A Sampling of US Research Activity in the Subpolar North Atlantic and Arctic

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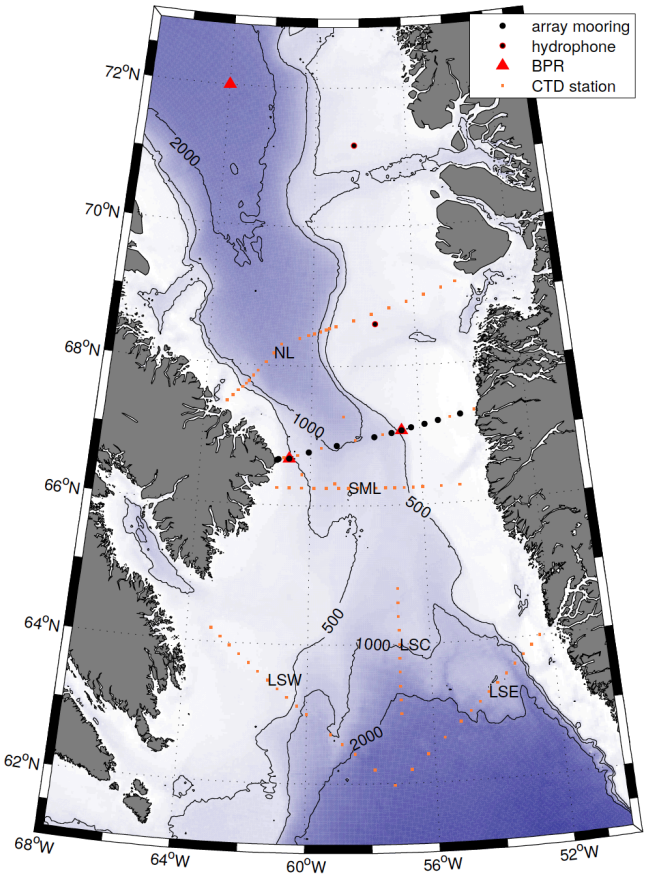
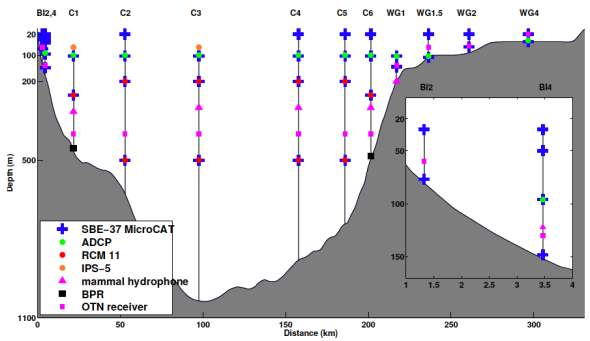
- Davis Strait status report.
- EXPORTS
- Near-inertial interactions with the mescoscale
- MIZ and Sea State Status report
- Canada Basin Acoustic Propagation Experiment
- Stratified Ocean Dynamics of the Arctic Ocean (SODA)
- US Arctic Observing Network

Davis Strait Status Report

- Present funding ended in 2015.
- Processing of 2013-2015 measurements proceeding (slowly)
- ‘Bootleg’ deployment 2015-2017 (with NSF agreement)
- Recovery uncertain, but likely autumn 2017
- Proposal for 2017-2022 under review (NSF-AON)





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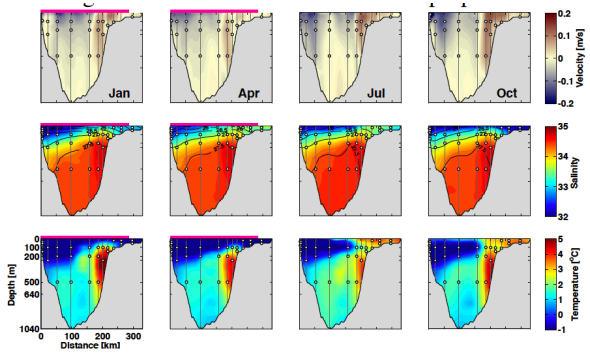
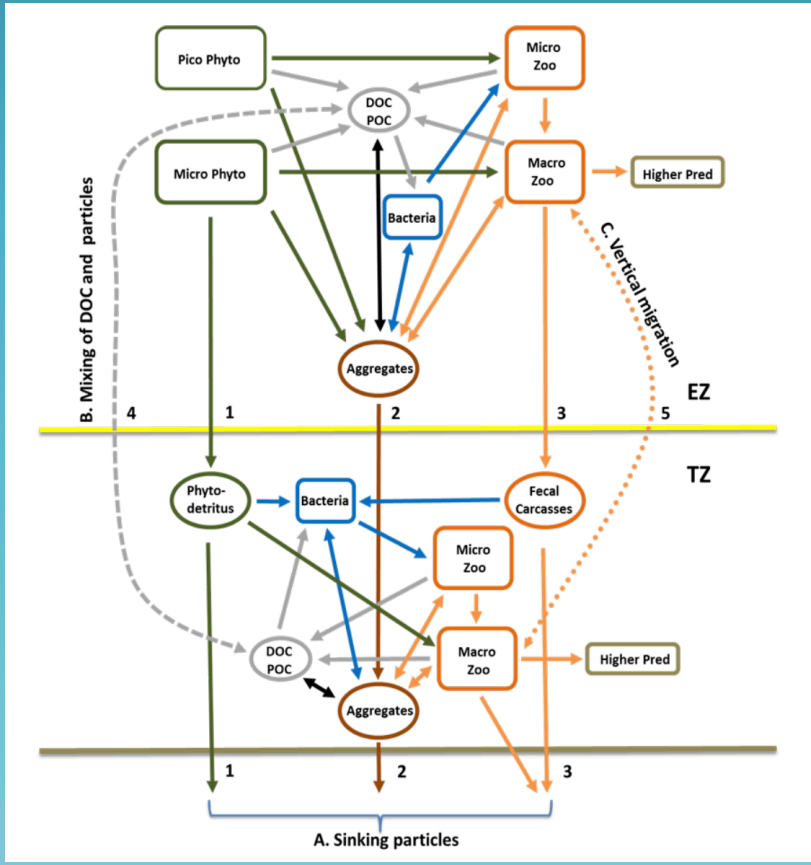


2017-2022 (proposed)

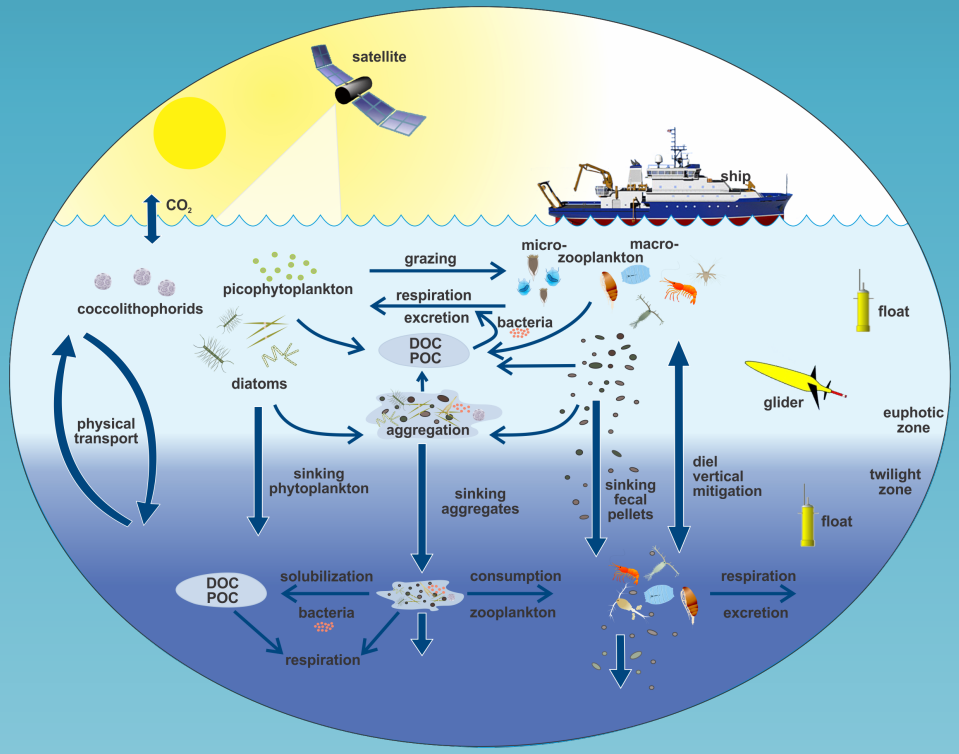
- US, Canada, Greenland, Denmark
- Mooring array
  - Fluxes
  - Ice
  - Fish
  - Marine mammals
- Bottom pressure recorders
- Ship-based hydrography

Export Processes in the Ocean from Remote Sensing (NASA EXPORTS)

Five export pathways from euphotic zone to twilight zone



- Intensive ship-based process work (pathways)
- Sustained sampling using autonomous platforms (states)



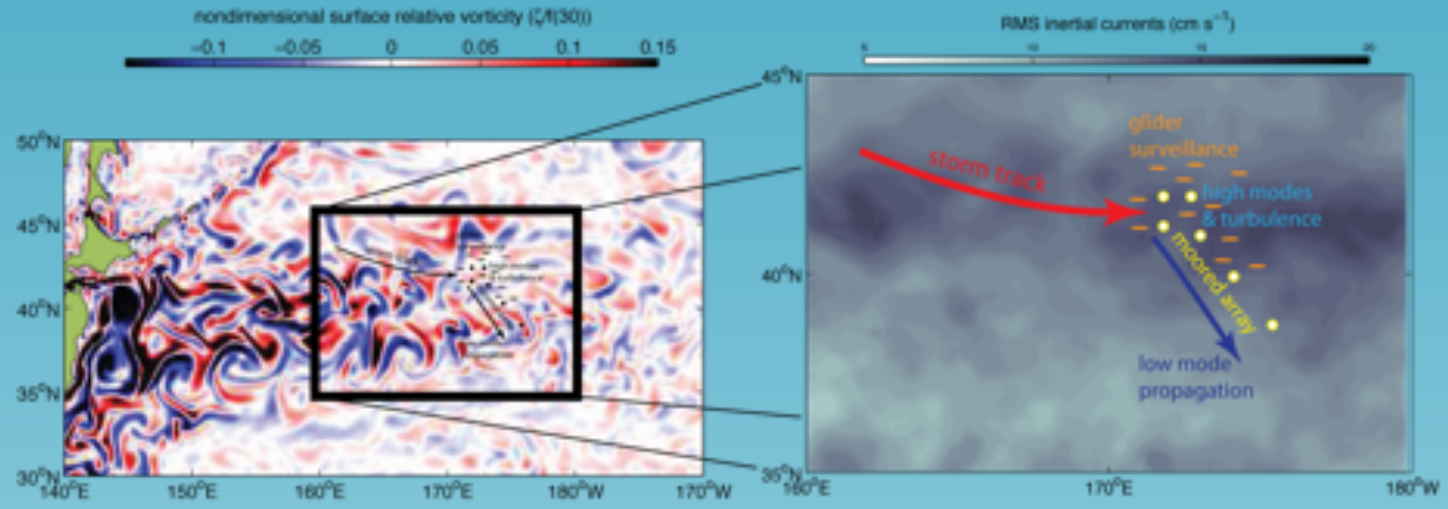
How do ecological and physical state govern pathway mix & intensity?

2017-2018: North Pacific
2020-2021: North Atlantic

Near-Inertial Wave Interactions with the Mesoscale and Submesoscale (2018-2023)

POC: Jen MacKinnon (Scripps Institution of Oceanography)

1. Near-inertial internal waves dominate upper ocean shear and strain, producing strong mixing and modulating acoustic propagation pathways.
2. Near-inertial wave generation and propagation are significantly affected by interactions with eddies and fronts.
3. Both wind input and the mesoscale/submesoscale vorticity field govern variability in near-inertial energy density.

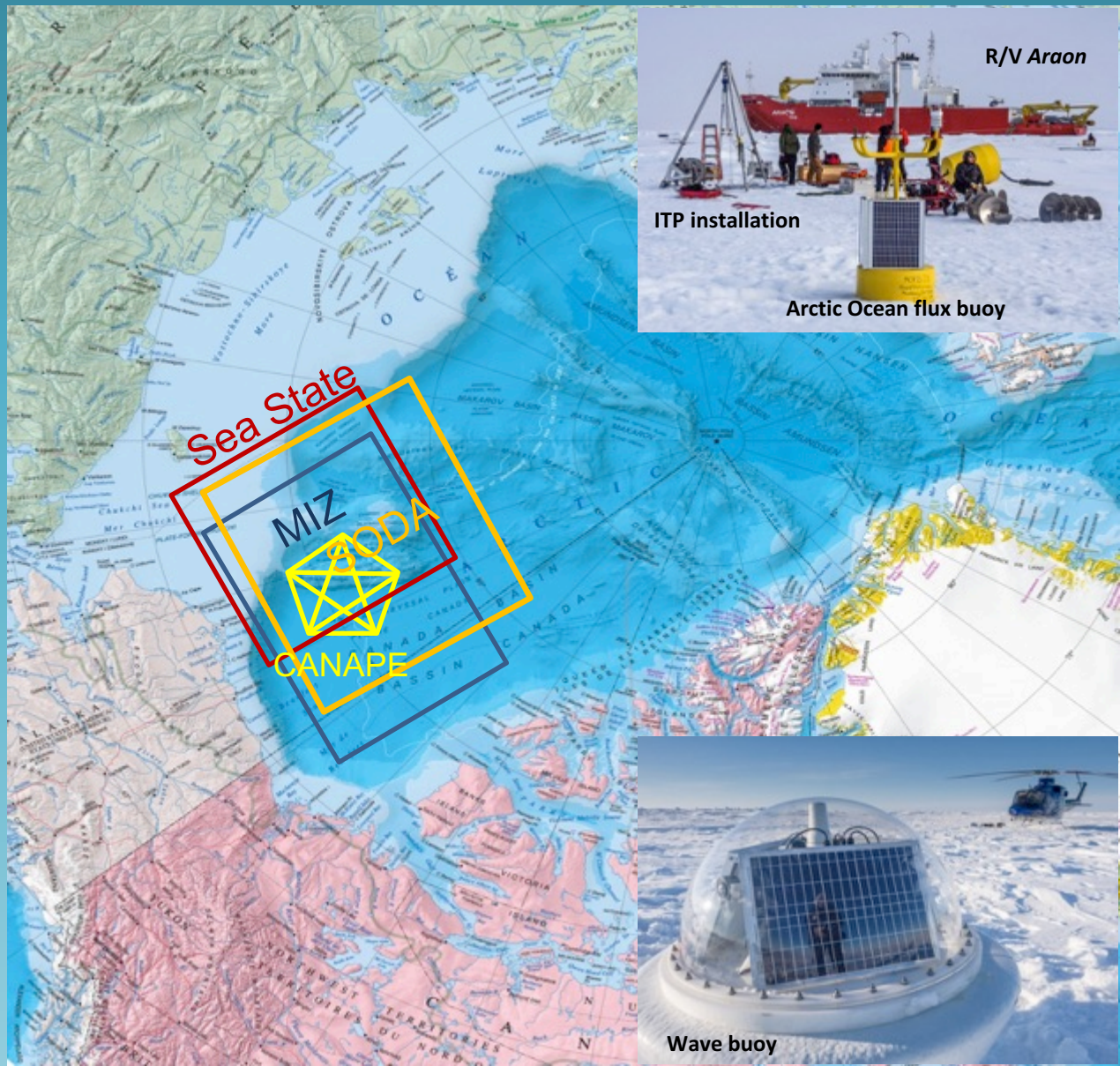


- Program at start of planning phase (funded, steering group formed)
- Pilot in 2018, intensive field program 2019-2020.
- Greenland-Iceland-UK Gap region selected as target site

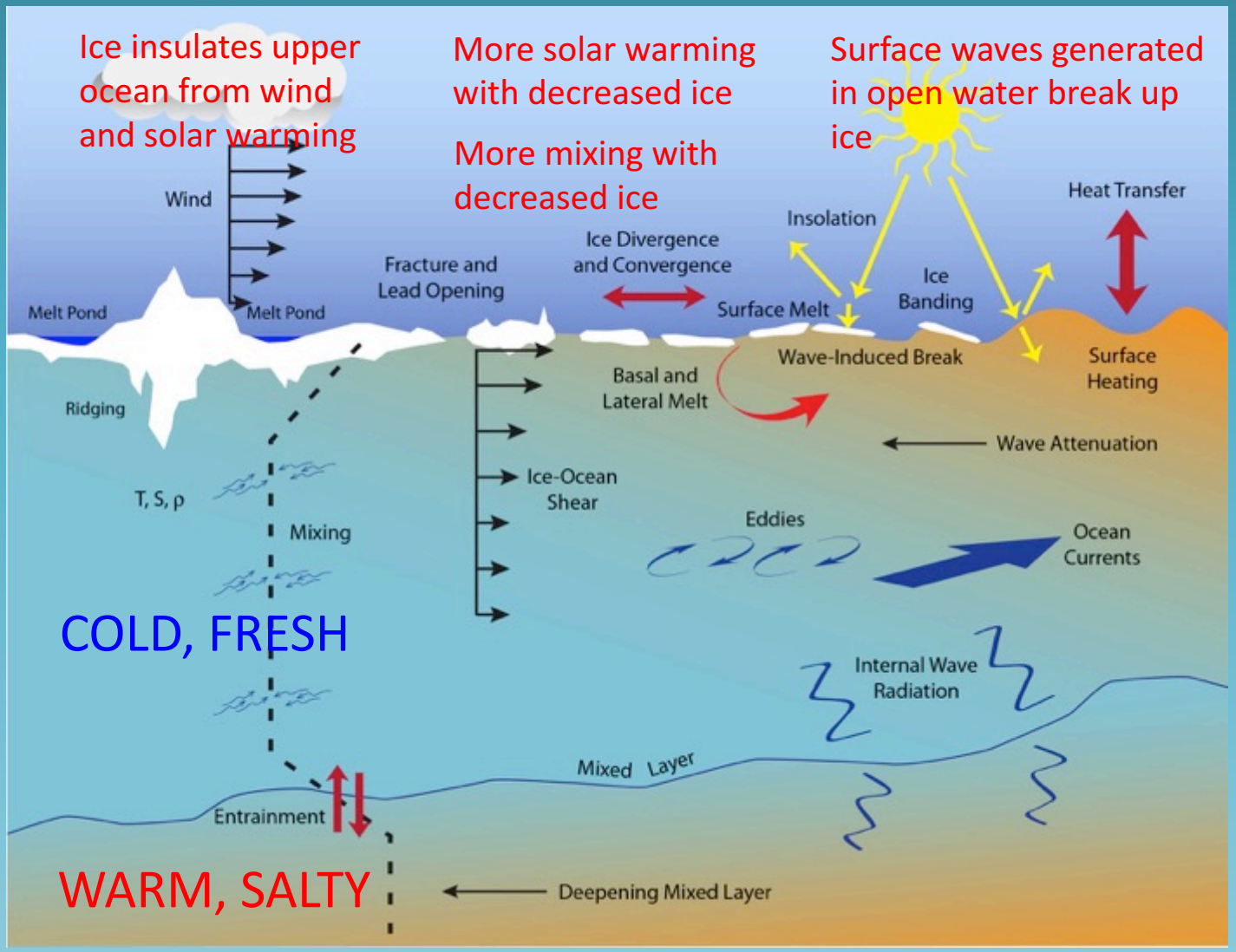
ONR Arctic Research Initiatives (2012-2020+)

- ❖ **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)
- **Mobile Arctic Onbserving Systems (AMOS)**
  2018-2023 (2019- fieldwork)



What Controls Sea Ice Melt & Upper-Ocean Structure?



Research Objectives

Enhance forecast capability- Improve numerical models

Science

1. Understand the physics that control sea ice breakup and melt.
2. Characterize changes in ice and upper-ocean physics associated with decreasing ice/increasing open water.
3. Explore feedbacks that might impact the speed of sea ice decline.

Technical

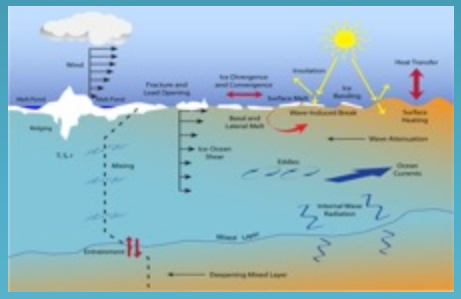
1. Develop and demonstrate new robotic networks for collecting observations in, under and around sea ice.
2. Improve interpretation of satellite imagery.

Marginal Ice Zone Program

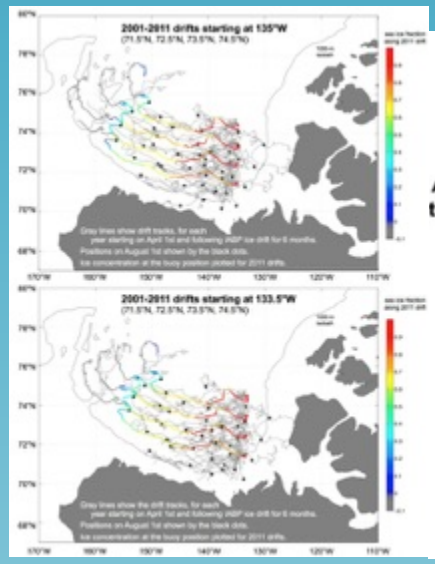
POC: Craig Lee (APL-UW)

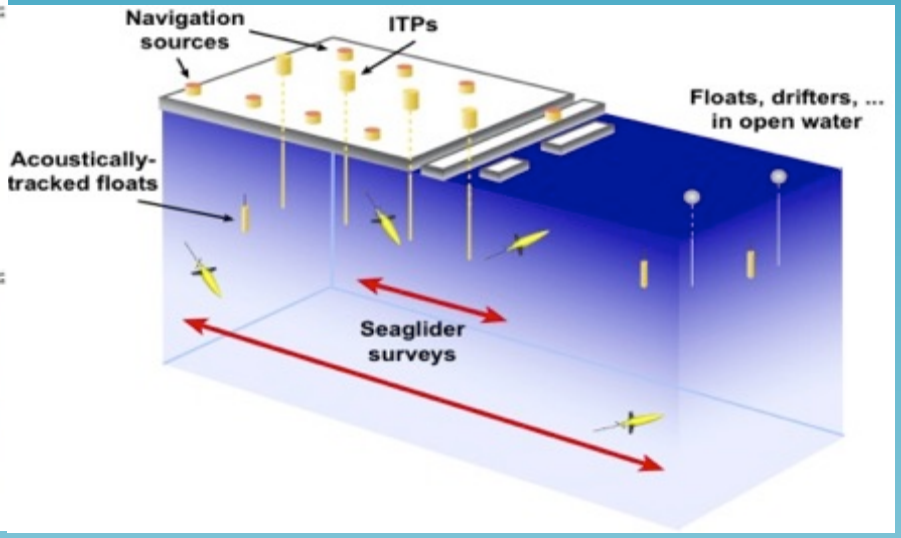
Marginal Ice Zone Initiative (FY12-FY16)

- 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





Publications appearing in ***Elementa*** special feature:

https://www.elementascience.org/collections/special/special-feature-marginal-ice-zone-processes-in-the-summertime-arctic/

http://www.apl.washington.edu/project/project.php?id=miz

Arctic Sea State Program

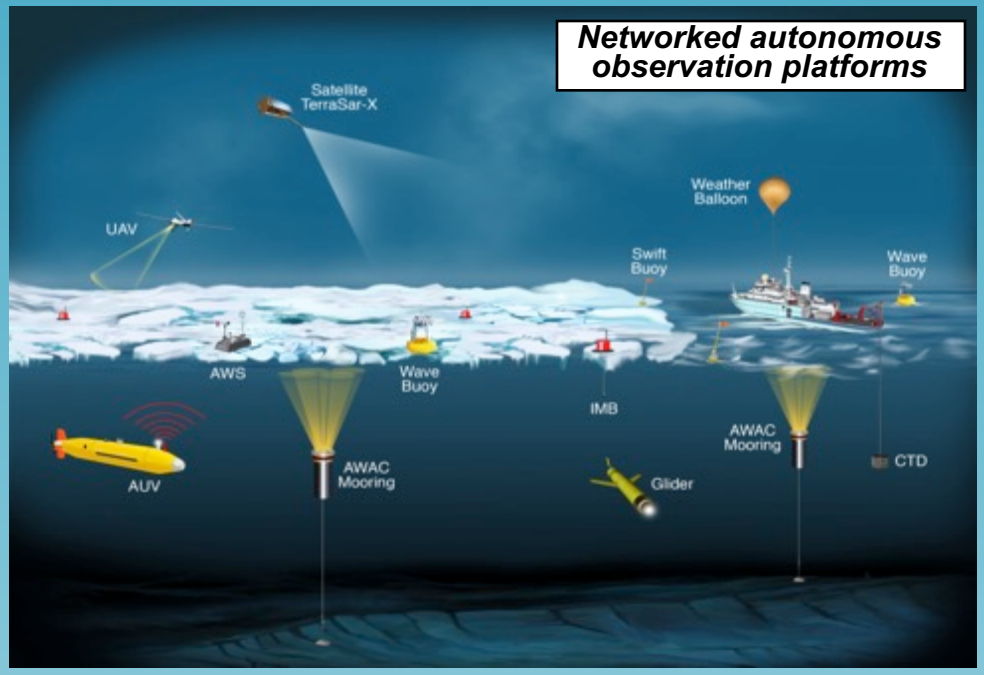
POC: Jim Thomson (APL-UW)

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

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



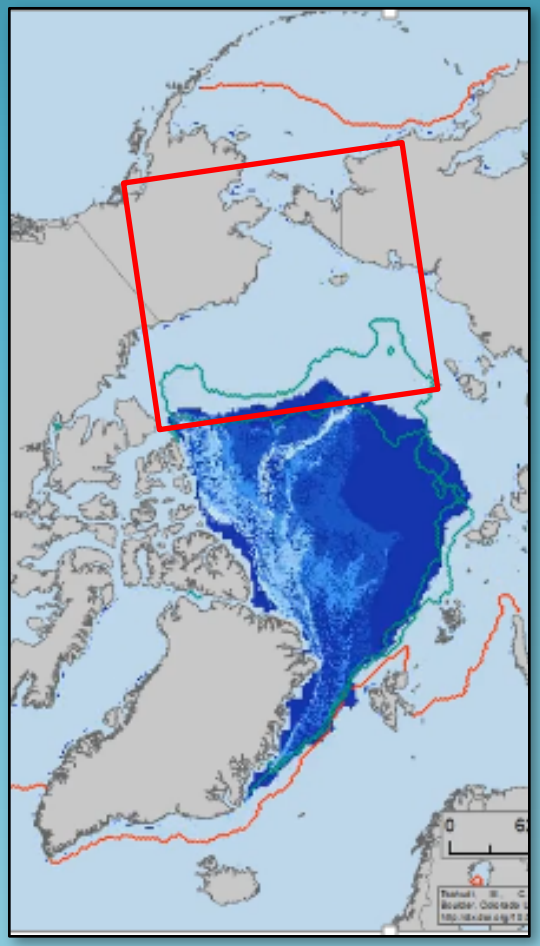
Publications will appear in JGR Oceans special section.

http://www.apl.washington.edu/project/project.php?id=arctic_sea_state

CANAPE

Canadian Basin Acoustic Propagation Experiment

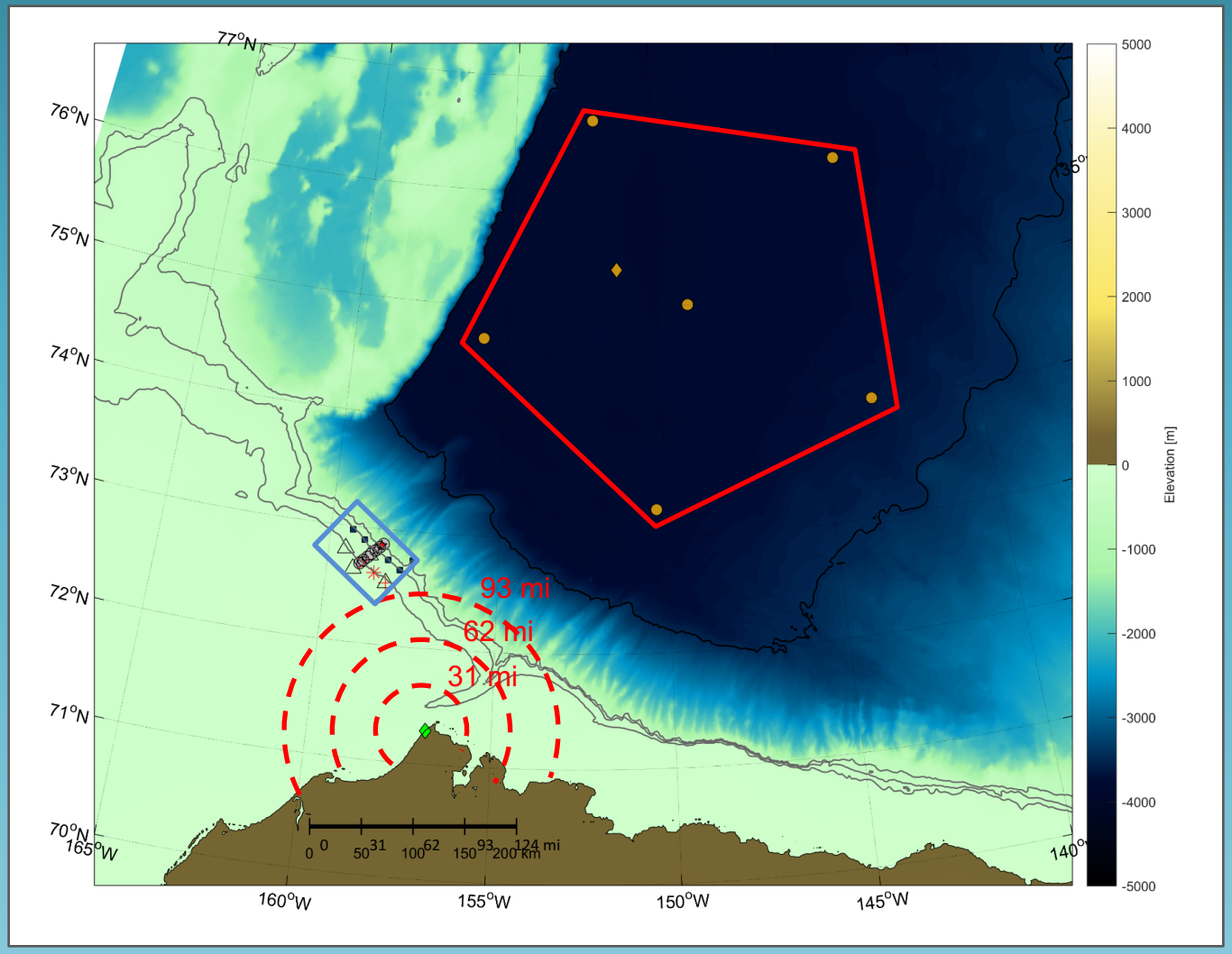
September 2012



- 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.
- 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.

CANAPE

Canadian Basin Acoustic Propagation Experiment



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)

Mooring array 2016-2017, with glider-based surveys in summer 2017.

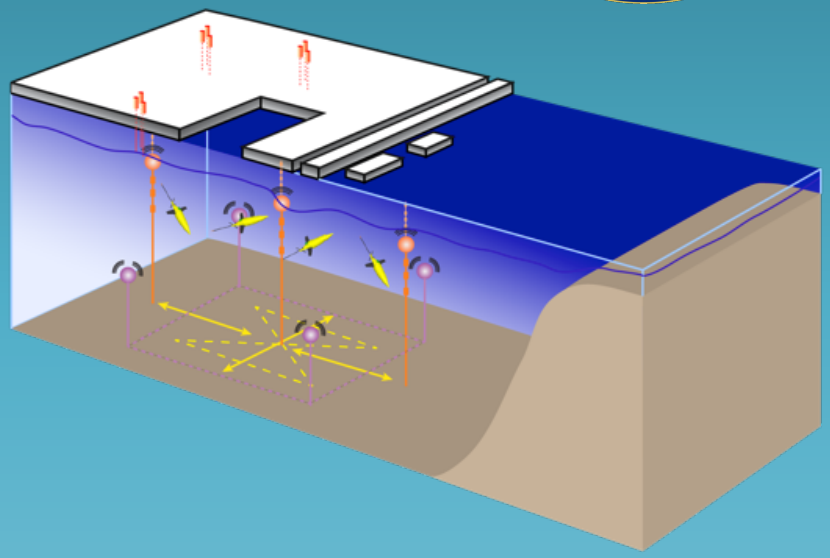
Stratified Ocean Dynamics of the Arctic Ocean (SODA)

POC: Craig Lee (APL-UW)

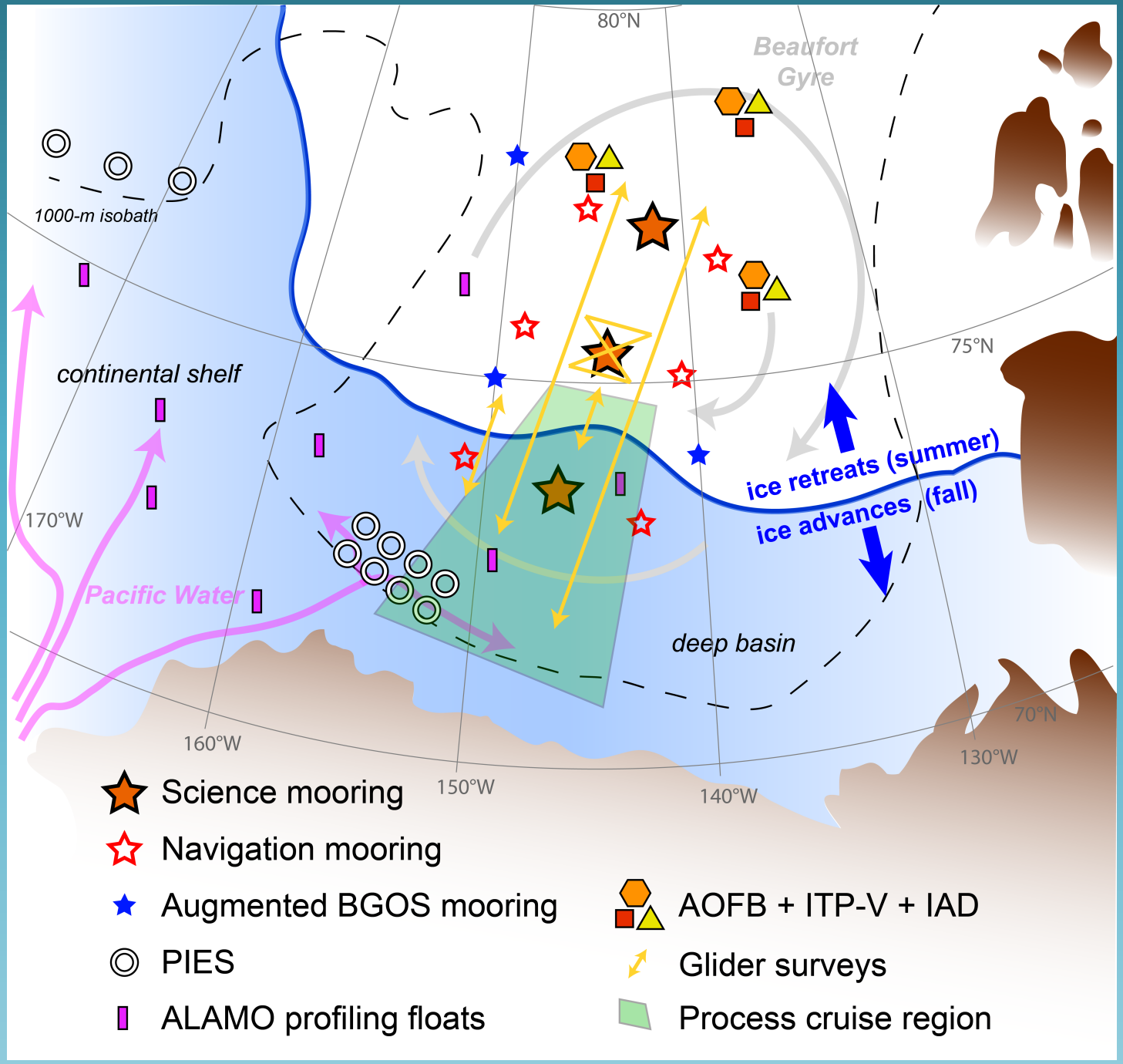
Buoyancy: What are the causes and consequences of the changing upper ocean stratification (mixed layer and Pacific Water)?

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

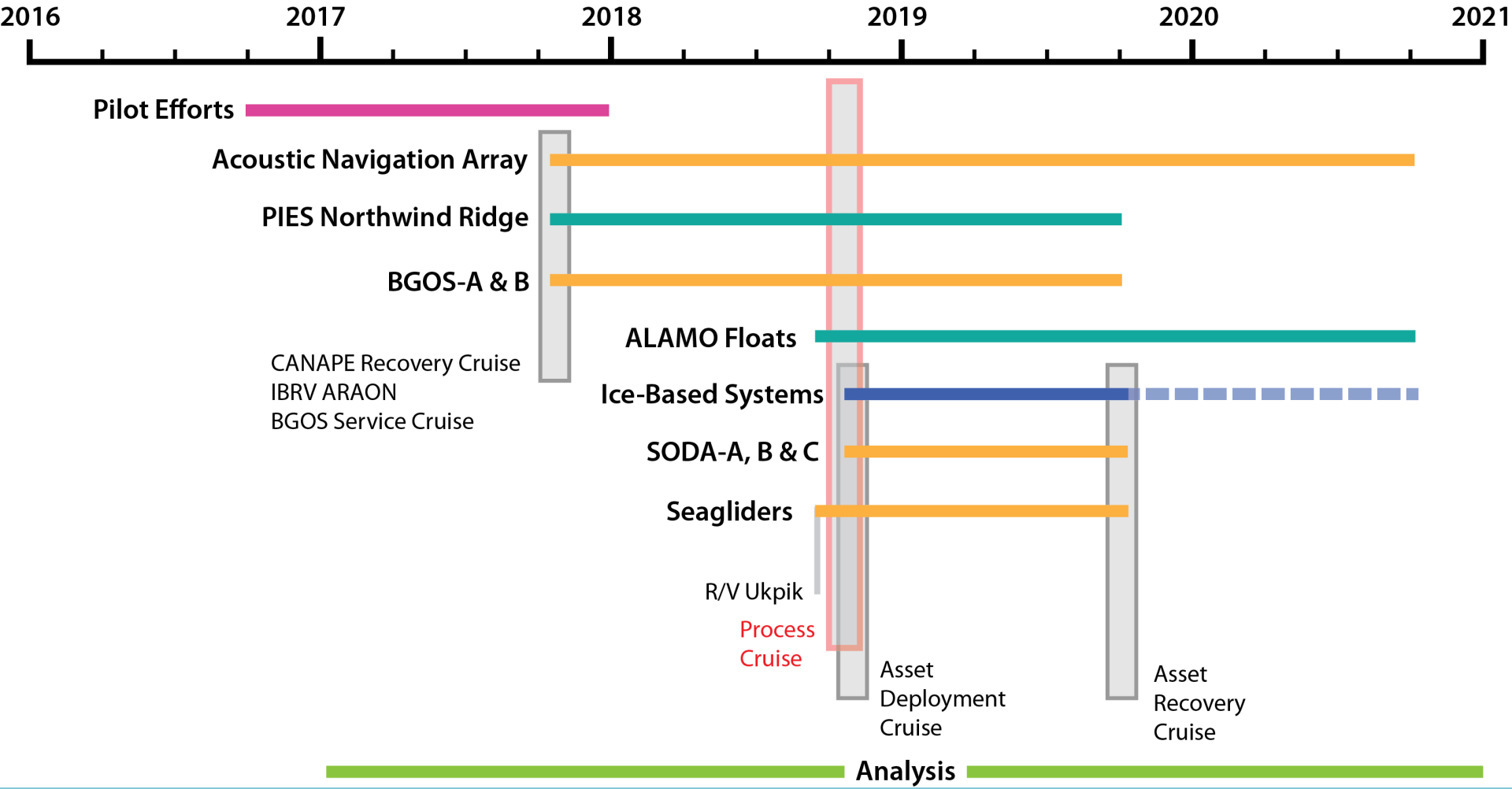
Heat: What is the fate and impact of the significant increase in upper ocean heat?

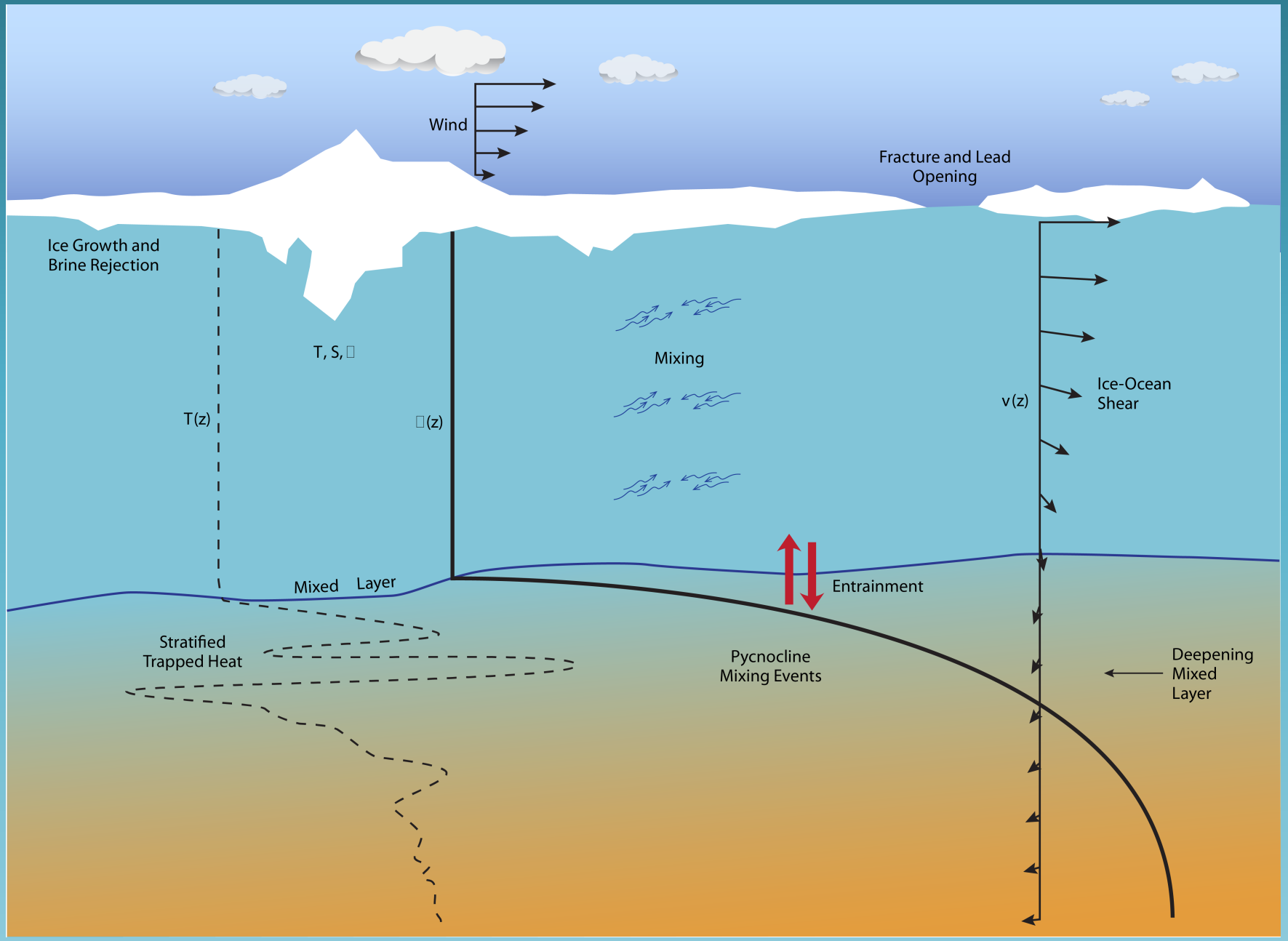


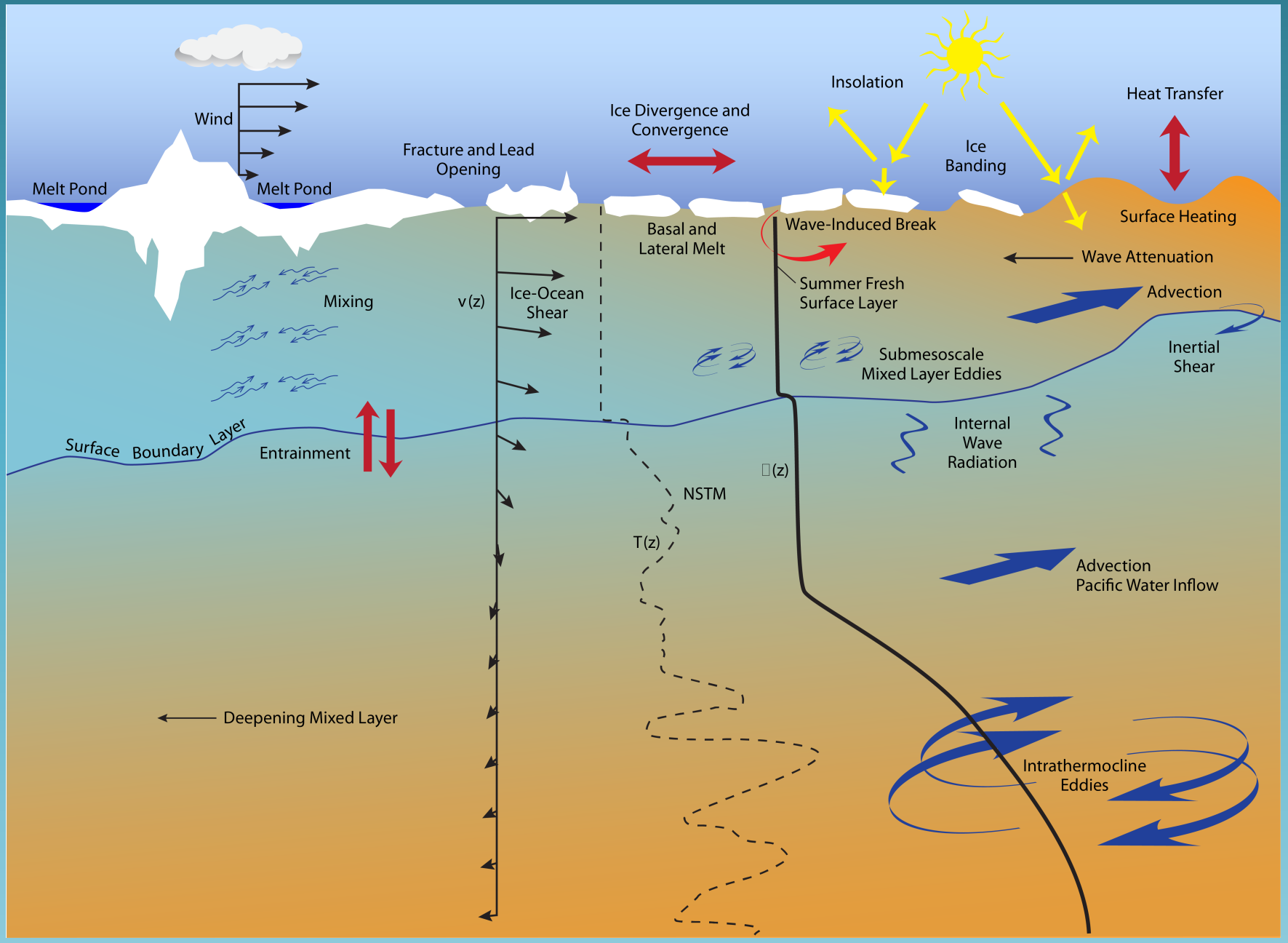
- 2018-2019.
- Central Beaufort Sea.
- One year of autonomous sampling (moorings, gliders, ice-tethered sensors).
- Autumn service cruises, ship-based measurements.


80°N
Beaufort Gyre
1000-m isobath
continental shelf
75°N
ice retreats (summer)
ice advances (fall)
170°W
Pacific Water
deep basin
70°N
160°W
150°W
140°W
130°W
Science mooring
Navigation mooring
Augmented BGOS mooring
PIES
ALAMO profiling floats
AOFB + ITP-V + IAD
Glider surveys
Process cruise region

SODA Program Timeline

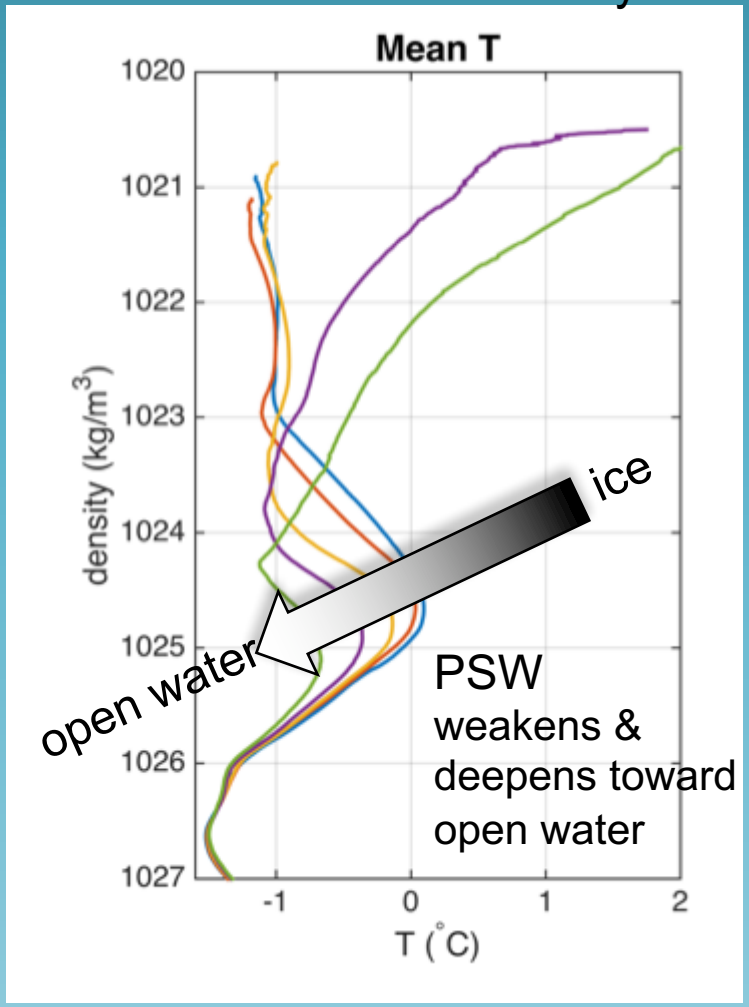


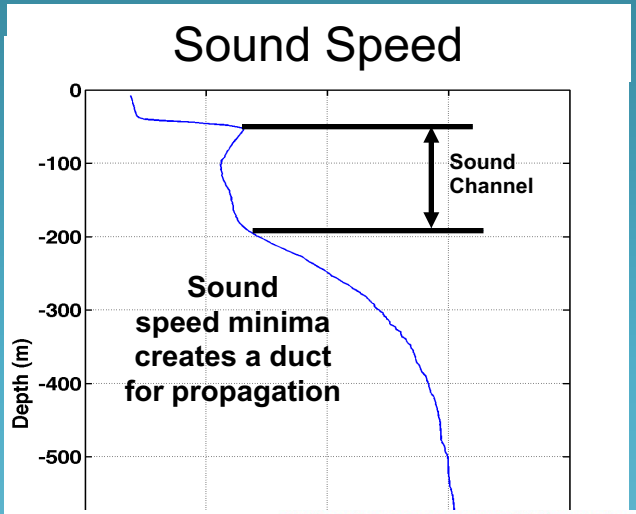

Wind
Fracture and Lead Opening
Ice Growth and Brine Rejection
T, S, □
T(z)
□(z)
Mixing
v(z)
Ice-Ocean Shear
Mixed Layer
Entrainment
Stratified Trapped Heat
Pycnocline Mixing Events
Deepening Mixed Layer


Wind
Melt Pond
Melt Pond
Fracture and Lead Opening
Ice Divergence and Convergence
Insolation
Ice Banding
Heat Transfer
Surface Heating
Basal and Lateral Melt
Wave-Induced Break
Wave Attenuation
Summer Fresh Surface Layer
Advection
Mixing
v(z)
Ice-Ocean Shear
Submesoscale Mixed Layer Eddies
Inertial Shear
Surface Boundary Layer
Entrainment
Internal Wave Radiation
(z)
NSTM
T(z)
Advection Pacific Water Inflow
Deepening Mixed Layer
Intrathermocline Eddies

Marginal Ice Zone Program
Mixing and Sound Transmission

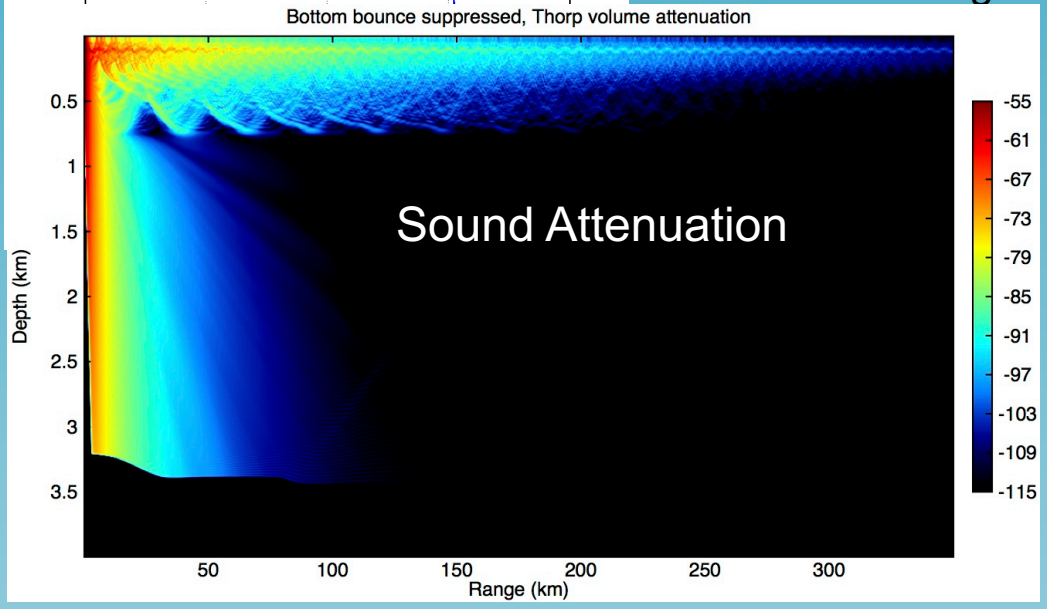
Mixing Deepens and Weakens Pacific Summer Water Layer



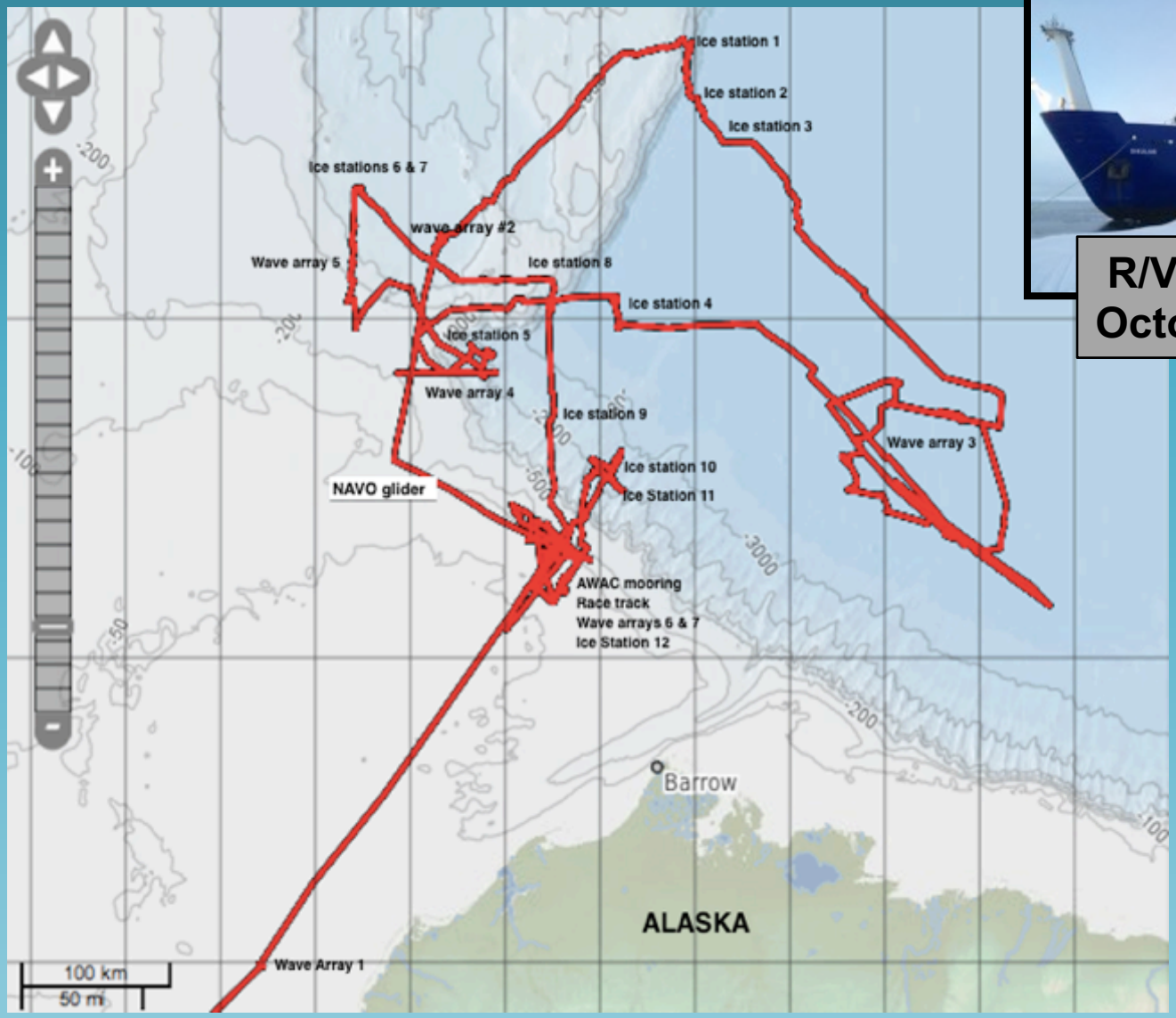


Pacific Summer Water creates sound channel

- Roughly 150 m (490 ft) depth.
- Long-range transmission
- Modified by ice cover & mixing

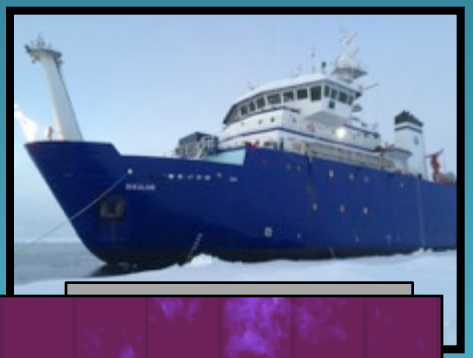


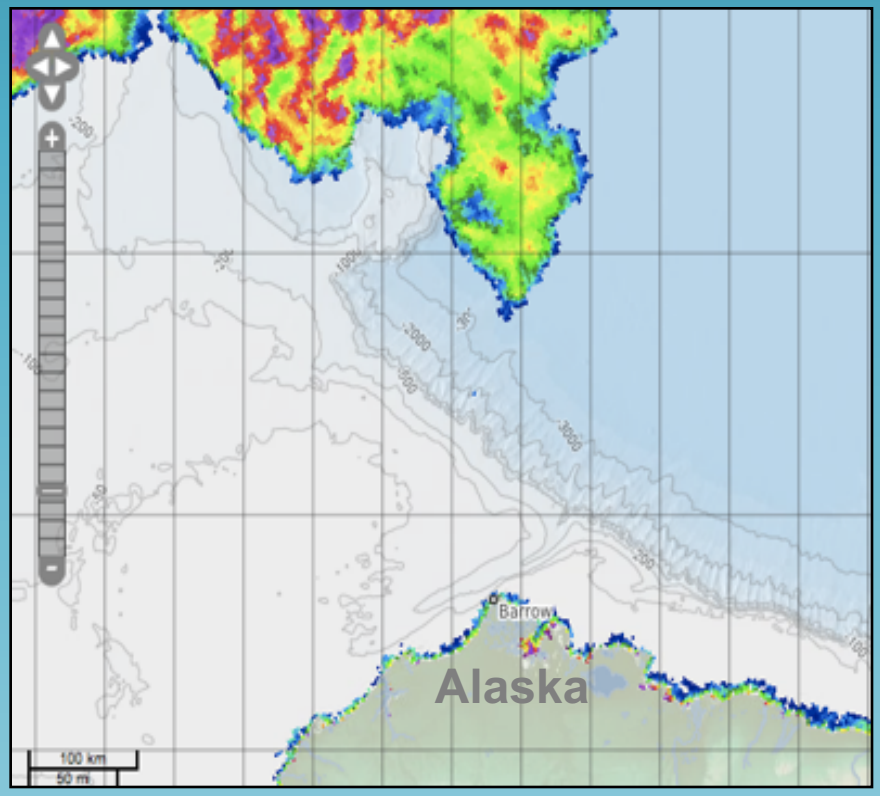
Arctic Sea State Program



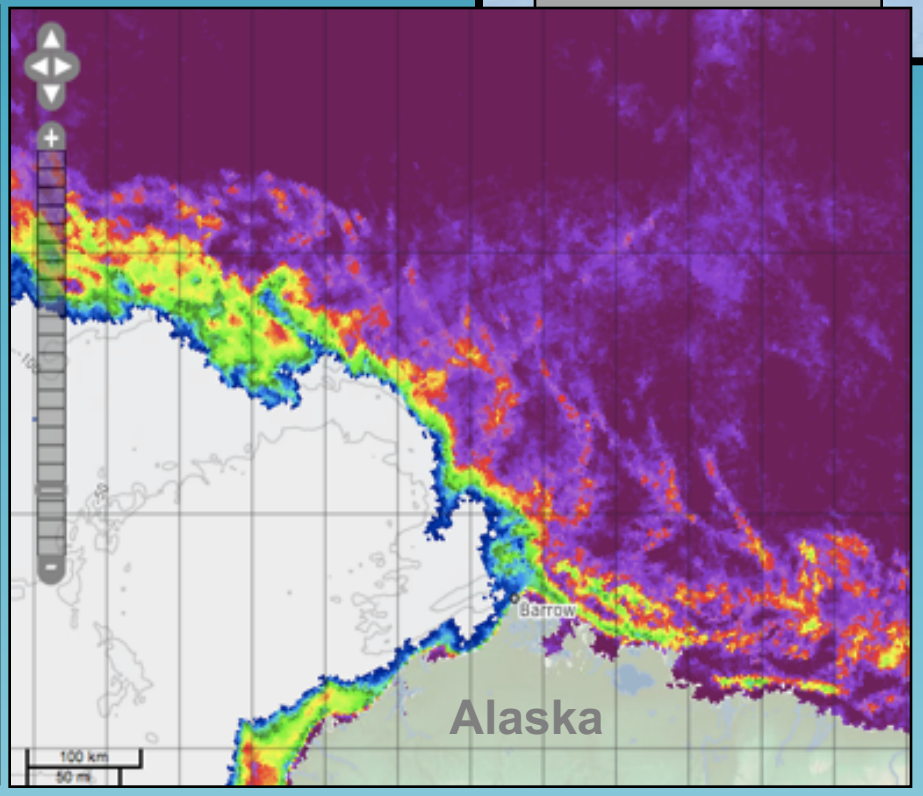
R/V Sikuliaq
October 2015

Arctic Sea State Program





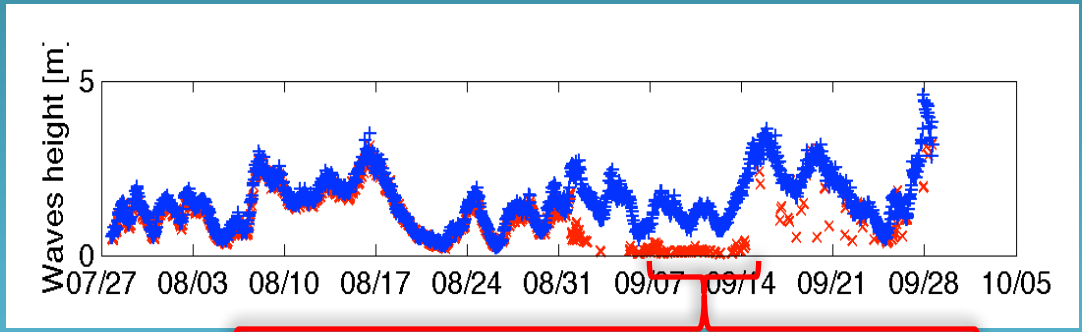
AMSR2 ice conc. on 1 Oct 2015

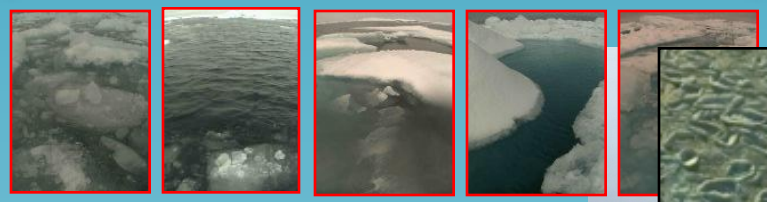


AMSR2 ice conc. on 1 Nov 2015

Surface Wave Impacts: Melt and Freeze-up

Melt: Waves Loose Energy Rapidly in Ice



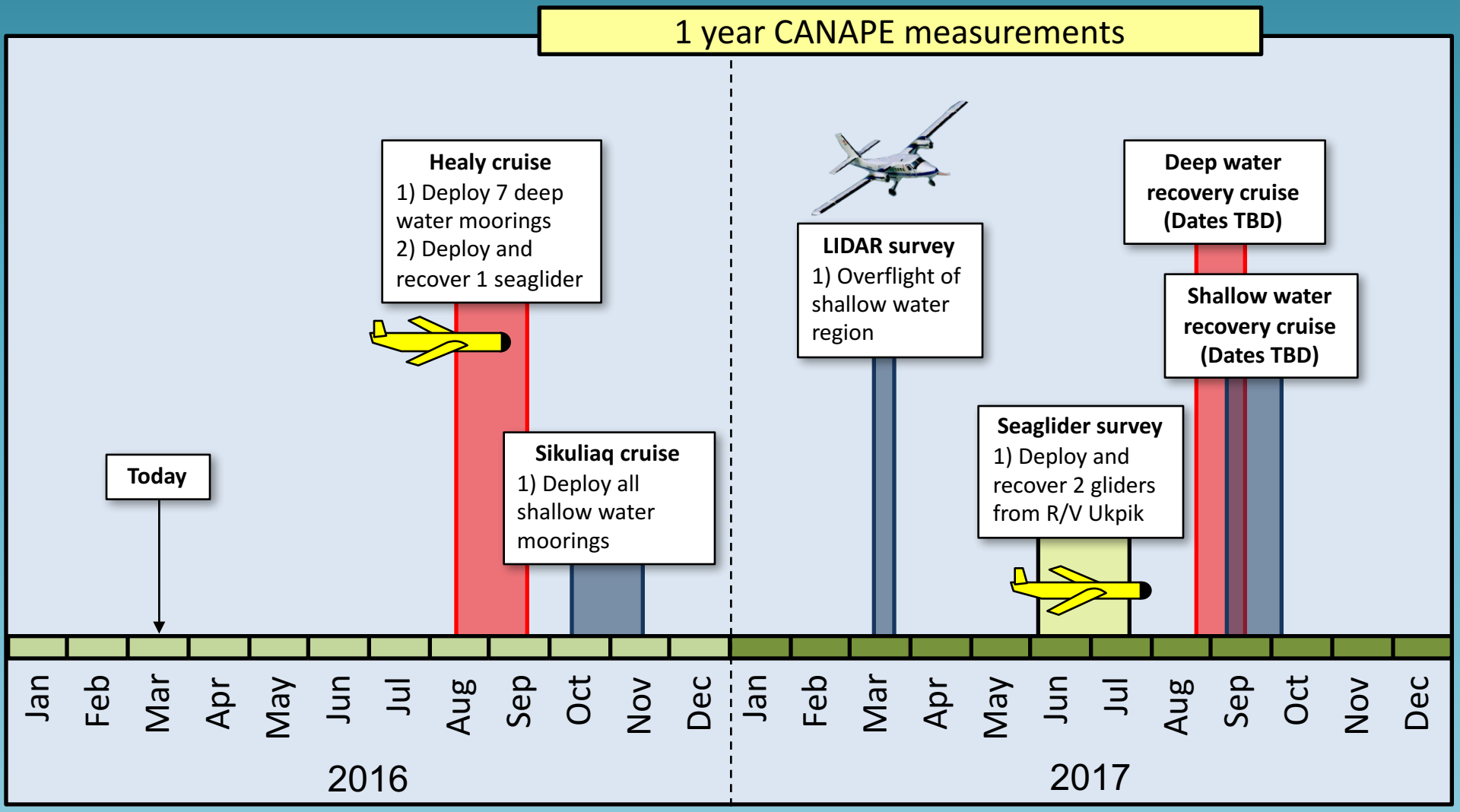


Daily telemetry images from SWI

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.

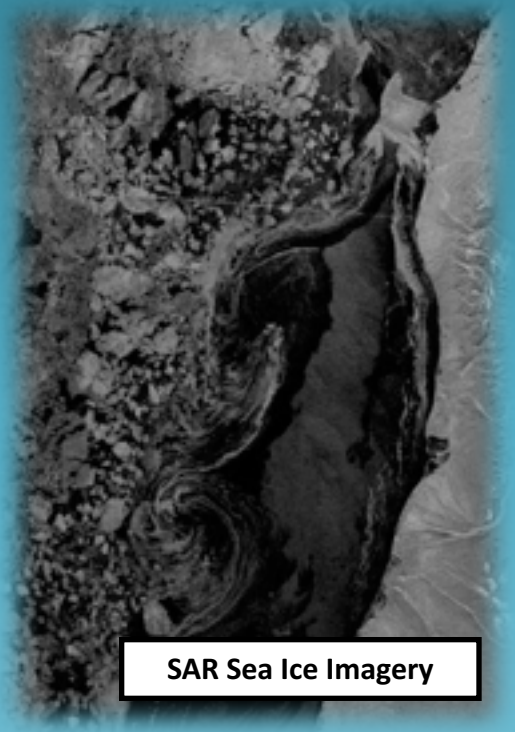
CANAPE Timeline



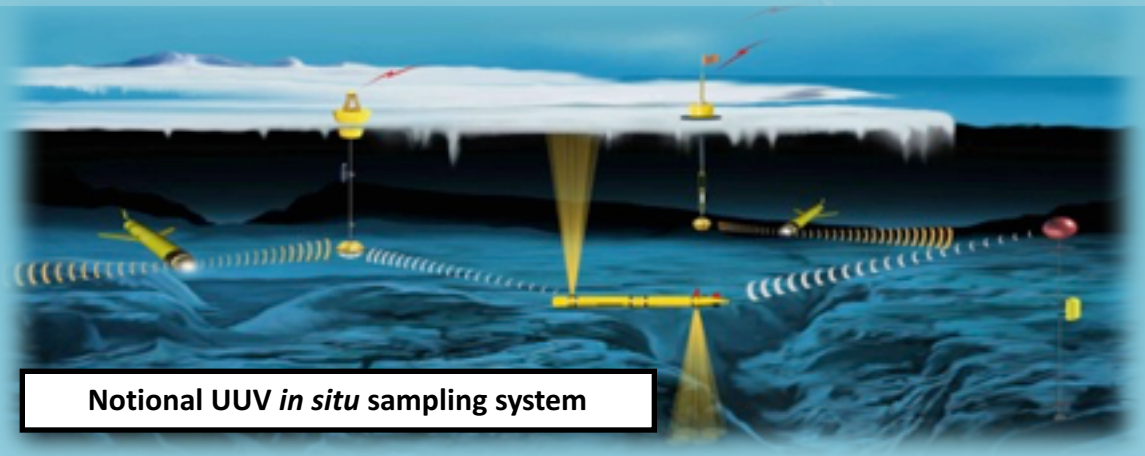
ONR Environmental Arctic Research

MAJOR THRUSTS

1. Generation of **new observing technologies** (platforms, sensors, communications) that will enable persistent observation and operation in the Arctic
2. **Improved basic physical understanding** of the Arctic environment and important coupled processes operating 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



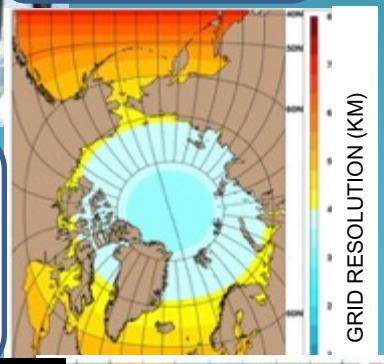
Notional UUV *in situ* sampling system

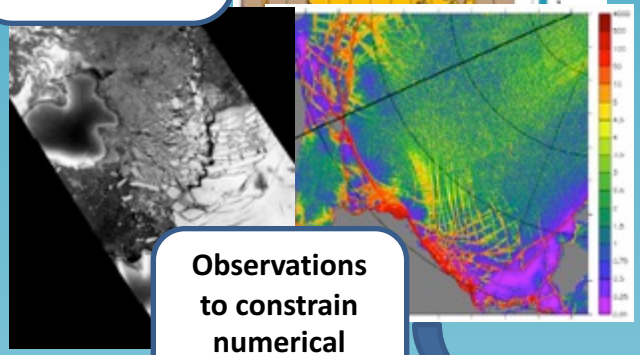
Advances in technology will be required to enable an interagency Arctic Observing Network that will support scientific exploration and be able to initialize predictive models of the environment

Forecast Capability Development and Transition

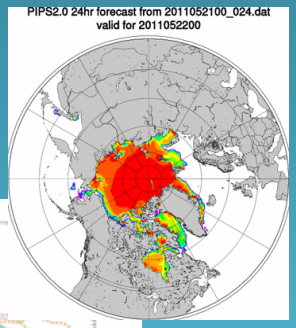
Fieldwork to better understand key physical processes

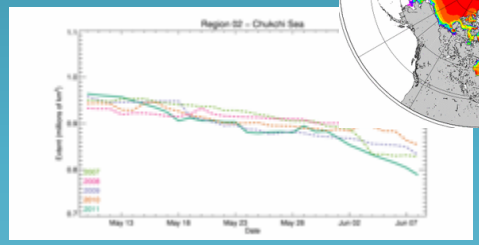
Improved physics built into improved Arctic System Models

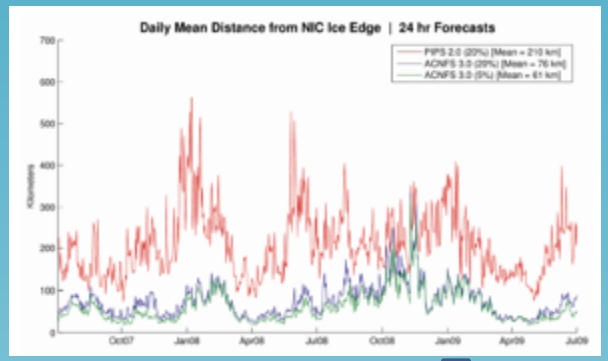


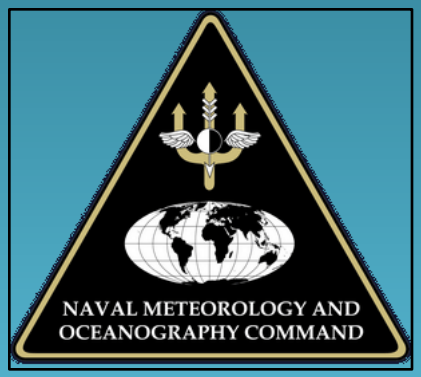


Observations to constrain numerical predictions









Arctic Prediction System Development

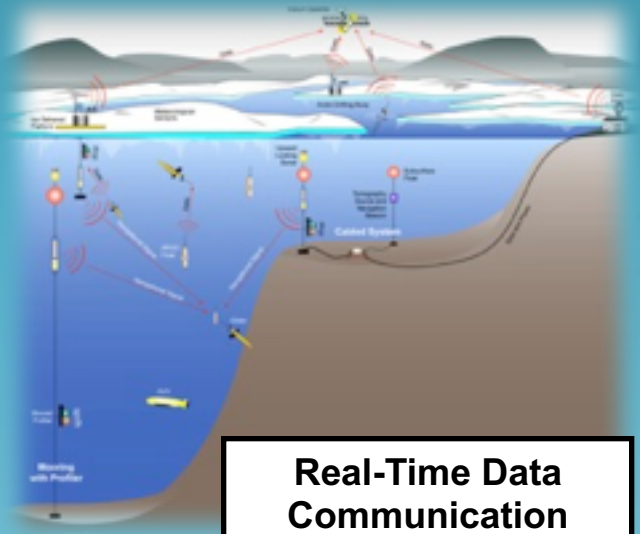
Validation and Verification

Transition to Operational Use

In situ Sensing Technology Development

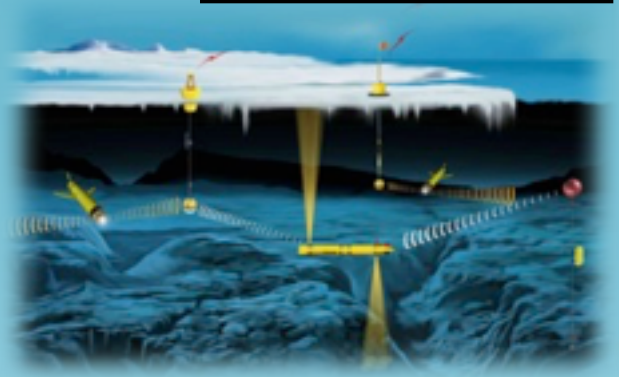
A sensing system must be developed to provide persistent observations that can further scientific understanding, provide long-term monitoring, and constrain the predictive models.

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

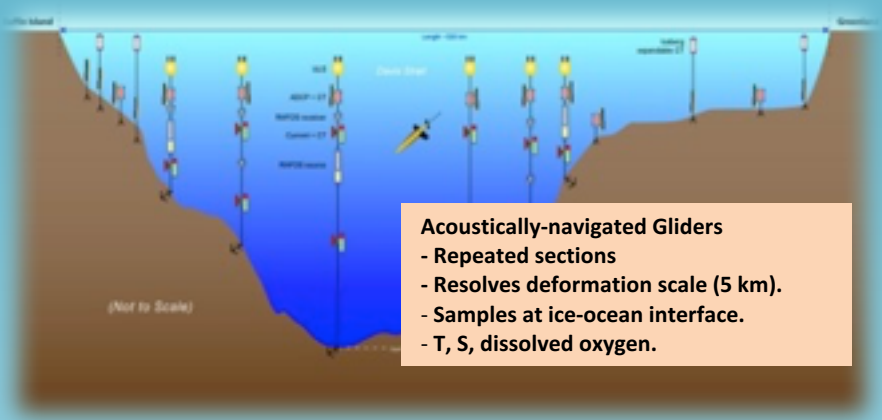


Novel Sensing Systems

Real-Time Data Communication



Autonomous Platforms and Enabling Technologies



Acoustically-navigated Gliders
- **Repeated sections**
- **Resolves deformation scale (5 km).**
- **Samples at ice-ocean interface.**
- **T, S, dissolved oxygen.**

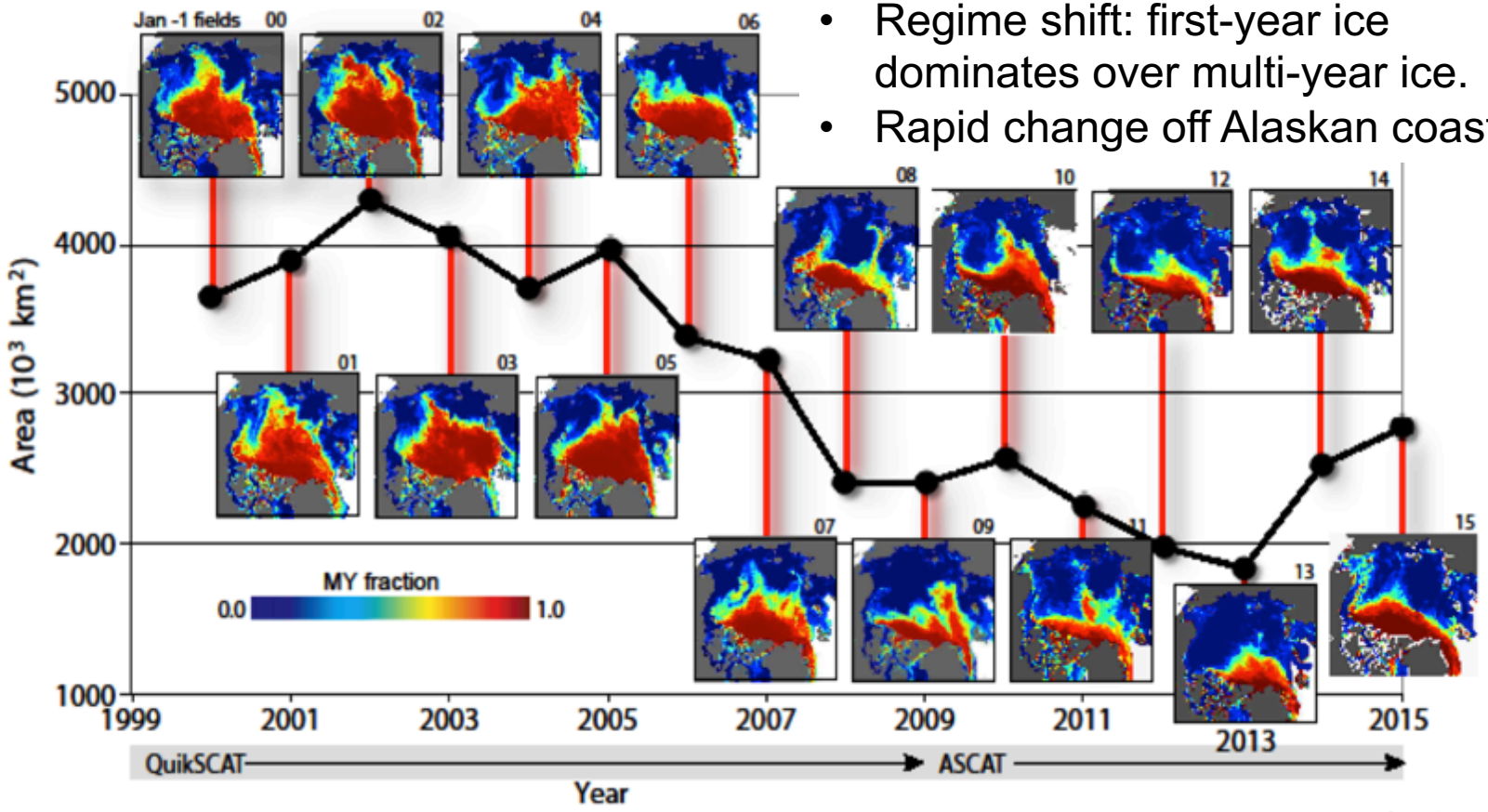
ONR Arctic Research Program

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.