A BAFFIN BAY ACOUSTIC COMMUNICATION AND NAVIGATION SYSTEM

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1 Introduction

In open water, autonomous floats and gliders can periodically surface and use GPS to determine their position. Iridium satellite communication can be used to send data back to land-based ocean data centers for analysis, research and operational decision-making. However, neither GPS nor satellite data communication systems function under the water. We propose a Baffin Bay Acoustic Navigation and Communication System (BBANC), which will use broadband low-frequency sources to provide basin-wide coverage of RAFOS-style signals for acoustic positioning of underwater assets. Low-frequency acoustic receivers would be collocated with the sources to enable ocean acoustic tomography for long-term study of heat content and currents. Finally, passive acoustic listening systems would enable the study of marine mammal communication and ambient noise from ships, sonar, ocean-based resource exploitation and ice dynamics, as well as gating acoustic source operation in the presence of marine mammals.

2 Motivation

Since 2002, the international Argo program has deployed a fleet of profiling floats, currently numbering over 3800, each measuring the temperature and salinity of the upper 2000 m of the ocean for up to 4 years. Over 30 countries, including Canada, have contributed to this program, yielding sustained real-time observations of the oceans that have revolutionized studies of global ocean circulation and the development and validation of climate models. Notice in Fig. 1**Error! Reference source not found.** that there are no Argo floats in the Arctic Ocean or Baffin Bay (red ellipse).

In open water, floats and gliders can periodically surface and use GPS to determine their position. Iridium satellite communication is used to send data back to land-based ocean data centers for analysis, research and operational decision-making. However, autonomous operation in the Arctic is not currently possible because ice cover prevents floats and gliders from positioning their measurements as well as relaying data to shore for long periods; neither GPS nor satellite data communications are possible under the water. As a result our current set of scientific observations of the Canadian Arctic is biased towards spring and summer, when it is navigable by ships and when autonomous platforms can safely surface. **To truly comprehend winter Arctic waters in the manner that has been achieved in the world's more temperate oceans, floats and gliders require additional capability for underwater geolocation and periodic communication.**

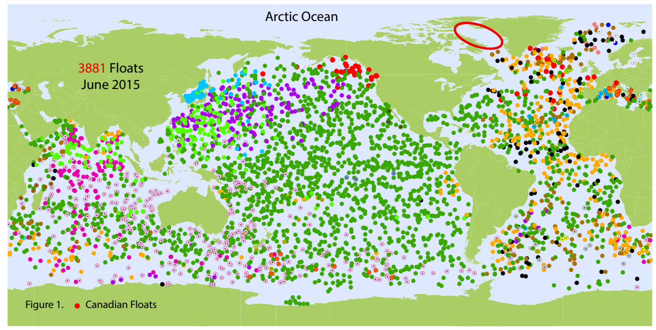

Figure 1 Argo floats.

Underwater geolocation and communication are possible using underwater sound. Refraction of sound within distinct ocean layers defined by their temperature, salinity and depth enables long distance propagation of sound deep in the ocean. RAFOS underwater positioning technology was developed in the 1980's, allowing autonomous scientific platforms to triangulate their position by listening to three or more underwater acoustic sources strategically-placed in these sound channels [1]. Since 2002, RAFOS-enabled platforms have been deployed in open and ice-covered high-latitude regions providing acoustic geolocation.

When ice-covered, Arctic waters poses special challenges for underwater acoustics due to the existence of a shallow sound channel with a highly reflective and scattering ice cover. This ice cover, along with the ambient noise created by ice formation, deformation, cracking and ridging, limits the maximum range for acoustic signals in the surface channel to a distance significantly less than that for signals in the deep acoustic channels. To meet these unique challenges of Arctic geolocation and communication, an international team of acousticians, autonomous platform developers, high-latitude oceanographers, and marine mammal researchers gathered at University of Washington in January 2005 for an NSF-sponsored "Acoustic Navigation and Communication for High-latitude Research" (ANCHOR) workshop [2]. They established international collaboration and developed an overarching system specification for the Arctic Ocean.

Following the workshop, several regional Arctic deployments of underwater acoustic positioning (Davis Strait, Fram Strait, Beaufort Sea) were achieved by a small number of partner nation efforts. Since 2006, UW-APL (USA) has completed 14 Seaglider missions across Davis Strait (~290 km) using acoustic geolocation [3], amounting to 1300 days of all-season operation (orange dots, Fig. 2). Since 2010, AWI (Germany) has enabled under-ice float and glider missions with acoustic geolocation as part of the Fram Strait Observatory; acoustic sources are separated by 200-300 km [4]. **A permanent installation of moored acoustic sources for Arctic under-ice geolocation and communication on the scale of Baffin Bay (≥ 500 km source separation) has yet to be realized.**

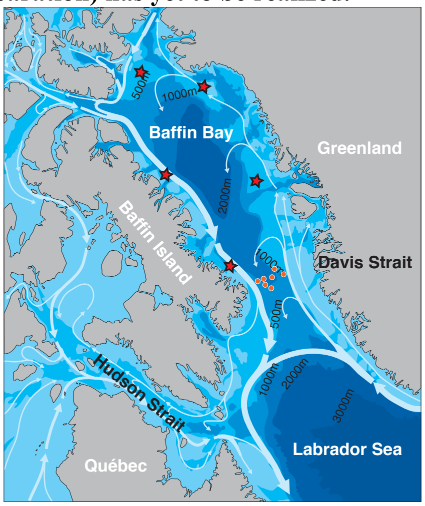

Figure 2 Baffin Bay and Davis Strait. White arrows indicate major circulation. Red stars indicate representative locations of possible acoustic sources, *only* for the purpose of comparing scale to existing 780 Hz Davis Strait RAFOS sources (orange dots). UW-APL gliders travel approximately East-West along a line of four moorings, with the three additional RAFOS moorings providing off-axis range measurements.

Characterization of acoustic propagation channels in Baffin Bay is incomplete, consisting of limited open-water results from Defence Canada (e.g., [5,6]) and marine mammal impact studies of shallow (<10 m) seismic air gun arrays (e.g., [7]) and core drilling operations for oil/gas exploration. Ice scattering losses are not well known for the largely first-year Arctic sea ice conditions of Baffin Bay [8].

3 Project Description

Our project consists of a feasibility study of a Baffin Bay Acoustic Navigation and Communication (**BBANC**) system, addressing the ANCHOR report recommendation of a pilot system "significantly larger" than current Arctic acoustic geolocation and navigation efforts. The benefits of this proposed system would be:

1. **Geolocation / "Underwater GPS":** Year-round, 24x7* underwater geolocation capability for autonomous platforms, supporting the study of the "unseen" winter arctic waters and springtime ice edge blooms. (*Gaps are possible due to maintenance and time and space outages or reduced duty cycle during whale migration, if necessary.)
2. **Data Communication:** Low data rate messaging capability for RAFOS system synchronization and autonomous platform command and control.
3. **Physical Oceanography:** Using co-sited acoustic receivers [9], acoustic tomography can "take the temperature" of Baffin Bay in less than one hour and repeat the measurements weekly on a year-round basis, enabling climate change research.
4. **Passive Acoustic Listening:** Passive acoustic recorders would enable the study of marine mammal communication and ambient noise from ships, sonar, resource exploitation, as well as wind and ice dynamics, as well as gating acoustic source operation in the presence of marine mammals.

The BBANC feasibility study will carry out underwater acoustic propagation and design modeling and simulation under partial and complete ice cover, exploring acoustic source type, location, frequency and transmission loss for basin-scale operation. Accomplishments to date include a large hydrographic database support range-dependent acoustic modeling across selected Baffin Bay sections. Ice cover thickness statistics along these sections has been derived from passive (SMOS) and active (CryoSat2) microwave satellite measurements of sea ice freeboard. An initial assessment of impacts on marine mammal communication will also be completed [10]. An international scientific network of underwater acoustics experts, marine mammal experts, and potential users is being established. We expect this study to lead to a field measurement program to verify and improve acoustic propagation modeling in an ice-covered Baffin Bay prior to implementation.

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