Enhancing observational capabilities for Arctic Ocean ecosystems: Innovations using Ice-Tethered Profilers

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Marine ecosystems in the central Arctic \( \rightarrow \) difficult to observe

‘Usual’ ecosystem observing tools often unsuitable or strongly challenged

- Ships: too few, too seasonal
- Satellites: clouds, aerosols, sea ice, geometry

Profiling drifters: ice cover \( \rightarrow \) data offload

- Arctic is far behind in terms of ocean observing approaches, esp. where ice is perennial.
- Emphatically so with respect to basic ecosystem properties.
‘Basic ecosystem properties’ in a changing Arctic Ocean?

One working definition: the biological actors & key resources associated with primary production (i.e., photosynthetic activity)

“base of the food web”

Actors:

algae living on, interstitially within, or on the underside of sea ice:

‘ice algae’, ‘sea ice algae’

Or in water column below (to ~100m):

‘phytoplankton’

Needed resources:

Sunlight & nutrients (C,N,P, trace metals, etc.)
Photosynthesis & production under perennial sea ice

• Much of primary production under Arctic ice still poorly known:
  • Where are phytoplankton found (vertically, spatially) & when?
  • How long is the growing season? When does it start, end?
  • Dynamics of interactions between ice algae – phytoplankton
Measuring ecosystem variables using Ice-Tethered Profilers

ITP: autonomous profiler system to measure water column property profiles under perennial sea ice. Like Argo float, except tethered to a cable in ice. Typically 4x profiles per day over the top 800m.

http://www.whoi.edu/itp
ITPs: a now-mature observing platform for the central Arctic

- 85+ ITPs deployed in Arctic to date
- Decade of experience: ITP1 in 2004
- A major contributor → physical oceanography component of NSF’s AON

2010-2014: a 5-year NSF AON project to measure basic ocean ecosystem properties using ITPs, robustly:

**Immediate goal:** to adapt off-the-shelf fluoros & PAR sensors to ITPs, to measure phytoplankton biomass & light (2 basic variables) over annual time scales.

**Longer term goal:** to begin broader interdisciplinary effort to improve robustness & sophistication in observing basic ocean ecosystem variables in Arctic basins
Prototype bio-optical sensor suite: using semi-custom sensors

- Irradiance sensor (PAR) Satlantic PAR
- ‘triplet’ fluorometer chl + bb + CDOM WETLabs ECOFLBB-CD
- CTD & dissolved O₂ SeaBird SBE41CP+IDO
- Copper shutter to minimize fouling
- Shutter actuator Satlantic BioShutter

- Chlorophyll fluorometer (phytoplankton biomass)
- Radiometer (light levels)
- (triplet: also CDOM, $b_{back}$)
- Copper shutter: for biofouling
- ‘Smart’ microcontroller to simplify integration of sensors & commercial McLane ITP
8 prototype “bio-optical” ITPs deployed in 2011-2013

7 of which collected profiles for at least 3 months

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Two systems: 1 year chl data
One system: 1 year light data
Chlorophyll (algal biomass): seasonal trends in depths & timing

Central Arctic (Transpolar Drift) vs. Canada Basin (Beaufort Gyre)
Regional ecosystem trends inferred from multiple years

E.g., *comparing the Central Arctic (CA) vs. Canada Basin (CB)*

Apparent consistent trends in algal biomass in CA & CB:

**Central Arctic**: high latitude & less light under ice → biomass higher in water

**Canada Basin**: lower latitude, more light → biomass deeper in water column. Chlorophyll shoals as insolation ↓ in fall.

Laney et al. 2014

E.g., comparing the Central Arctic (CA) vs. Canada Basin (CB)
Arctic growing season is short: frequent profiling is valuable

ITP48 – Central Arctic

4 profiles day\(^{-1}\) Mar-Oct
1.5 profiles day\(^{-1}\) Nov-Feb
All profiles: 25 cm vertical resolution

Day-to-day trends in chl
In time derivative of chl can see 1-2 week perturbs →
Associated with changes in apparent particle export
Vertical perturbations on plankton: bio-optical tracers

- Using colored dissolved organic matter (CDOM) as a tracer for vertical displacements due to passing eddies
- Different eddy signatures $\rightarrow$ different effect on biology ($\downarrow$ vs. $\uparrow$)
- Impact on photosynthesis & production?
Under-ice light field: penetration depths & seasonal trends
Robust Autonomous Arctic Observations: **Successes** & Challenges

- High-resolution, year-long time series of basic ecosystem variables (algae & light) in perennially ice-covered regions of the central Arctic.
- New perspectives into key trends and patterns in under-ice primary producers, on newly observed spatiotemporal scales.
- Added important biological variables to ITP capability & the AON.
- Data available on ITP ([www.whoi.edu/itp](http://www.whoi.edu/itp)) & PI websites.

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Assessing algal biomass and bio-optical distributions in perennially ice-covered polar ocean ecosystems

Samuel R. Laney, Richard A. Krishfield, John M. Toole, Terence R. Hammar, Carin J. Ashjian, Mary-Louise Timmermans
Robust Autonomous Arctic Observations: Successes & Challenges

- Caught many issues with these sensors before deployment; not all!
- Safe to say: underestimated the robustness of commercial sensors for long-term unattended use in Arctic on ITPs → many sensor failures

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Most sensors not designed for long term, unattended Arctic use

- Few “biology” sensors are tested for long-term, polar immersion.
- “Improvements” for production purposes might introduce new problems in field use.
- Even highly reputable companies encounter such issues.
- Even to do something ‘simple’ (PAR & chlorophyll fluorescence) on ITPs required considerable customization with vendors.

- Few incentives for vendors to develop robust, ‘Arctic-grade’ sensors
- Leaves the research community ill-equipped for Arctic observing
The future did not arrive as planned

Q: Who was keeping an eye on sensor drift, degradation, etc.?
A: It used to be the vendors...

Oceanographic sensors to measure ecosystem variables typically lack BITE.

Oceanographic sensor industry has largely abandoned built-in test approaches.

This leaves us poorly equipped.
“Would anyone trust data from a fluorometer or PAR sensor that had been dangling in the ocean without maintenance for 3 years?”

– anonymous NSF AON reviewer with a very reasonable concern

Sensitive to fouling: Shutter

Drift? Rigid fiber to feed fluoro

EX → PAR sensor

Qualitative view of long-term trends in feedback.

Far from an ideal solution for drift monitoring.
Improved robustness: some suggestions

These problems are nothing new, just acute because it’s the Arctic…

How can we do better?

1) Consumer Reports → independent assessment of reliability of sensors for AON (i.e., a seal of approval). If a sensor’s likely to fail, don’t use it.
A vision for better observing ice covered ecosystems

Cross-disciplinary measurements:
★ IMBs ★ incident solar insolation

Depths < 7m unobserved by ITPs (!) very important depths ecologically

Aspects affecting water column productivity:
✓ Chlorophyll ✓ light ✗ nutrients
★ Ecologically appropriate profiling

Export production: sinking & C fluxes

Similarly, ‘ecosystem’ observing on other platforms in Arctic Observing Network
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