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


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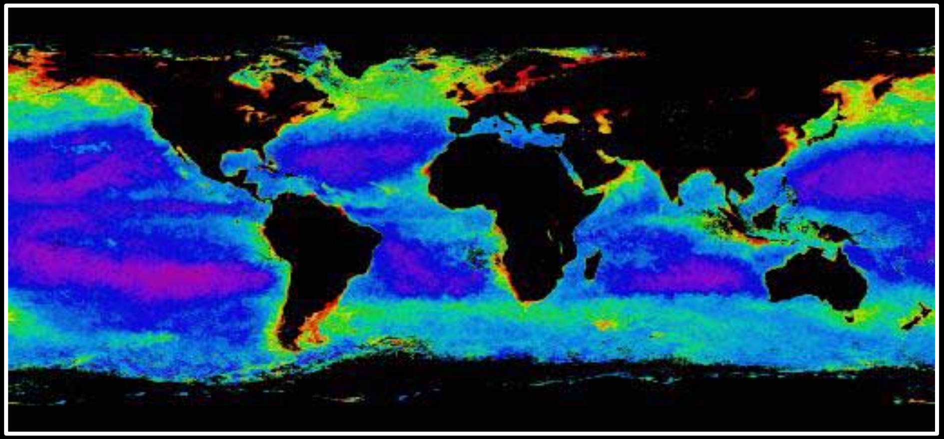
# Marine ecosystems in the central Arctic → difficult to observe

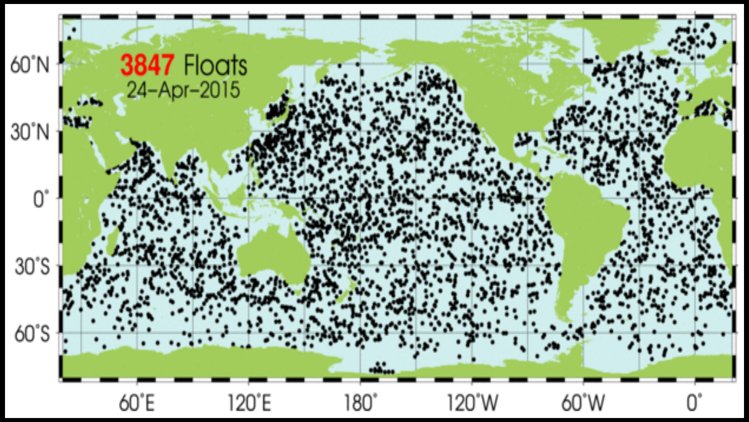
*'Usual' ecosystem observing tools often unsuitable or strongly challenged*

Ships: too few, too seasonal

Satellites: clouds, aerosols, sea ice, geometry



Profiling drifters: ice cover → data offload

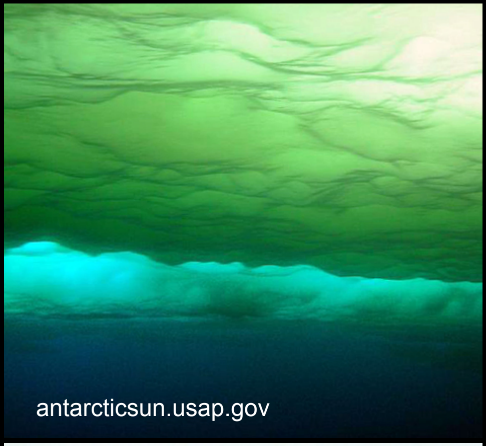


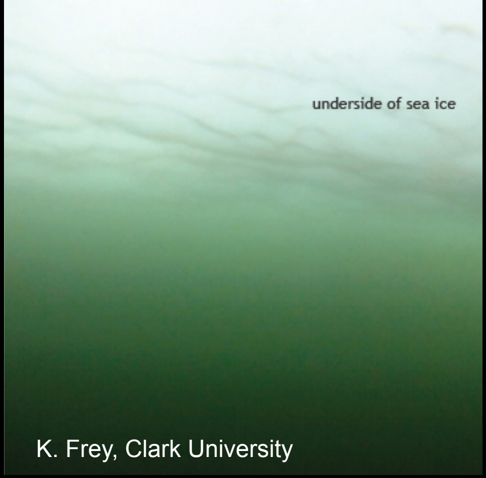

- *Arctic is far behind in terms of ocean observing approaches, esp. where ice is perennial.*
- *Emphatically so with respect to basic ecosystem properties.*

# ‘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’*

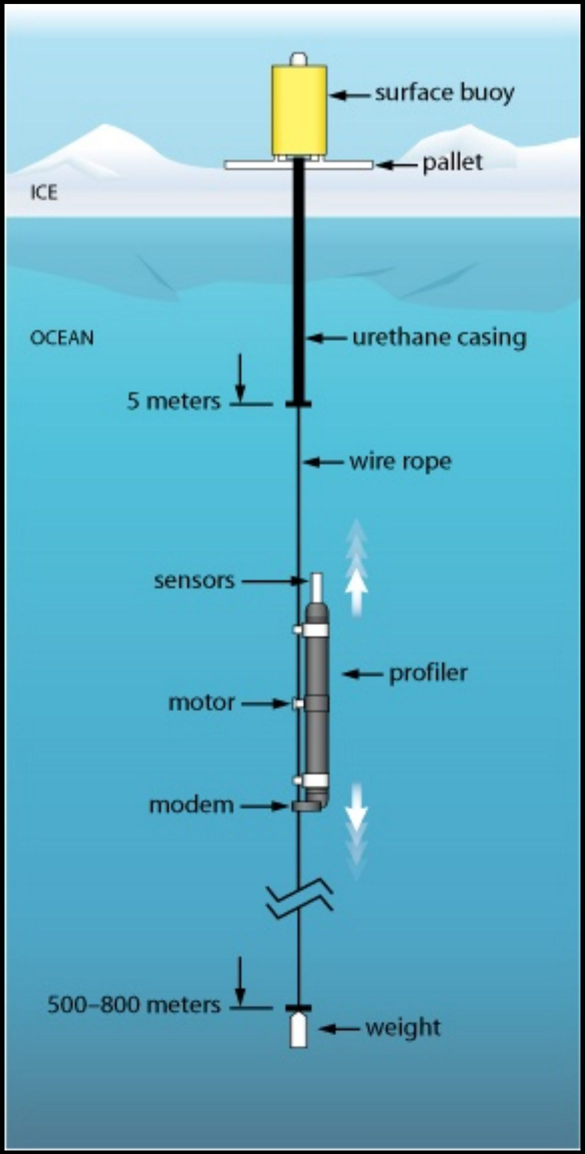
Needed resources:

Sunlight & nutrients (C,N,P, trace metals, etc.)

# Photosynthesis & production under perennial sea ice

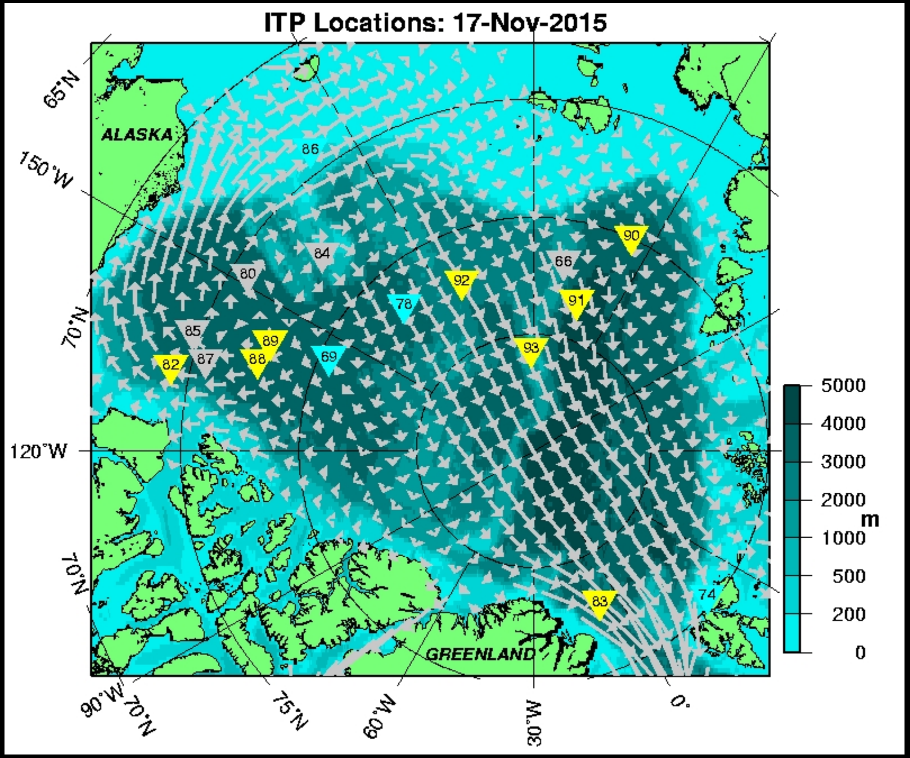
- Much of primary production under Arctic ice still poorly known:
    - Where are phytoplankton found (vertically, spatially) & when?
    - How long is the growing season? When does it start, end?
    - Dynamics of interactions between ice algae – phytoplankton

# 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

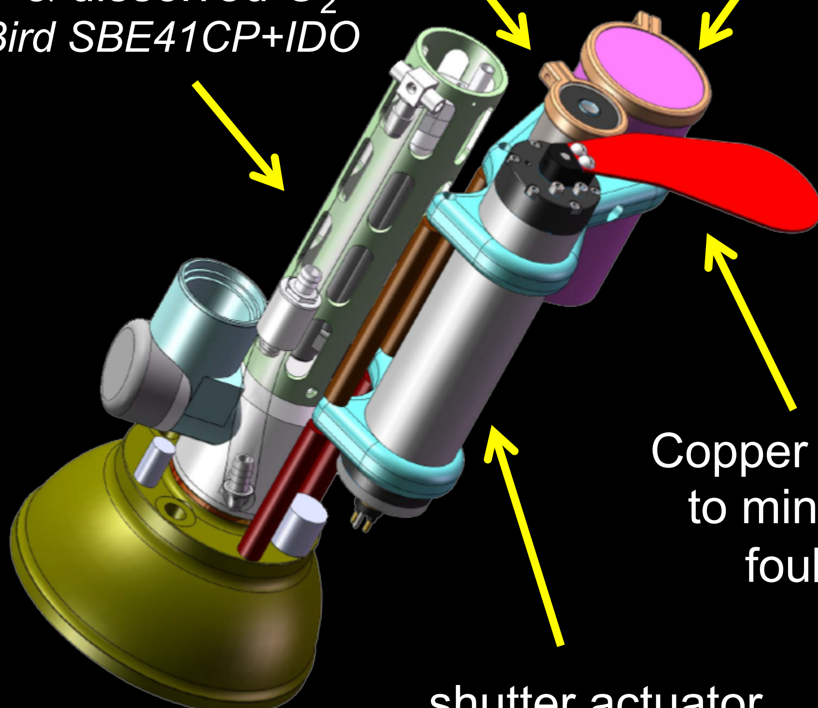
- 85+ ITPs deployed in Arctic to date
- Decade of experience: ITP1 in 2004
- A major contributor → physical oceanography component of NSF's AON

*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



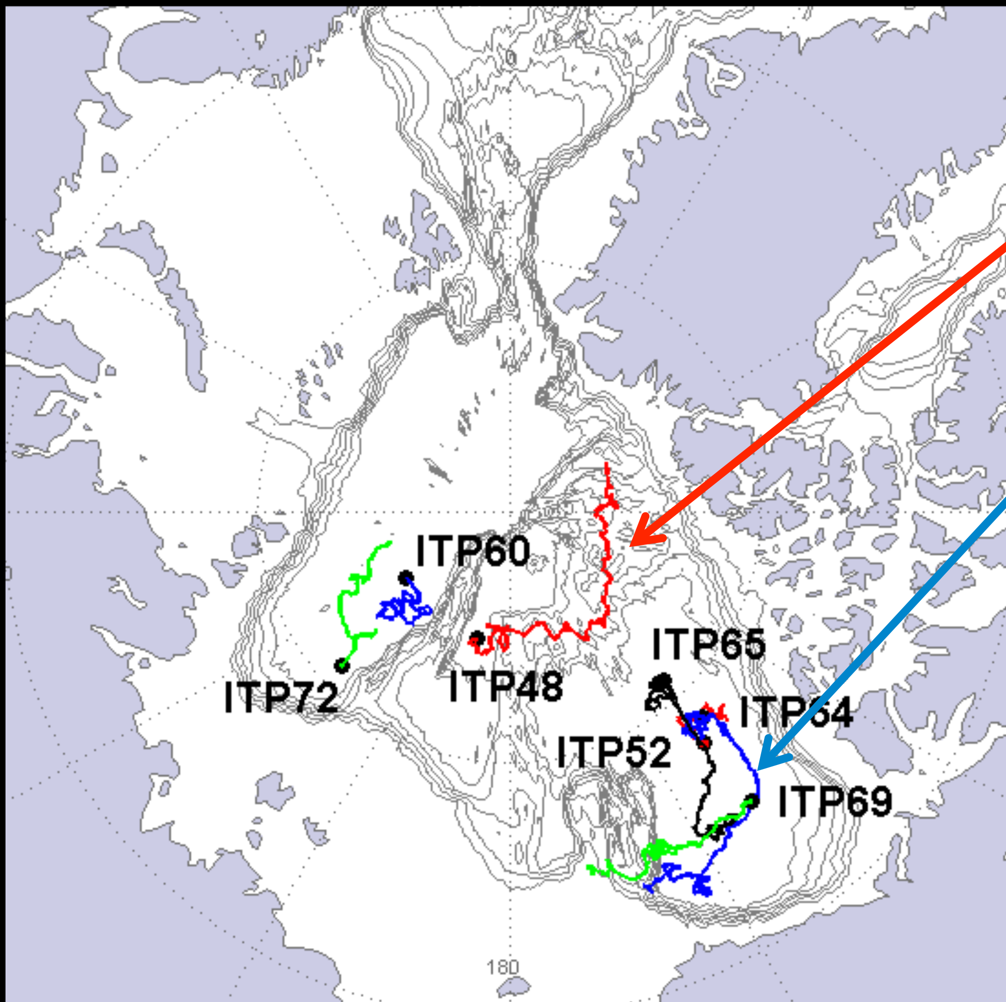

- Chlorophyll fluorometer (phytoplankton biomass)
- Radiometer (light levels)
- (triplet: also CDOM, $b_{back}$)
- Copper shutter: for biofouling
- 'Smart' microcontroller to simplify integration of sensors & commercial McLane ITP



Laney et al. 2014

# 8 prototype “bio-optical” ITPs deployed in 2011-2013

*7 of which collected profiles for at least 3 months*



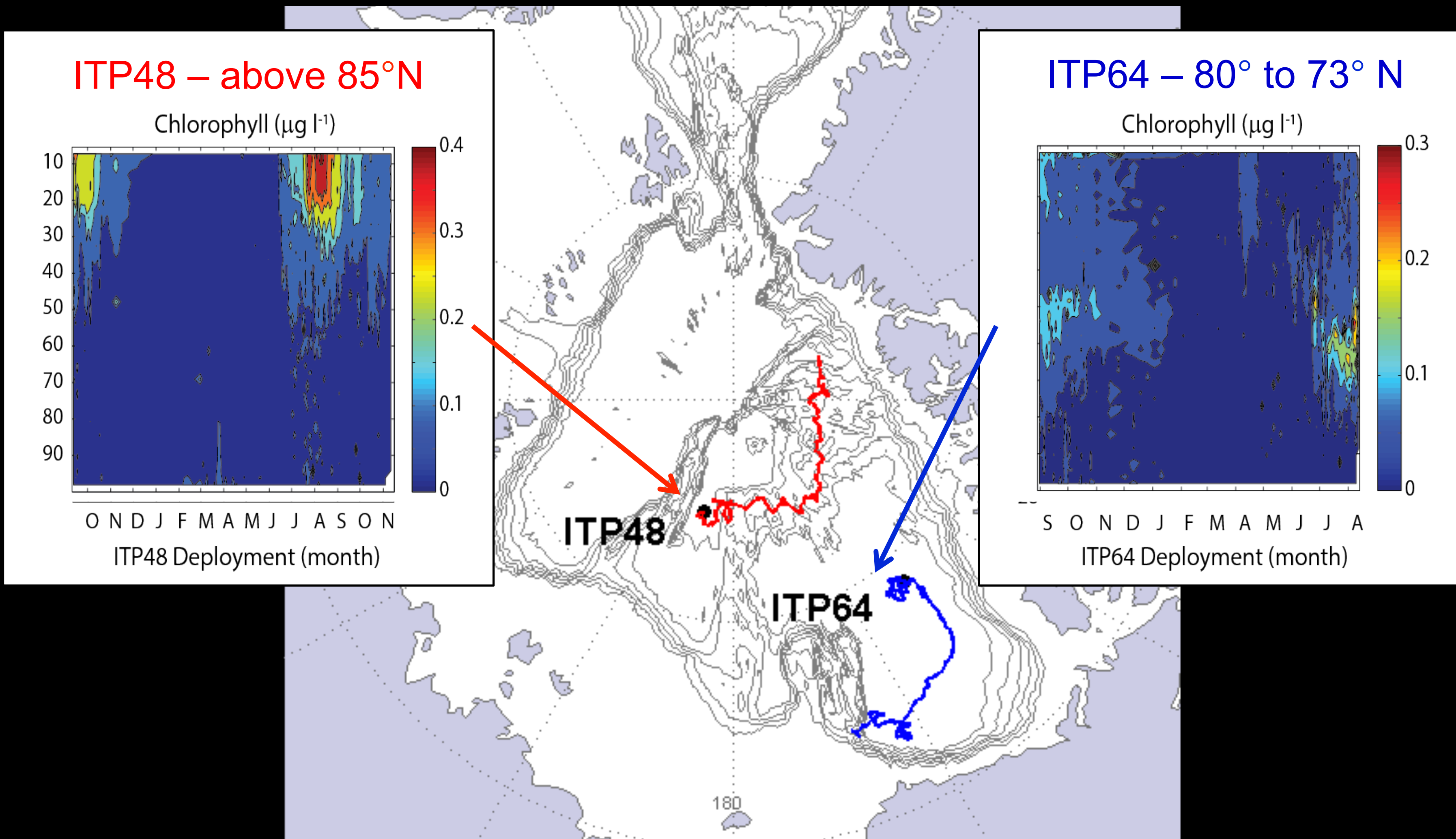

| ITP | days | km | # profs | ECO data | PAR data |
|---|---|---|---|---|---|
| 48 | 433 | 3085 | 1370 | ✓ | ✗ |
| 52 | 99 | 925 | 377 | ✓ | ✓ |
| 60 | 105 | 1200 | 260 | ✓ | ✗ |
| 64 | 360 | 3324 | 1124 | ✓ | ✓ |
| 65 | 405 | 2671 | 904 | ½ | ✗ |
| 68 | ☠ | ☠ | ☠ | ✗ | ✗ |
| 69 | 182 | 2067 | 414 | ✓ | ✓ |
| 72 | 107 | 1196 | 242 | ¾ | ✓ |

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)*



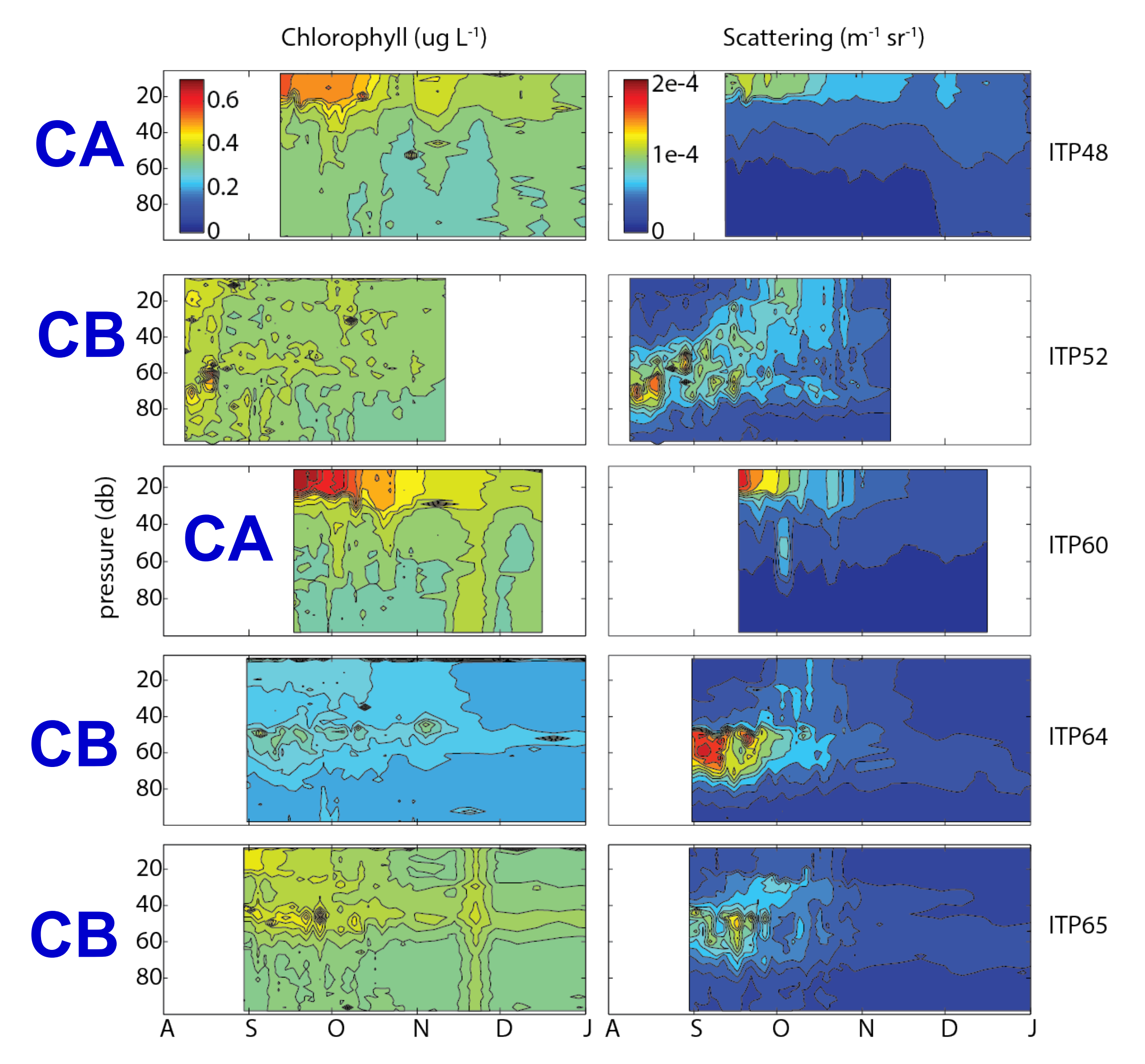
# Regional ecosystem trends inferred from multiple years

*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.



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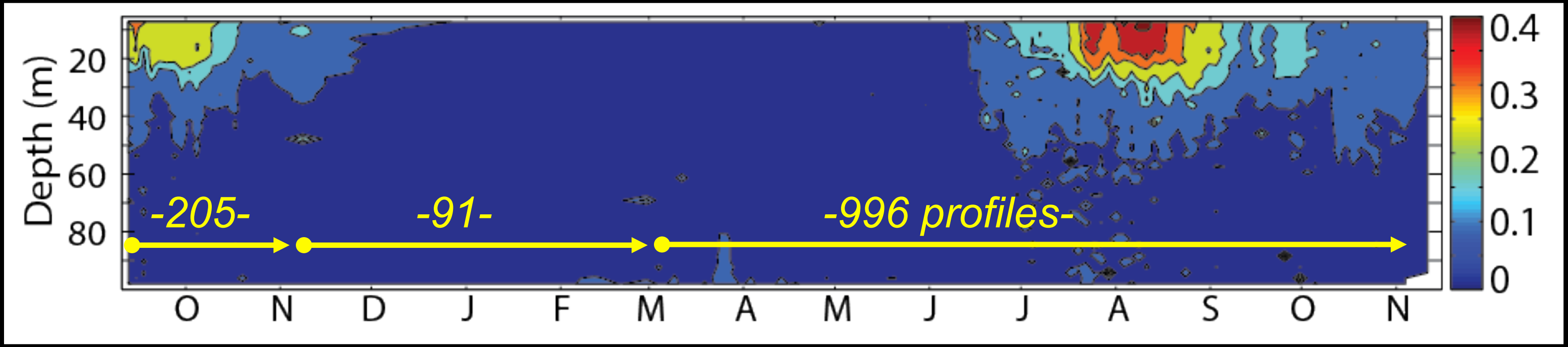
# Arctic growing season is short: frequent profiling is valuable

ITP48 – Central Arctic

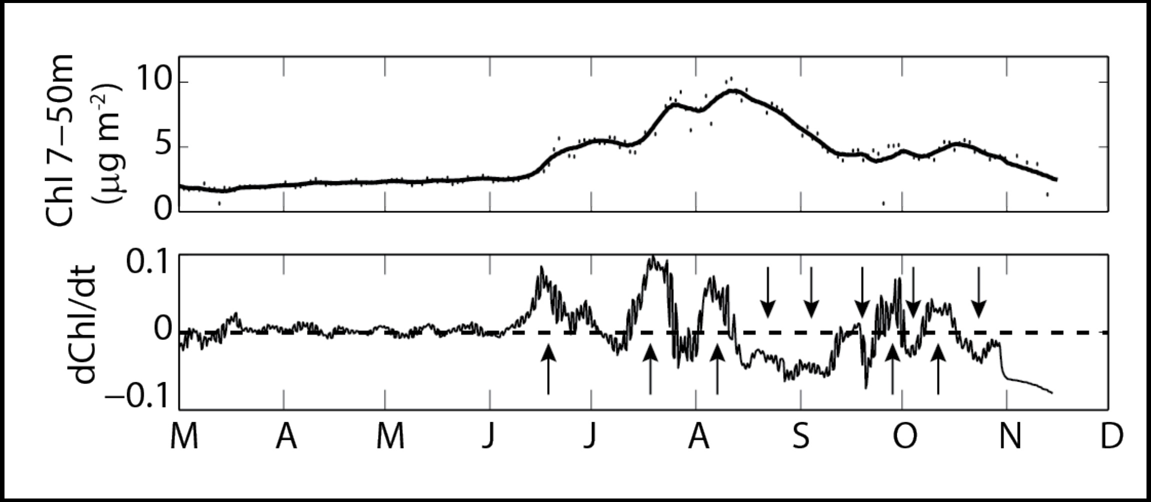
- 4 profiles day$^{-1}$ Mar-Oct
- 1.5 profiles day$^{-1}$ Nov-Feb
- All profiles: 25 cm vertical resolution




Day-to-day trends in *chl*

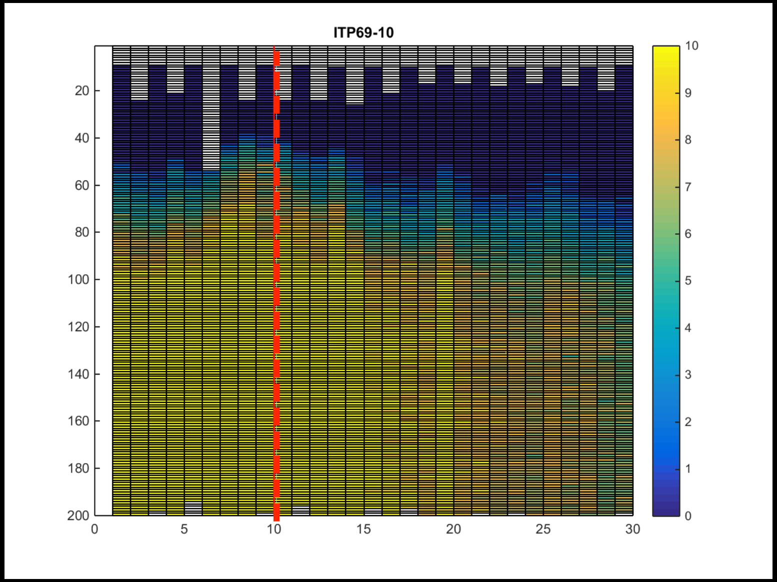
In time derivative of *chl* can see 1-2 week perturbs →

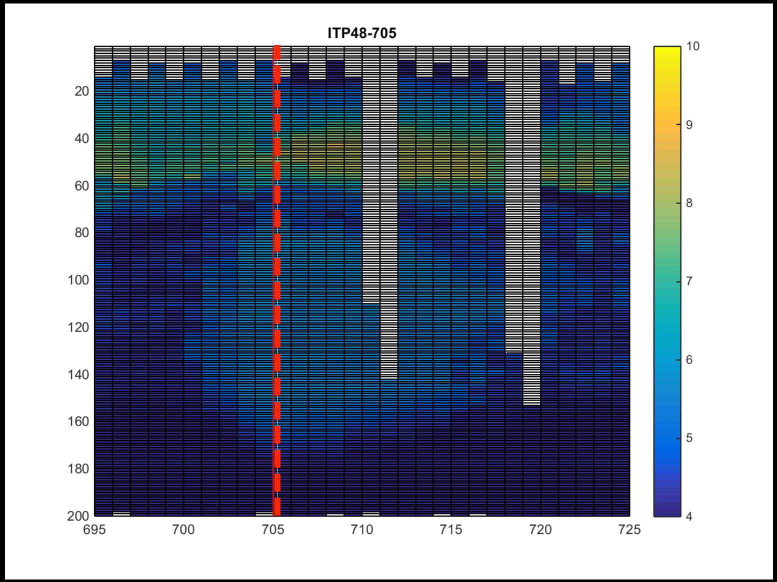
Associated with changes in apparent particle export

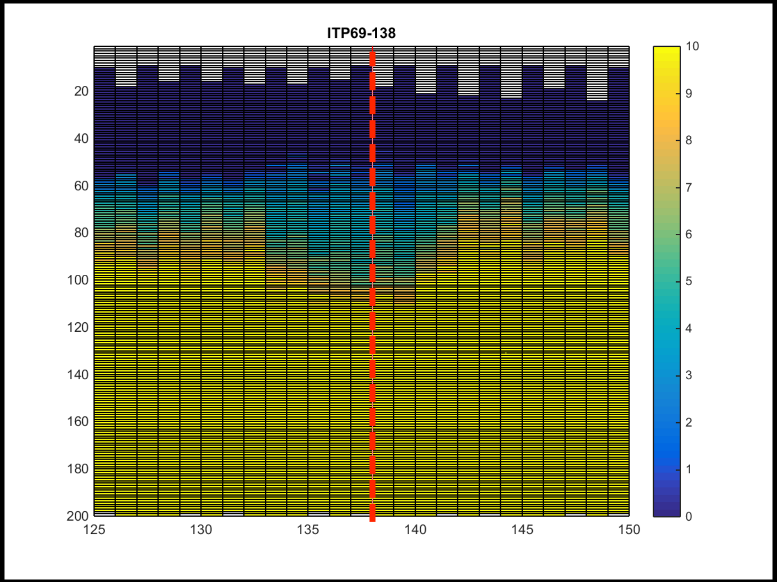


# Vertical perturbations on plankton: bio-optical tracers

- Using colored dissolved organic matter (CDOM) as a tracer for vertical displacements due to passing eddies
- Different eddy signatures → different effect on biology (↓ vs. ↑)
- Impact on photosynthesis & production?

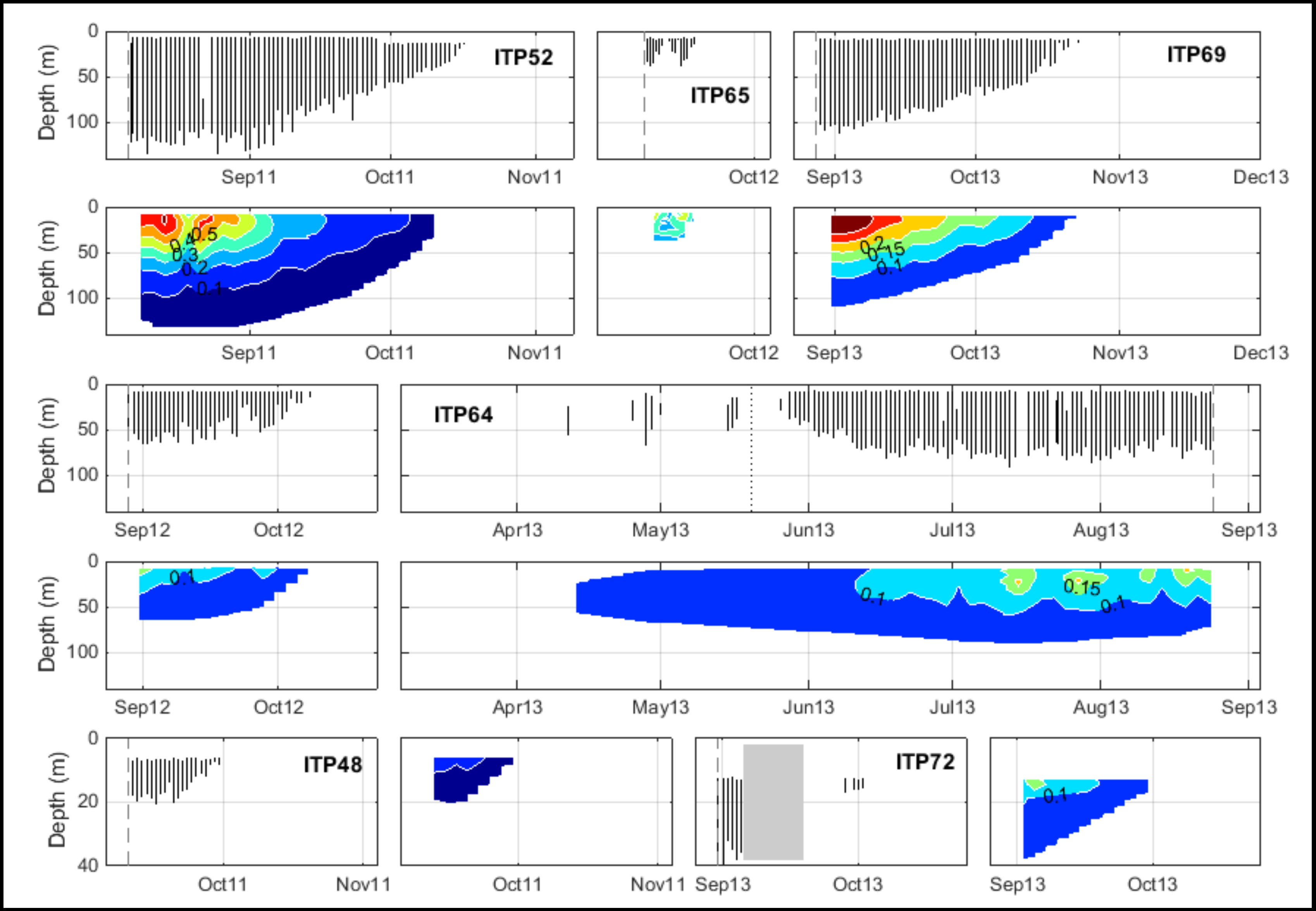



Laney & Timmermans unpubl.

# 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) & PI websites.

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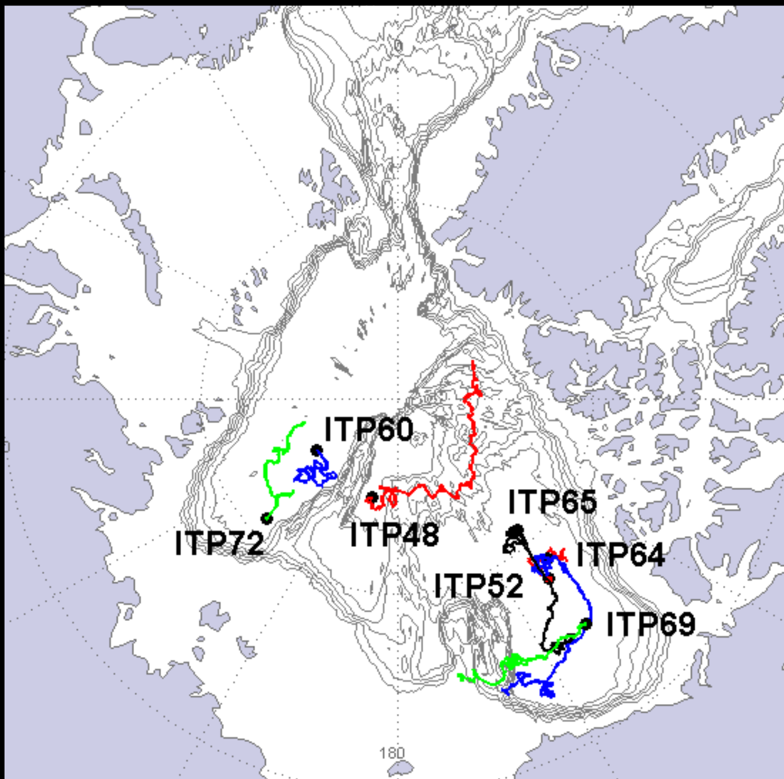
**Assessing algal biomass and bio-optical distributions in perennially ice-covered polar ocean ecosystems**

Samuel R. Laney[a], Richard A. Krishfield[a], John M. Toole[a], Terence R. Hammar[a], Carin J. Ashjian[a], Mary-Louise Timmermans[b]

# Robust Autonomous Arctic Observations: Successes & Challenges

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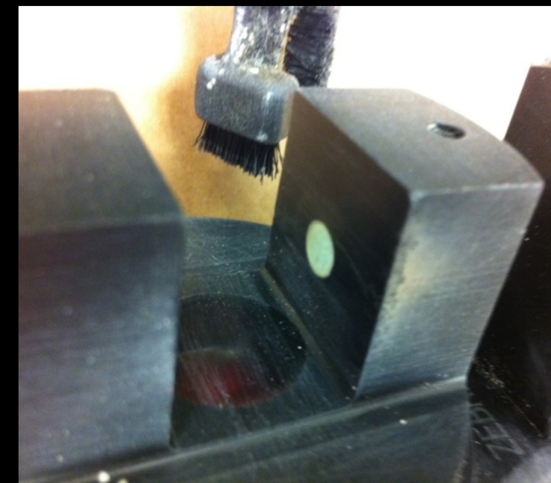
| 72 | 107 | 1396 | 242 | ¾ | ✓ |

| ITP | ITP days | # 'bio' profs | Total ITP profs | QC ECO profs | QC PAR profs | # PAR > 0 |
|---|---|---|---|---|---|---|
| 48 | 433 | 1375 | 1375 | 94% | 17% | 21 |
| 52 | 99 | 379 | 379 | 95% | 96% | 191 |
| 60 | 105 | 260 | 260 | 50% | 0% | N/A |
| 64 | 360 | 1124 | 1124 | 98% | 99% | 373 |
| 65 | 405 | 904 | 904 | 45% | 99% | 30 |
| 68 | ☠ | 0 | 683 | 0% | 0% | N/A |
| 69 | 182 | 478 | 478 | 86% | 99% | 107 |
| 72 | 107 | 311 | 311 | 72% | 77% | 30 |

- *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*

# 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.



SBE

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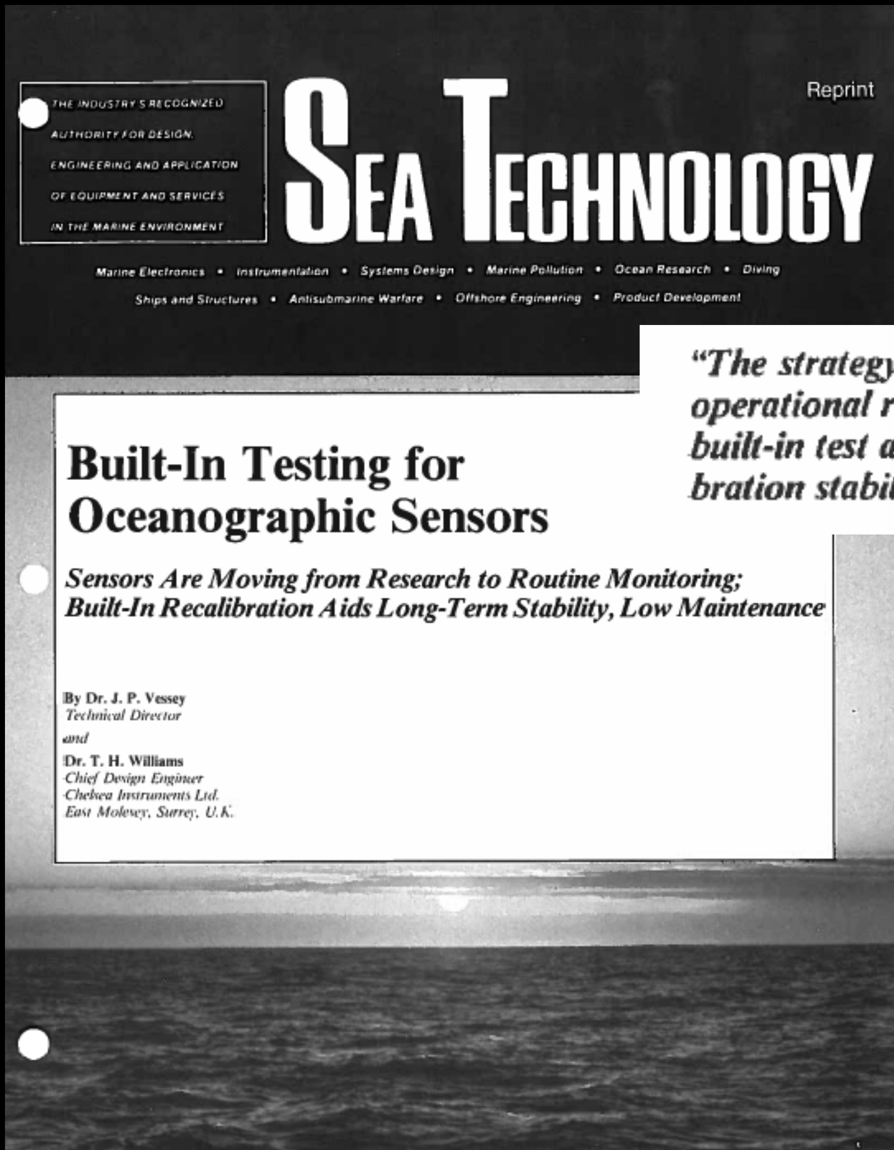
**Field Service Bulletin 24** **January 2012**

**SBE 43, 43I, and 43F Dissolved Oxygen Sensors**

- *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


Reprint

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**Built-In Testing for Oceanographic Sensors**

*Sensors Are Moving from Research to Routine Monitoring; Built-In Recalibration Aids Long-Term Stability, Low Maintenance*

By Dr. J. P. Vessey
*Technical Director*
*and*
Dr. T. H. Williams
*Chief Design Engineer*
*Chelsea Instruments Ltd.*
*East Molesey, Surrey, U.K.*

Q: Who was keeping an eye on sensor drift, degradation, etc.?

A: It used to be the vendors…

*"The strategy adopted at Chelsea Instruments Ltd. to achieve the operational requirements is to design oceanographic sensors using built-in test and recalibration equipment to achieve long-term calibration stability and low maintenance."*

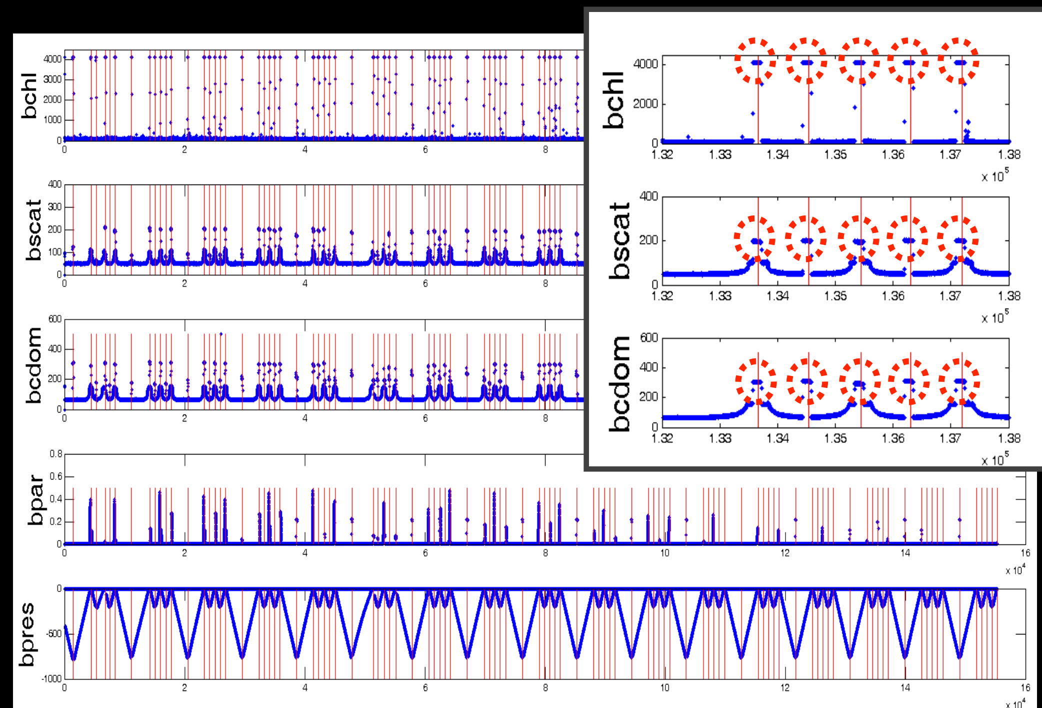
- Oceanographic sensors to measure ecosystem variables typically lack BITE.
- Oceanographic sensor industry has largely abandoned built-in test approaches
- This leaves us poorly equipped

# “ 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.

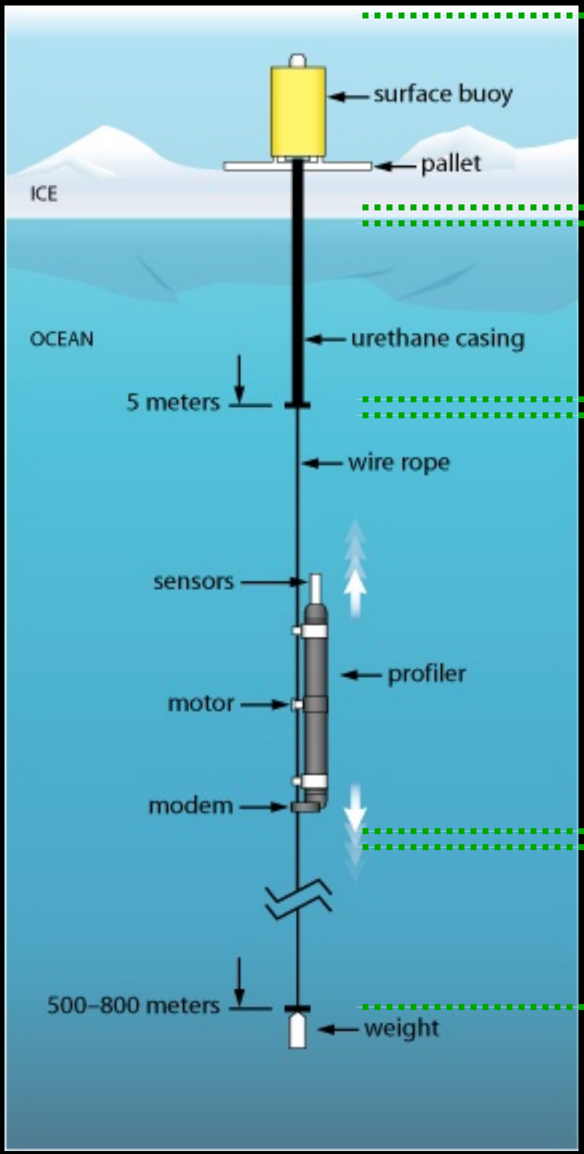
# Improved robustness: some suggestions

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

# Acknowledgements

## ITP team key members:

John Toole & Rick Krishfield (Woods Hole Oceanographic Institute)

Mary-Louise Timmermans (Yale University)

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