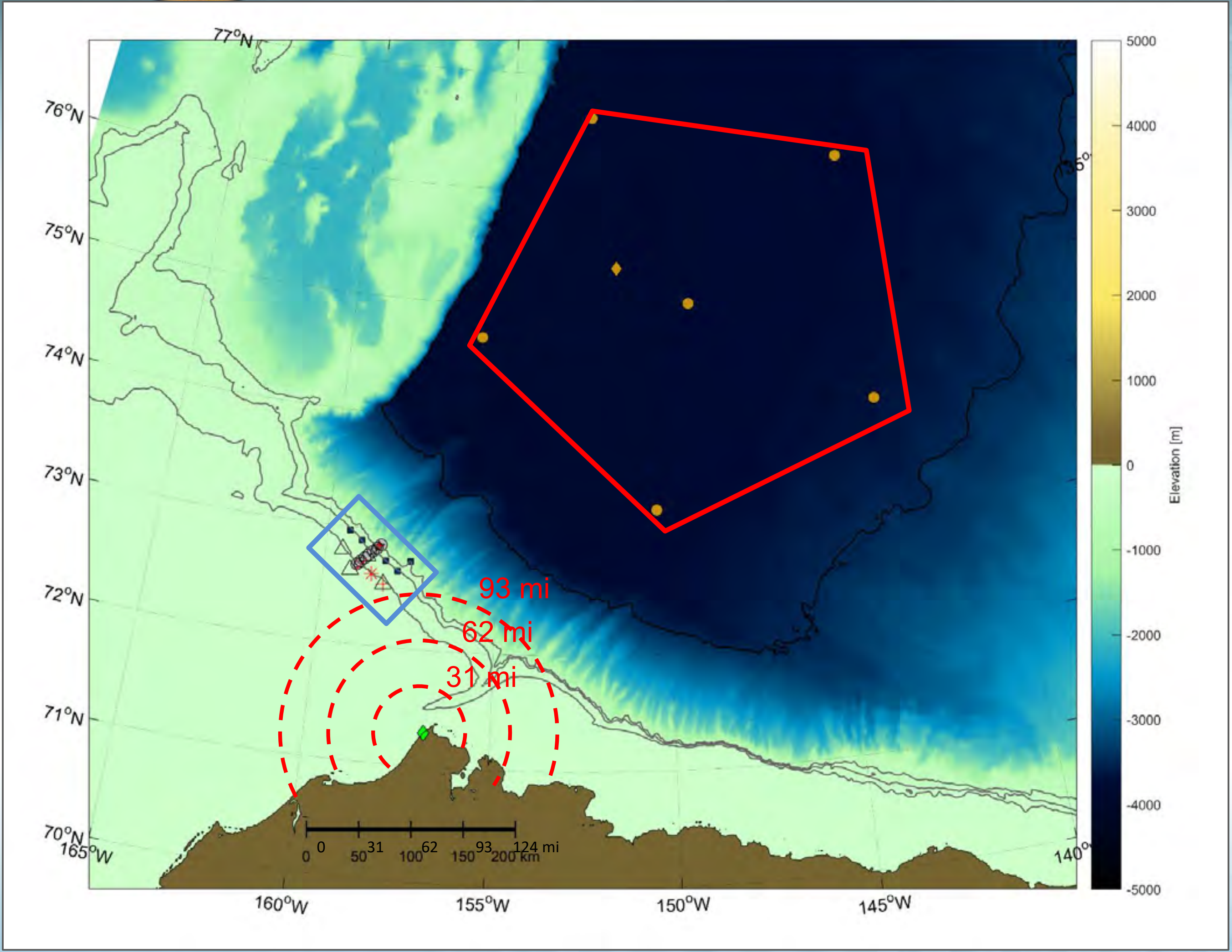


- The Pacific Arctic Region is experiencing the greatest seasonal ice *retreat* and *thinning* of sea ice in the entire Arctic
- Changes in ice coverage may trigger positive feedbacks that would further increase melt rate.
- <u>These changes impact soundscape by changing the dominant ambient noise mechanisms, the distance sound travels in the water, how it is scattered by the ice, etc.</u>

Proposed Cruise Tracks



Proposed Mooring Locations



Deep-water site
(Canadian Basin, ~3500m)

6 transceiver moorings

- Oceanographic sensors
- Ice draft measurements
- Acoustic receivers
- Acoustic sources (250 Hz)

1 receiver mooring (DVLA)

- Oceanographic sensors
- Acoustic receivers

Shallow-water site
(Chukchi Shelf, 100-600m)

20 observational moorings

- Oceanographic sensors
- Acoustic receivers
- Ice draft measurements

3 source moorings

- Oceanographic sensors
- Acoustic sources (400-4000 Hz)