Autonomous Platforms in the Arctic Observing Network

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1. Integrated Network and Challenges
2. Examples:
   - Distributed measurements: IBOs and floats
   - Mobile platforms: Gliders
   - Shelves and the ice-ocean interface: moorings
   - Marine mammals
   - Satellite measurements critical but not discussed here.
3. Critical Infrastructure- navigation and communication
4. Autonomous Platforms and the Arctic Observing Network

Nested Networks Require Flexible Systems

Policy- ‘science’ (climate) driven

- Focus: Environmental change, planning.
- Time scale: Decades, value placed on long records.
- Spatial scale: Distributed, may be far from population centers.
- Data: Real-time data return not necessary.
- Long, consistent records. Committed observing.
- Resource constraints force choice of restricted measurement suite.

Strategy

- Focus: Planning for high-risk activities (extraction, navigation).
- Time scale: Seasons to decades, long records valued.
- Spatial scale: Limited geographic scope, perhaps near population centers.
- Data: Rapid data access (near real time) may be required.

Tactical- ‘stakeholder’ driven

- Focus: Support for specific activities.
- Time scale: Rapid spin-up, spin-down. Flexible design,.
- Spatial scale: Tightly focused on regions of human activity.
- Data: Useful products delivered in real time. Data have little shelf life.

How do we build a sustainable Arctic Observing capability that resolves a broad range of scales (climate to process) and meets the needs of basic research, policy makers and stakeholders?

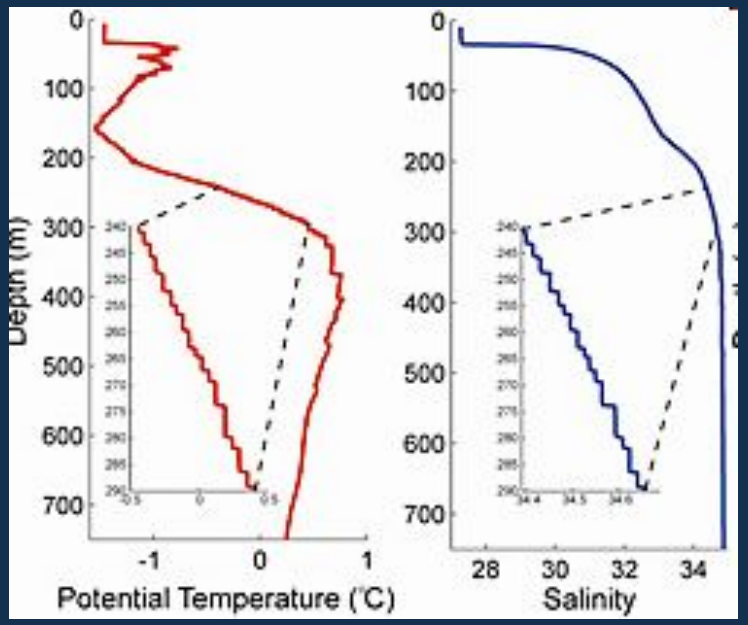
Challenges

- Access- Far from areas of human activity.
  - Poor for ships, good for aircraft (for now…).
  - Exploit ice as measurement platform.
  - Limited access to critical services (GPS, Iridium).
- Risk- Unforgiving operating environment, extended development arc.
- Persistence- Resolve important timescales, transient events.
- Cost/Scalability- Sustain broad, long-term activity.
- Adaptability/Flexibility
  - Sea ice decline- seasonal ice cover, marginal ice zone.
  - Needs evolve with changing environment and understanding.
  - Meet disparate stakeholder needs: climate to tactical.

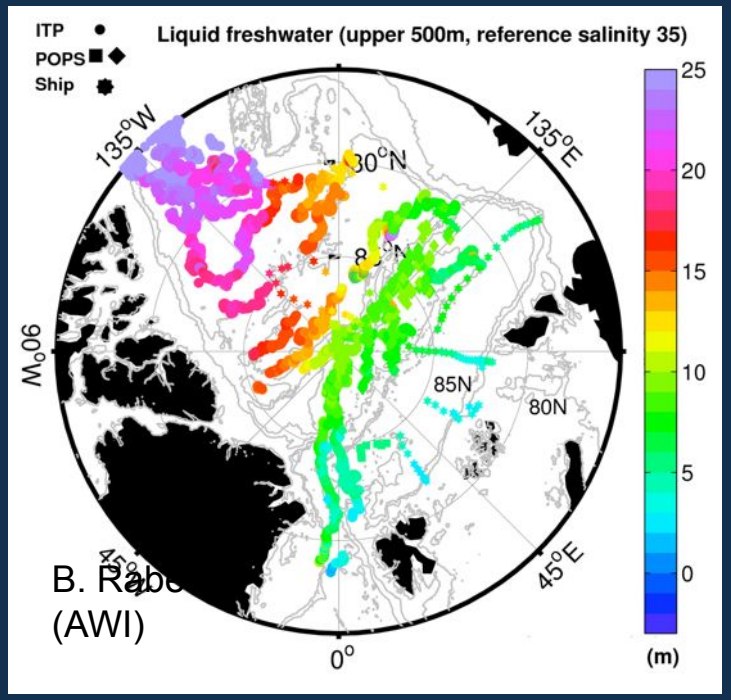
Example 1: Distributed Measurements in the Central Arctic: Ice-Based Observatories & Floats

Ocean, Ice and Atm. Boundary Layer

- Ice thickness distribution.
- Storage (mass, freshwater and heat).
- Pathway watermass modification- small-scale mixing processes
- Pycnocline structure & evolution.



Timmermans et al. (2008)
ITP-based observations of double-diffusive staircase.

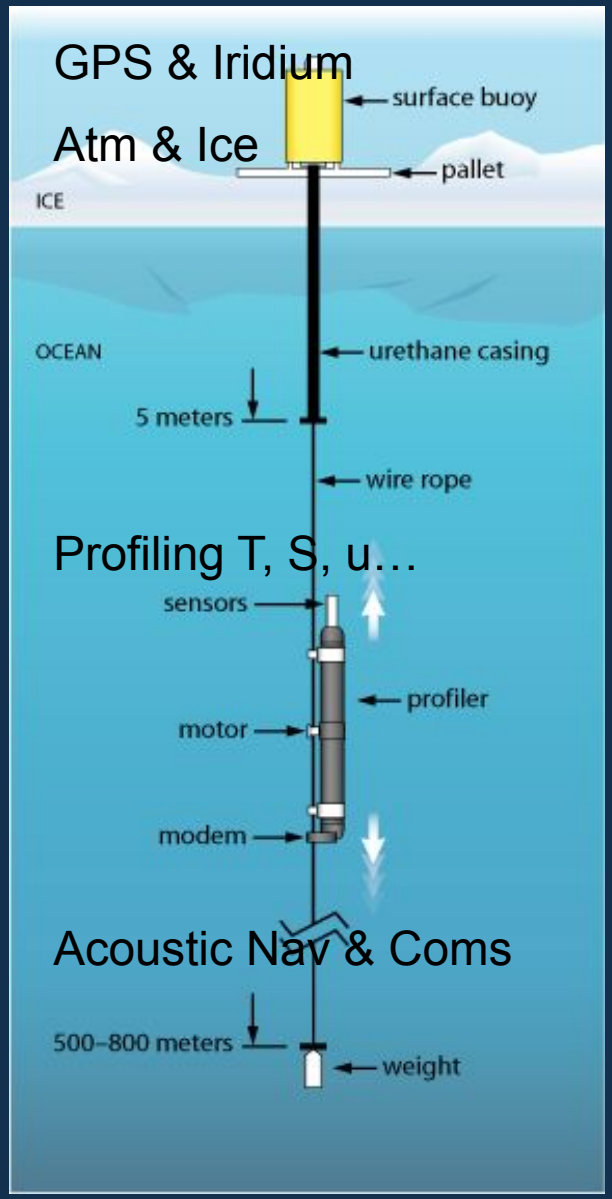


B. Rabe
(AWI)

Key Attributes

- Access remote locations.
- Distributed: many sites- must scale.
- Persistence: Year-round sampling
- Efficient: maintain over decades.
- Access ice-ocean-atm interface.

Ice Based Observatories (IABP, ITP, POPS, IMB)



Krishfield, Toole, Proshutinsky (WHOI)
Perovich, Richter-Menge (CRREL)
Kikuchi (JASMTECH)
Shimada (Tokyo Univ)

- Atm, ice & ocean measurements in real time.
- Navigation for autonomous platforms.
- Data relay for platforms operating beneath ice.

Access
- Distributed
- Drift pattern may not access all areas of interest.

Risk
- Break-up and refreeze, open water drift.
- Real-time data return mitigates risk.

Persistence/Cost/Scalability
- Persistent presence, long endurance.
- Modest cost (configuration dependent), scalable.

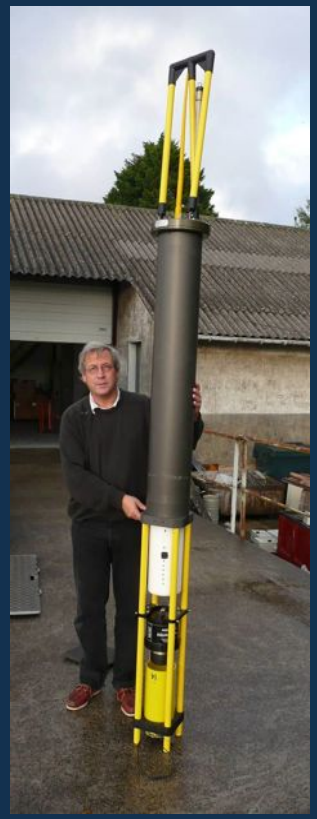
Adaptability/Flexibility
- Adapt for use in marginal ice zone.

Arctic Floats

Gascard (UPMC)
Loaec, LeReste (IFREMER)
Owens (WHOI)

Polar Profiling Floats

- Modified ARGO float.
- Probes ice-ocean interface for leads.
- Profile to 1500 m, 3-5 year endurance.
- Must find lead for nav & comms.



Access

- Distributed.
- Ice-ocean interface, marginal ice zone.
- Drift may limit access.

Risk

- Surfacing in ice-threatened waters.
- Mitigate with real-time data return.

Persistence/Cost/Scalability

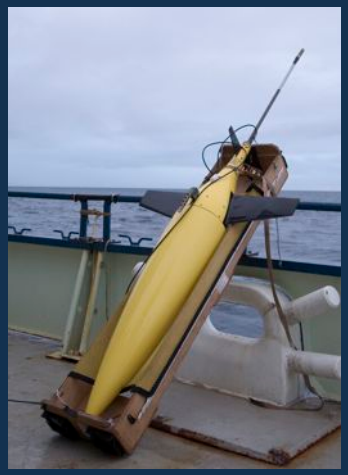
- Persistent, long endurance.
- Low cost, highly scalable operation
- Nav & comms infrastructure required for scalability.

ULS Floats (MSI Provor)

- Drifting ULS (ice draft).
- 1 year endurance.
- Geolocation: RAFOS (780 Hz) & SOFAR(1560 Hz).
- Short-range acoustic comms.
- Deploy within IBO array.

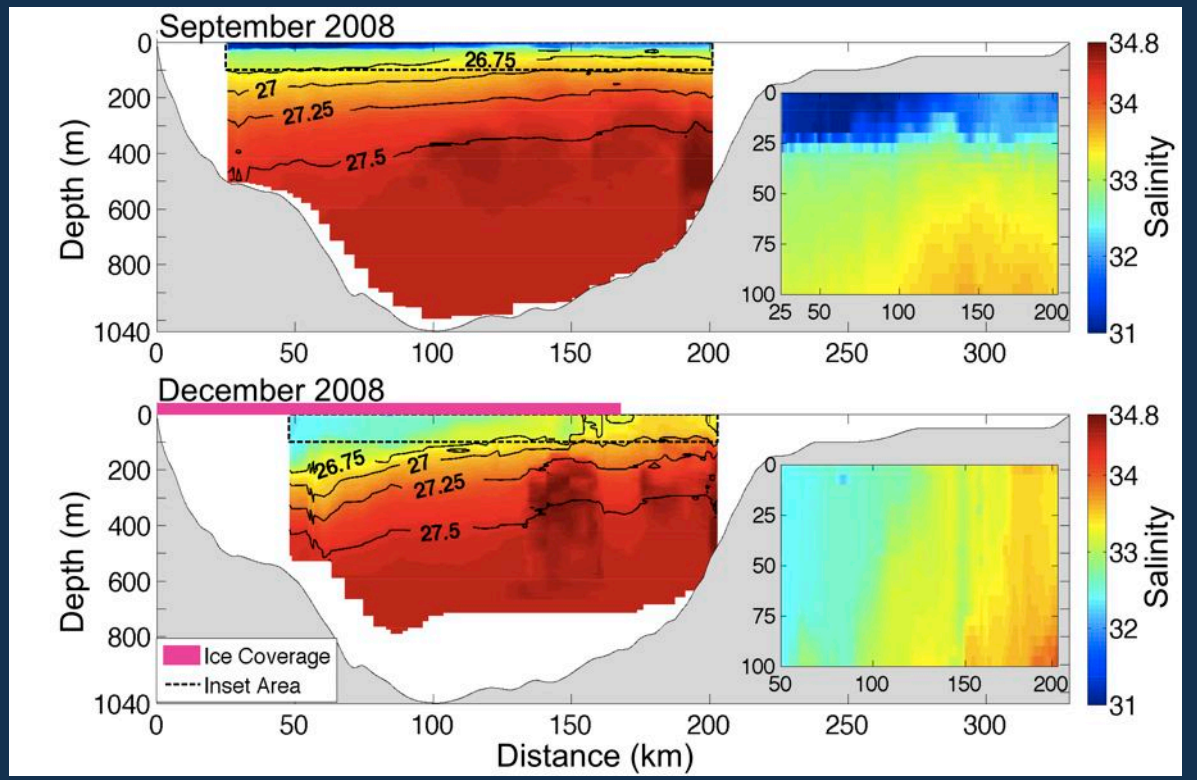
Example 2: Gateway, Fronts, Sections: Ice-capable Long-range Gliders

Lee, Gobat, Shilling, Huxtable (APL-UW)



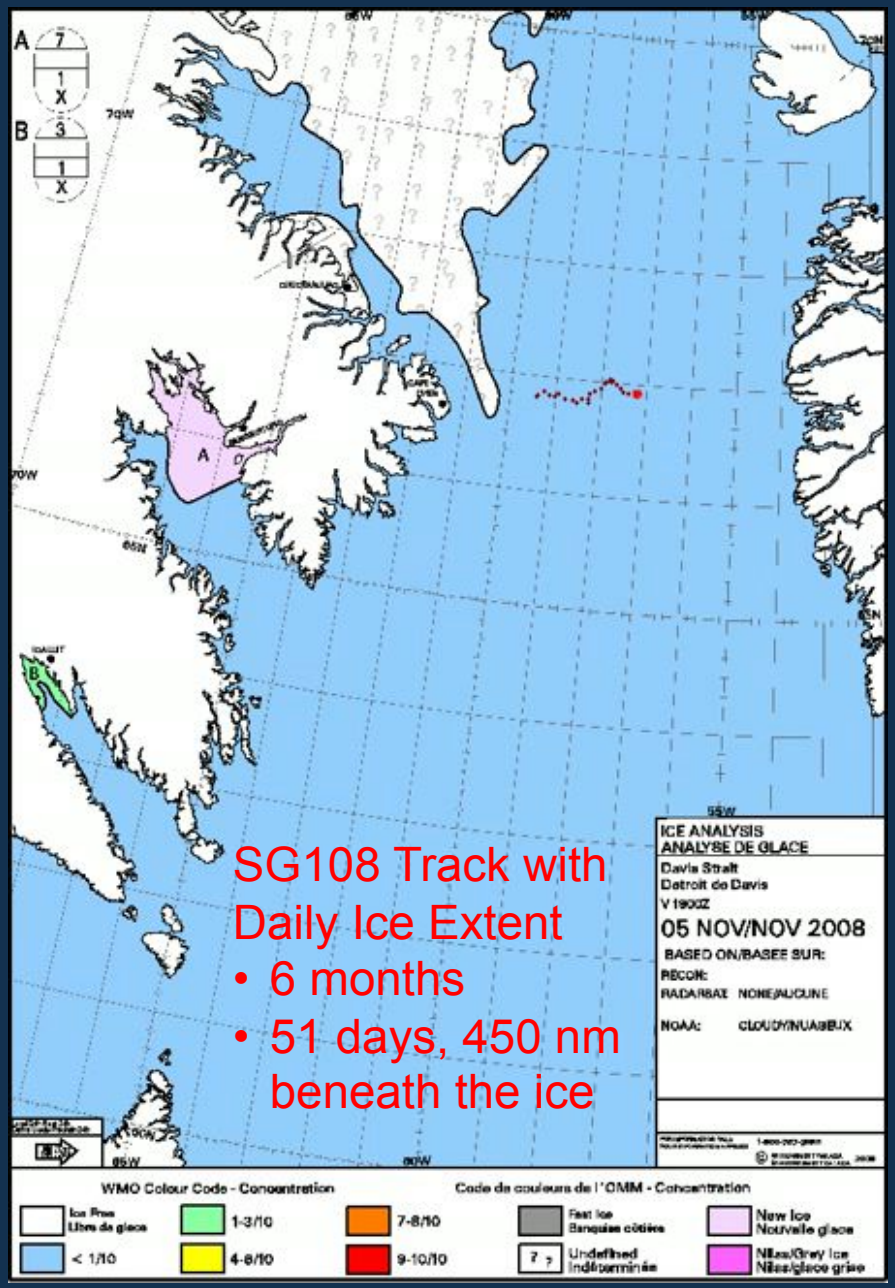
- Hull length: 1.8 m, Wing span: 1.0 m, Mass: 52 kg
- Surface to 1000 m.
- Slow: 0.1 - 0.45 m/s (~22 km or 12 nm per day @0.25 m/s)
- Endurance depends on stratification, dive depth and speed
- Endurance: 9 months (737 profiles), 4700 km. Target- 12 months.
- SBE T-C, SBE43 or optode DO. [Fluorometers, backscatter, ADCP, turbulence]
- Autonomy, acoustic navigation and communications, ice 'behaviors', endurance, reliability.

- Access
  - Remote regions.
  - Marginal ice zone, interface.
- Risk
  - Limited exposure to surface.
  - Data return in open water.
  - Acoustic data upload.
- Persistence & Scope
  - Long endurance.
  - Scalable given infrastructure.
- Adaptability
  - Simple logistics.
  - Real time reprogramming.
  - Flexible sampling.

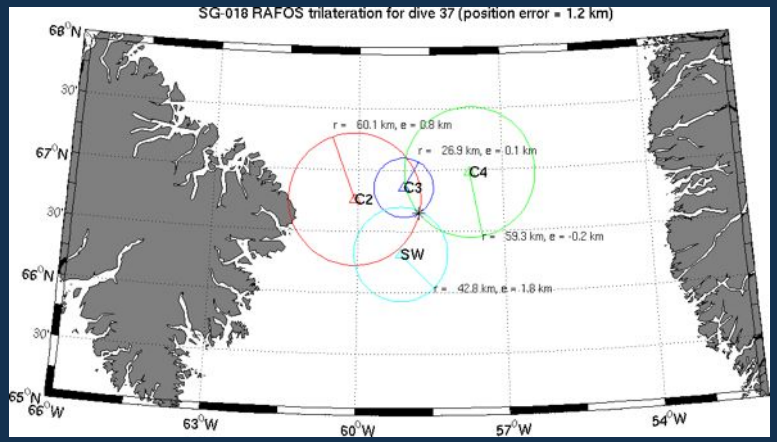


Under -ice Glider Surveys

Charts Provided by Canadian Ice Service



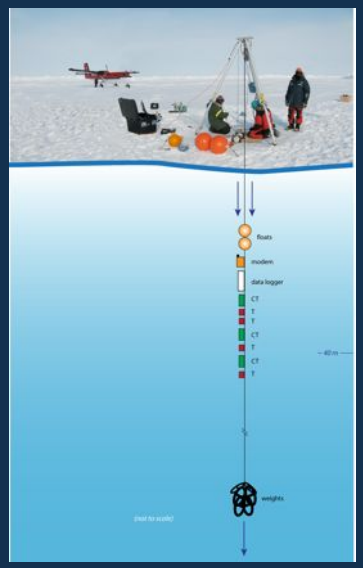
- Arctic Missions (06, 08/09, 09/10)
  6 month max duration
  Fully-autonomous under ice ops:
  51 days, 800+ km.
  Profiles to within 5 m of ice-ocean interface.
  Utilized 8 leads (33 attempts).
- For 2010
  Extended endurance.
  More sophisticated navigation.
  Acoustic download to moored data depots.



Example 3: New Mooring Technologies

- Boundary currents, fluxes.
- Broad, shallow shelves.
- Exchanges across shelf-slope systems.

Lightweight, Expendable Air-serviced

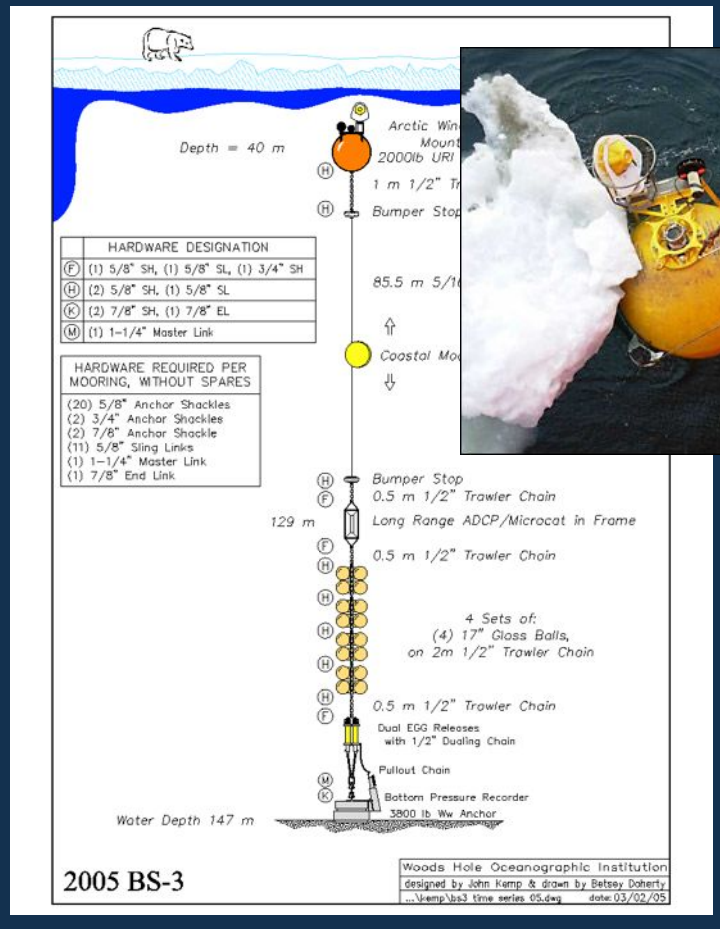


Acoustic data recovery

- Light-weight logistics
- Low-cost, 3-year endurance

Profiling Moorings

Pickart (WHOI)

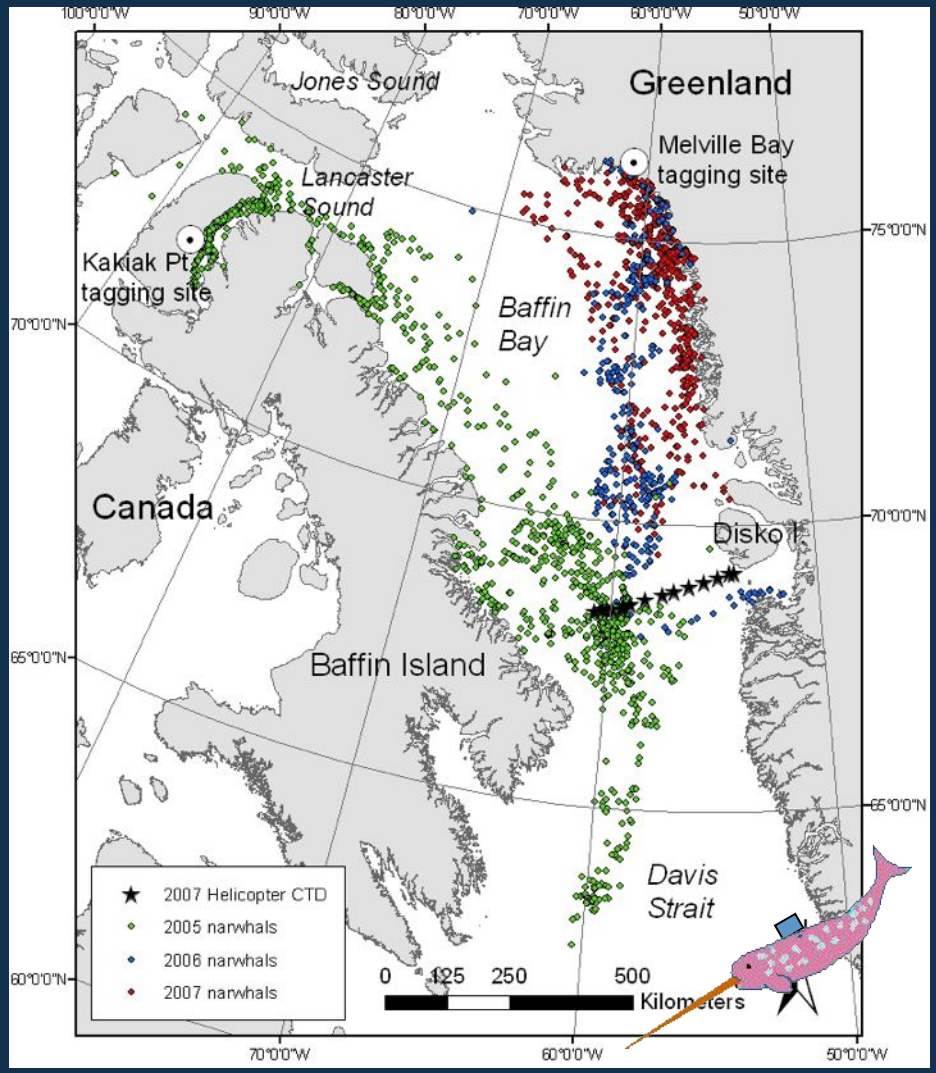


Example 4: Marine Mammals as Sensor Platforms

Seal-borne CTD tags

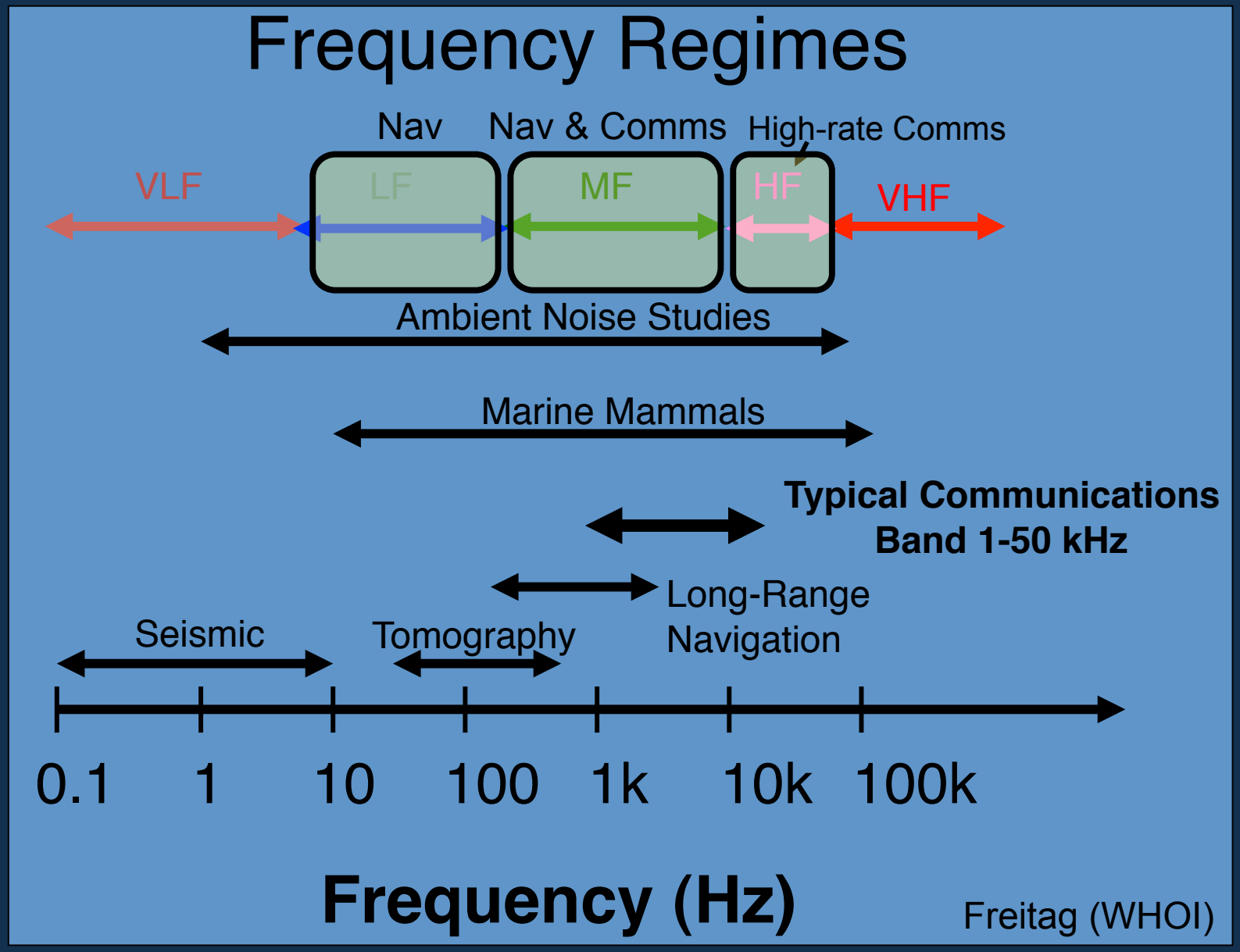
- Winter sampling
- Always find the surface
- 25 dives/day
- >1,500 m
- Cheap and reliable

Temperature Profiles Collected by Narwhals (Laidre, APL-UW)

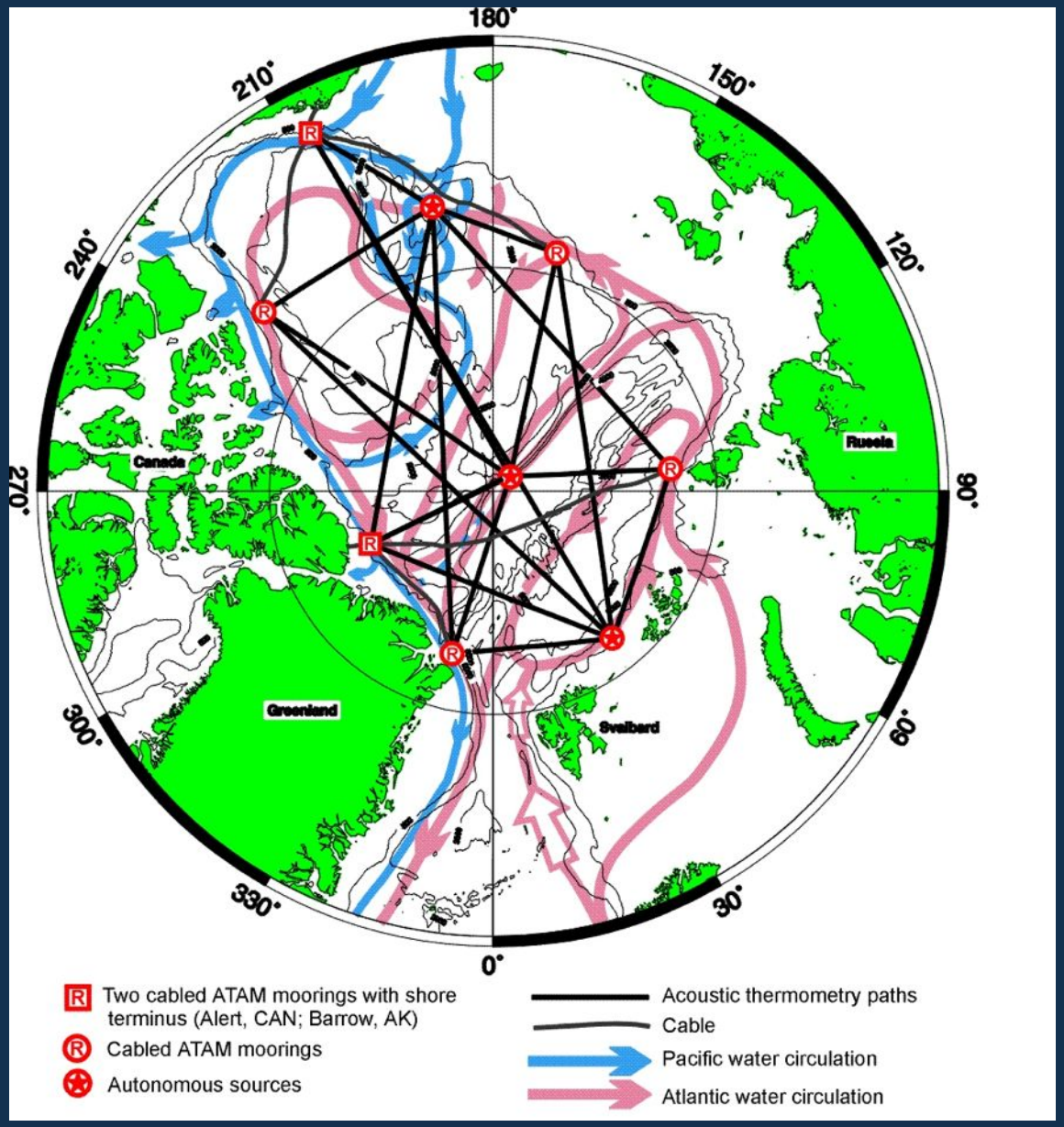


Acoustic Geopositioning & Communication for Autonomous Platforms

Critical infrastructure for scalability of floats and gliders for distributed sampling.



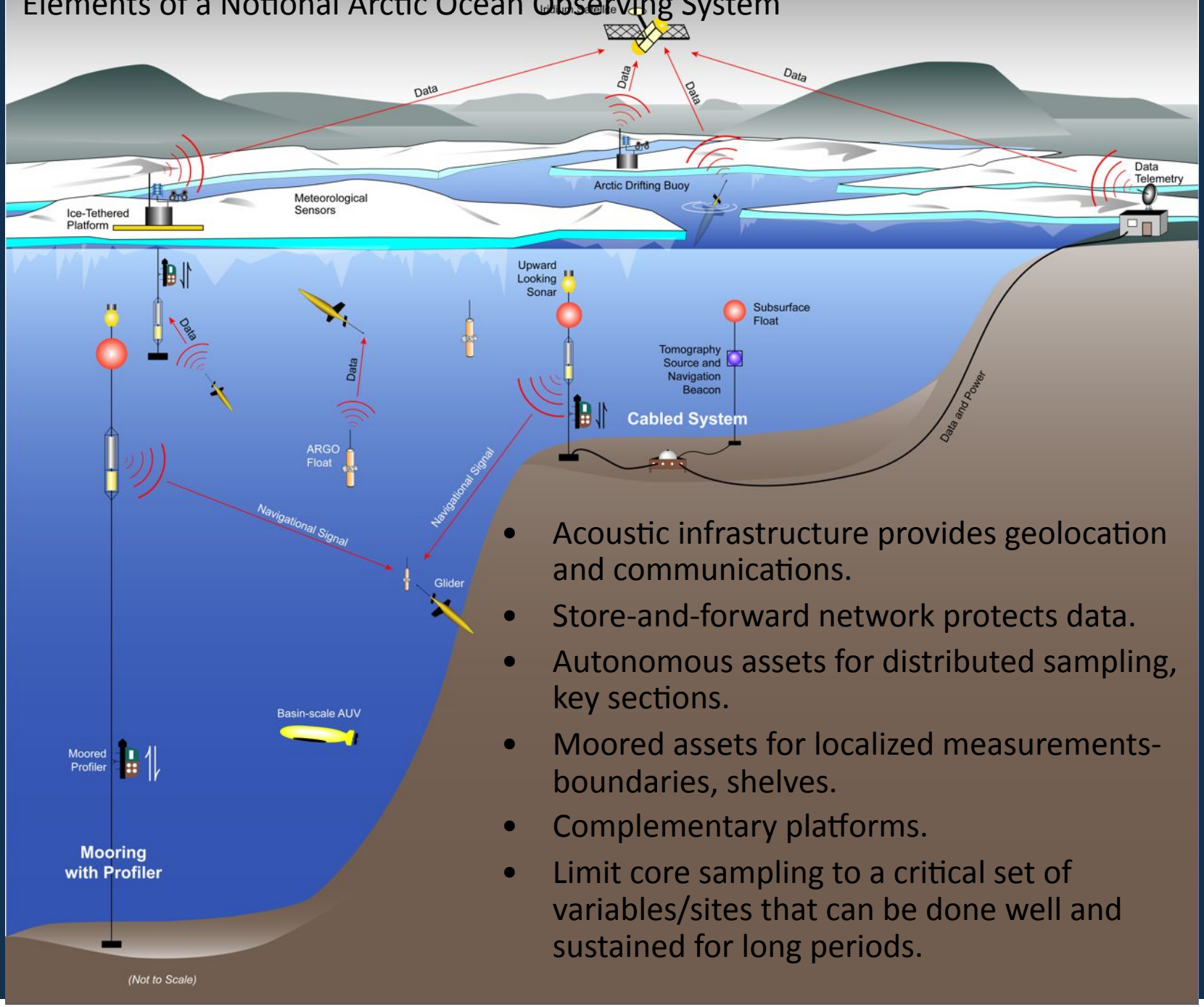
LF Network- Geolocation, Thermometry



Navigation System Challenges

- Ice-cover reduces MF range to < 150 km.
- MF systems impractical for basin-scale geolocation.
- LF (20-80 Hz) for basin-scale range.
- Weight, reliability and power requirements.
- Marine mammal impacts.
- Sites in multiple EEZs.
- Costly maintenance-collaboration required.

Elements of a Notional Arctic Ocean Observing System



- Acoustic infrastructure provides geolocation and communications.
- Store-and-forward network protects data.
- Autonomous assets for distributed sampling, key sections.
- Moored assets for localized measurements-boundaries, shelves.
- Complementary platforms.
- Limit core sampling to a critical set of variables/sites that can be done well and sustained for long periods.

Recommendations

Near-term

- Continue integration of autonomous capabilities into post-IPY AON:
  - IBOs for distributed measurements.
  - Novel moorings, gliders for regional systems.
- International coordination for improved access to eastern Arctic.
- Technology development priorities:
  - ‘Amphibious’ IBOs (IABP buoys, ITPs, etc).
  - Refined ice-capable floats and gliders.
  - Low-frequency acoustic source (basin-scale navigation).

Long-term

- Regional pilot experiment (Beaufort Gyre).
- Build-out basin-scale acoustic network.
- Establish appropriate mechanism for supporting decadal scale Arctic Observing Network.

Autonomous Observing in the AON

From the SEARCH Implementation Plan

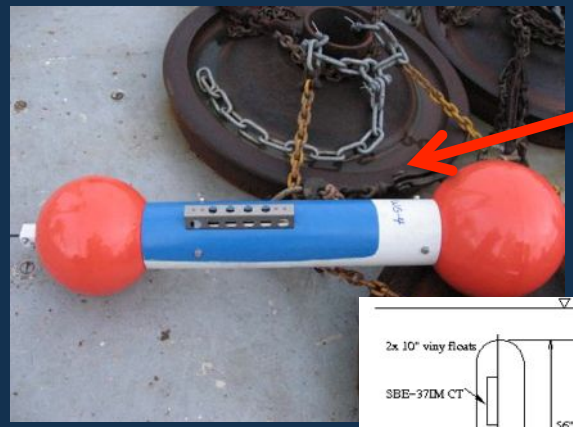
Glider surveys

Moored array

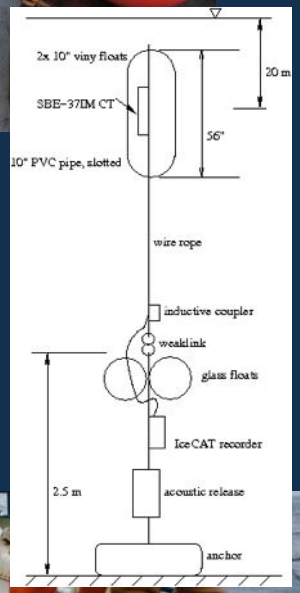
IBOs & Floats (distributed)

Ice-Sacrificial Mooring (ICECAT)

Lee, Gobat, Johnson (APL-UW)

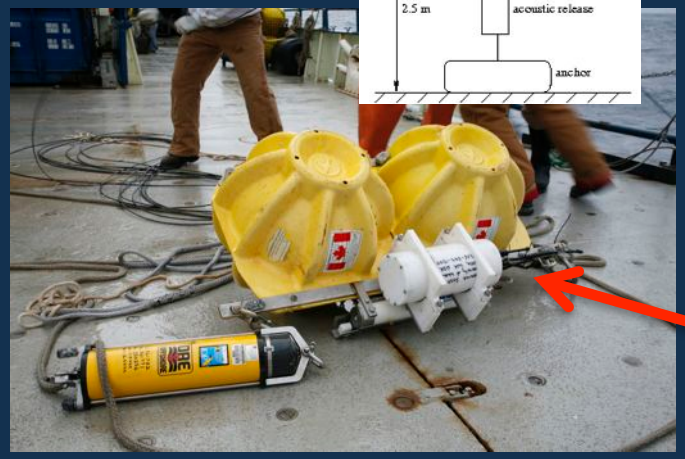


Expendable shallow element samples ice-threatened near-surface layer.



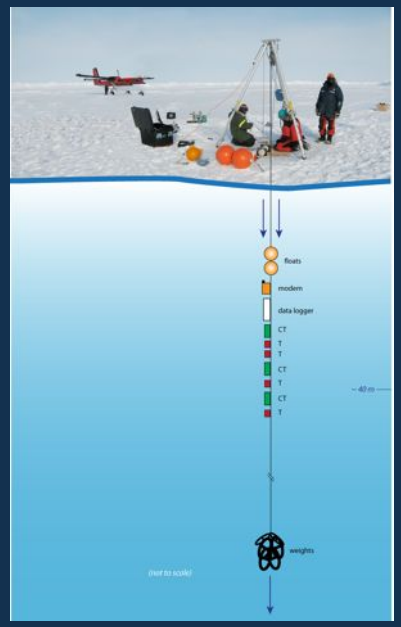
- Access
  - Localized.
  - Ice-ocean interface, marginal ice zone, shelf-slope (1000 m).
- Risk
  - Sensor(s) exposed but data protected.
  - Acoustic data upload makes recovery optional.
  - Mitigate by deploying many.
- Persistence/Cost/Scalability
  - Low cost (expendable)
  - Multi-year endurance possible- would want acoustic upload.
- Adaptability/Flexibility
  - Lightweight logistics (for a mooring).

  Extensive use in Davis Strait and Bering Strait.

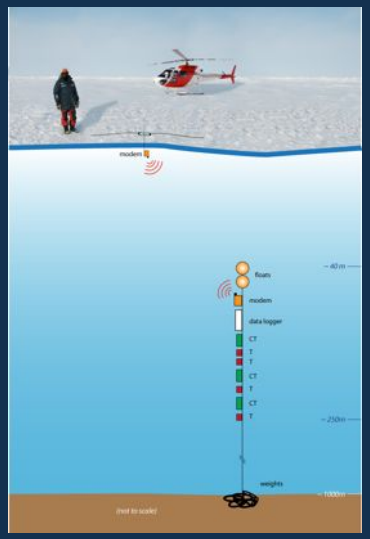


Data logged below, protected by weak link.

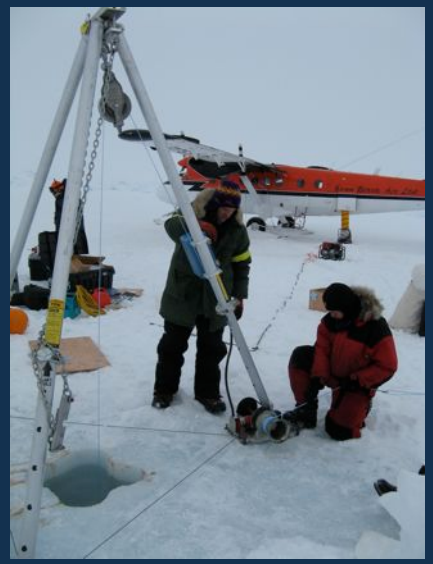
Lightweight, Expendable Air-serviced Moorings



Data recovery by acoustic modem.

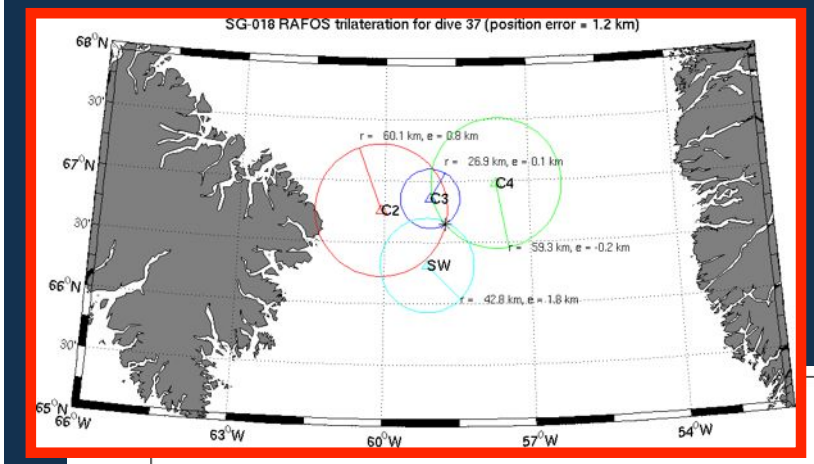


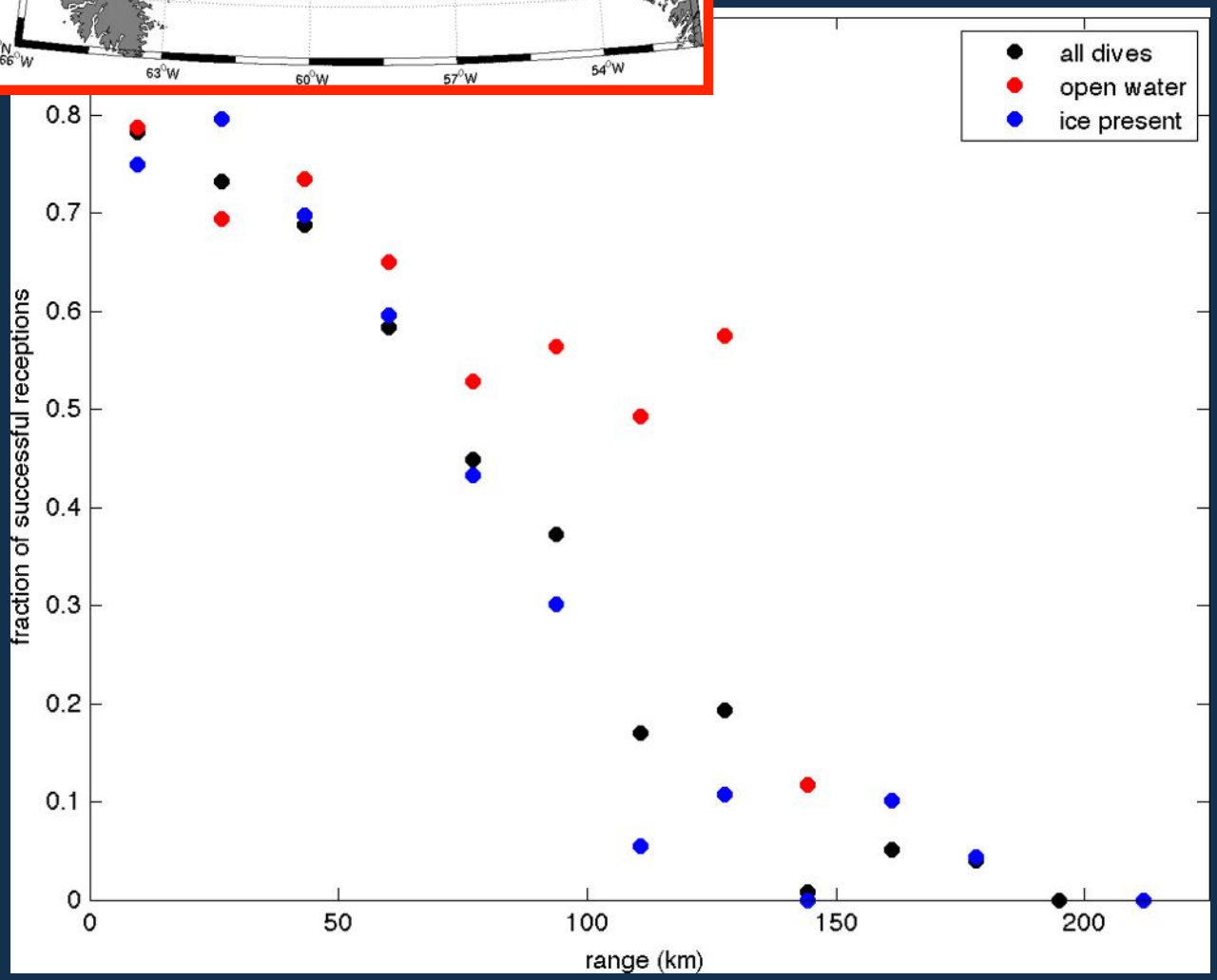
- Deploy through hand-augered hole.
- Twin Otter, single-load logistics.
- Light-weight, low-drag design.
- Three-year battery life.

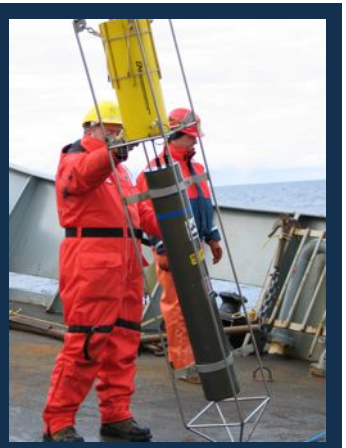


- Access
  - Difficult to access regions, year-round ice cover.
  - Aircraft logistics.
  - Expendable- hardware costs much lower than recovery operation.
- Risk
  - Low-cost and acoustic data return mitigate.
- Persistence & Scope
  - Three-year endurance, acoustic upload as desired.
- Adaptability
  - Designed for depths to 1000 m, might go deeper.
  - Deployment requires ice (possible in open water, but why?).
  - Extremely lightweight logistics (for a mooring).
  - Three operational in Lincoln Sea, three more in May 2010.

Acoustic Navigation

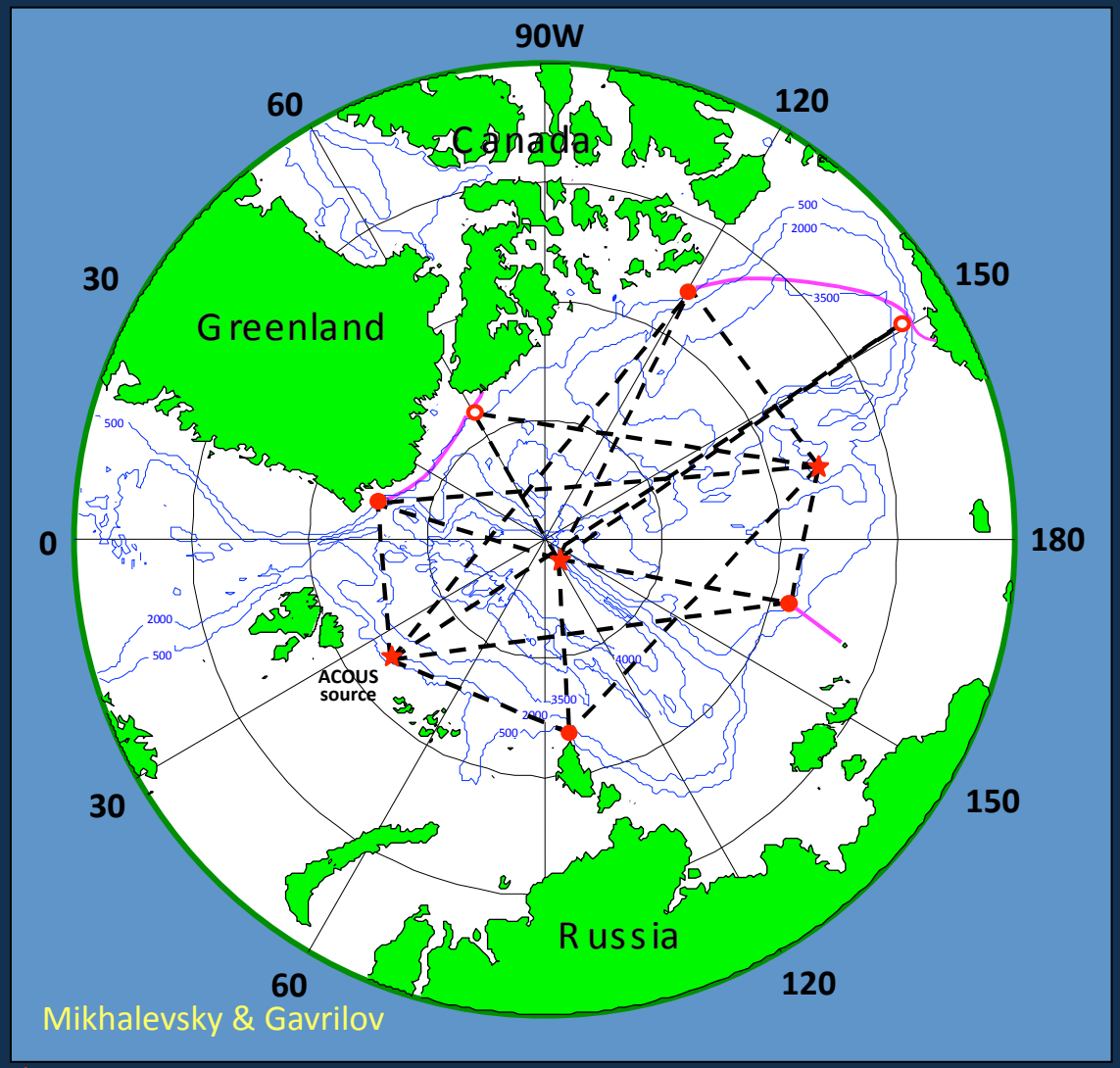






- Glider navigates by trilateration using multiple sources.
- Ice cover greatly reduces range of mid-freq O(1 kHz) signals.
- Range < 150 km in ice-covered waters (~2000 km in open water).
- Accuracy ~1-2 km.
- More sophisticated navigation algorithms may improve range.

LF Network- Geolocation, Thermometry



★ Autonomous sources

○ Cabled transceiver nodes with shore terminals

● Cabled/autonomous transceiver nodes

– – – – Acoustic observation paths

——— Cable

Navigation System Challenges

- Ice-cover reduces MF range to < 150 km.
- MF systems impractical for basin-scale geolocation.
- LF (20-80 Hz) for basin-scale range.
- Weight, reliability and power requirements.
- Marine mammal impacts.
- Sites in multiple EEZs.
- Costly maintenance-collaboration required.

Example 3: Boundaries & Shelves- New Mooring Technologies

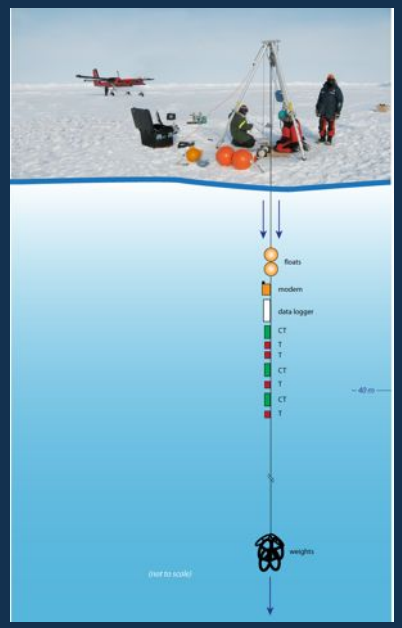
SEARCH Implementation Plan

- Boundary currents, fluxes.
- Broad, shallow shelves.
- Exchanges across shelf-slope systems.

Challenges

- Proximity to magnetic pole.
- Small deformation radius.
- Ice complicates operations.
- Shelf, upper ocean ice-threatened.
- Upper ocean threatened by ice.
- Heavy logistics burden.

Lightweight, Expendable Air-serviced Moorings



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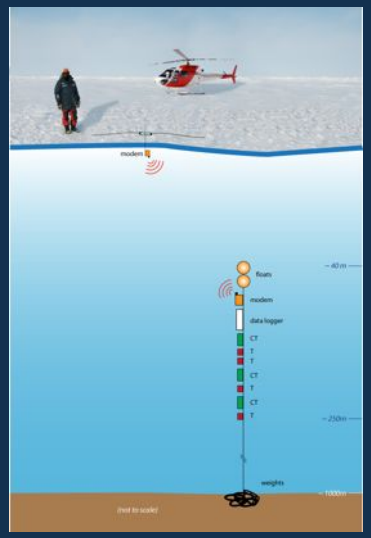
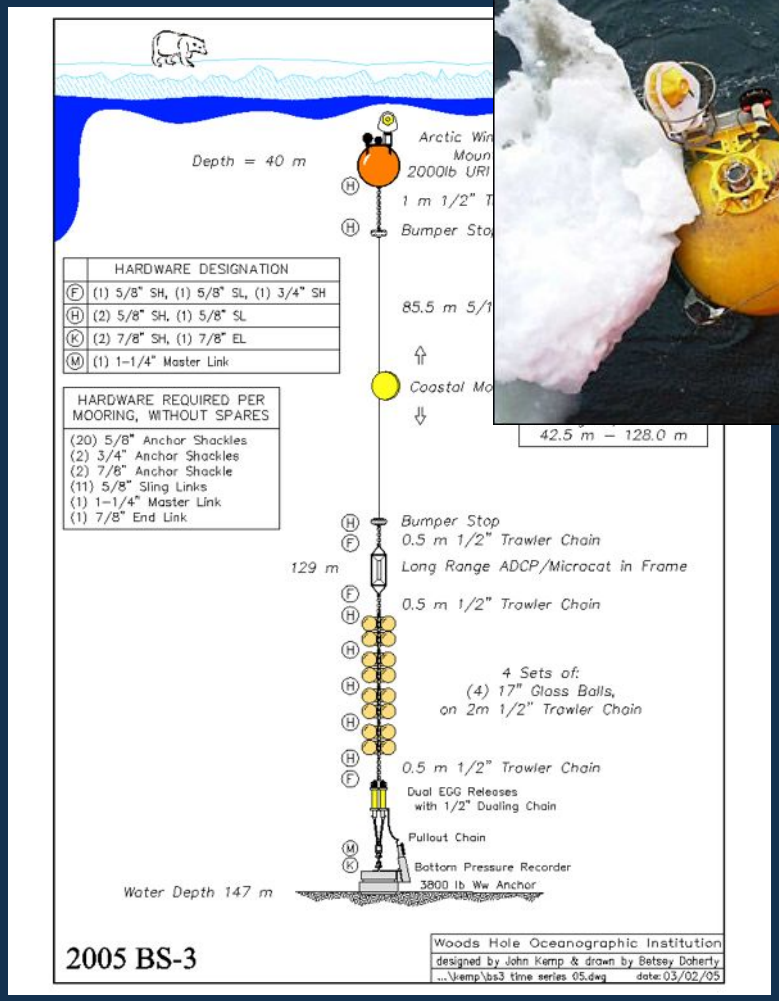


- Light-weight logistics
- Low-cost, 3-year endurance

Profiling Moorings

Pickart (WHOI)



- Arctic Winch provides CTD profiles to within 8 m or surface.
- ULS measures ice draft.
- Profiler samples deeper waters.