Autonomous Platforms in the Arctic Observing Network

Craig M. Lee
Applied Physics Laboratory, University of Washington

H. Melling (IOS), J.I. Gobat, K. Laidre (APL-UW); A. Beszczynska-Möller, E. Fahrbach (AWI); J. Toole, R. Krishfield, R. Pickart (WHOI); E. Hansen (NPI); J.C. Gascard (UPMC)

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.

Key Attributes

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

Timmermans et al. (2008)
ITP-based observations of double-diffusive staircase.
Ice Based Observatories (IABP, ITP, POPS, IMB)

- 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

- 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.

SG108 Track with Daily Ice Extent
- 6 months
- 51 days, 450 nm beneath the ice
Example 3: New Mooring Technologies

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

Profiling Moorings

Pickart (WHOI)

Lightweight, Expendable Air-serviced

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

Frequency Regimes

- VLF
- LF
- MF
- HF
- VHF

- Ambient Noise Studies
- Marine Mammals
- Seismic
- Tomography
- Long-Range Navigation
- Typical Communications Band 1-50 kHz

0.1 1 10 100 1k 10k 100k

Frequency (Hz)

Freitag (WHOI)
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.
- 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

- 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**

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![Map of LF Network with geolocation and thermometry information](image)

- Autonomous sources
- Cabled transceiver nodes with shore terminals
- Cabled/autonomous transceiver nodes

**Mikhalevsky & Gavrilov**
Example 3: Boundaries & Shelves- New Mooring Technologies

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

**Lightweight, Expendable Air-serviced Moorings**

Data recovery by acoustic modem.

**Challenges**

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

- 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.