Acoustic Technology for Glider Long-Range Navigation and Communications

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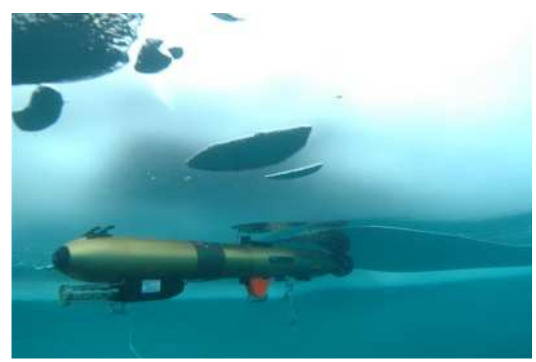


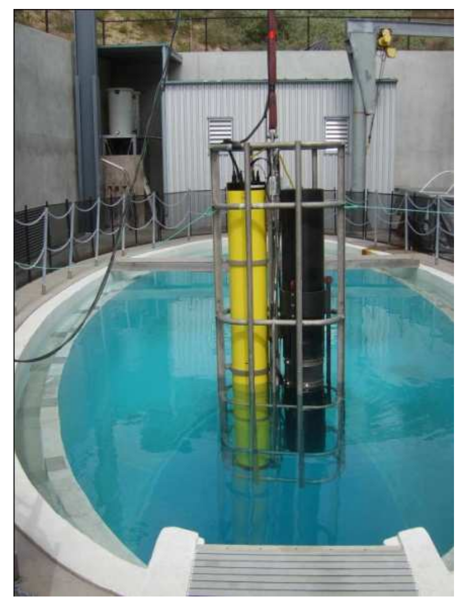
Teledyne Low Frequency Sound Sources for Long-Range Underwater Navigation RAFOS and tomography

RAFOS

Frequency range: Standard RAFOS sweep, 261Hz
SPL: 181 dB re 1 micropascal at 1 m
Projector: "Organ-Pipe" free flooded, 36 cm diameter
Controller: SeaScan/Tillier design. Programmable via external connector. Temperature compensated time base. (Delta f)/f = 5 x 10-8
Batteries: Alkaline "D" cell assembly
Endurance: 4000 transmissions
Maximum operating depth: 2000 m
Material: Aluminum 6061-T6, End-caps hard anodized
Weight: 360 kg (140 kg submerged)
Mooring Tension Maximum: 4400 kg, (10,000 kg with optional external tension member)

Broad-band Frequency Sweep

Frequency sweep, 200-300Hz; RAFOS sweep; CW signals 200-300Hz
Max SPL: 195 dB re 1 micropascal at 1 m, efficiency 50%
Directivity index: 3 dB in horizontal direction
Projector: Micro-controller tunable “Organ-Pipe” with a symmetrical Tonpliz transducer, free flooded, 36 cm diameter
Controller: 32 bit Motorola MC68CK338 micro-controller. Programmable via external SAIL connector. Integrated with 4-channel STAR receiver system (SCRIPPS) with the hybrid Rubidium low power clock and underwater acoustic navigation. Long term stability: 3 ms for 1 year.
Batteries: Alkaline "D" cell assembly
Endurance: 3000 transmissions
Maximum operating depth: 6000 m for electronic housing, operating depth for projector unlimited
Material: Aluminum 6061-T6, End-caps hard anodized, weight: 1000 kg



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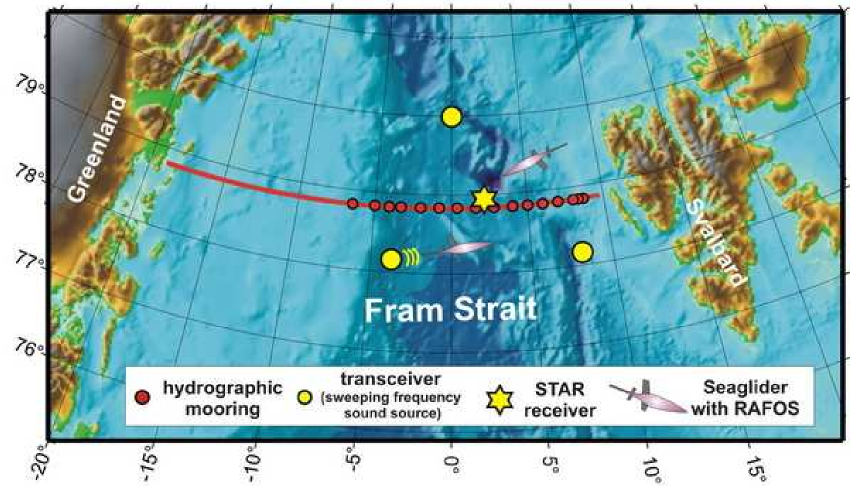
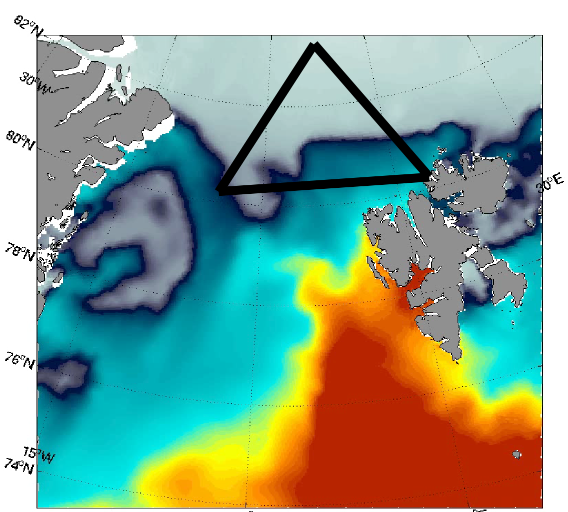
ACOBAR – acoustic system for tomography and Glider navigation

ACoustic technology for OBserving the interior of the ARctic ocean. Courtesy of Stein Sandven and Hanne Sagen

European infra structure:
15-17 standard oceanographic moorings, 2 gliders – one operational at each time, 2 RAFOS sources @ 800 m, 3 tomography transceivers @ 400 m, 1 long vertical receiver array hydrophones @ 300 -1000m, high resolution ocean model (3.2 km) and simulation schemes.

FSO Fram Strait Ocean Observatory
Tomographic and oceanographic moored arrays across one on main gateways to the Arctic Ocean





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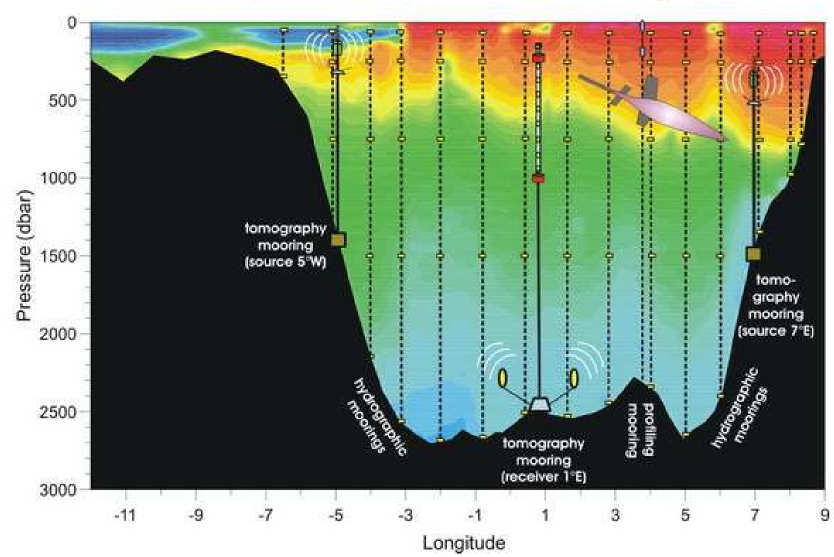
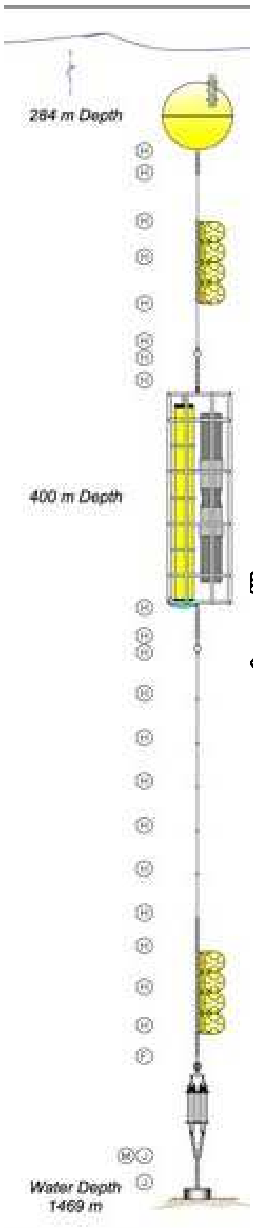


ACOBAR Fram Strait Experiment 2010-2012

Three transceiver arrays and one receive array in the middle



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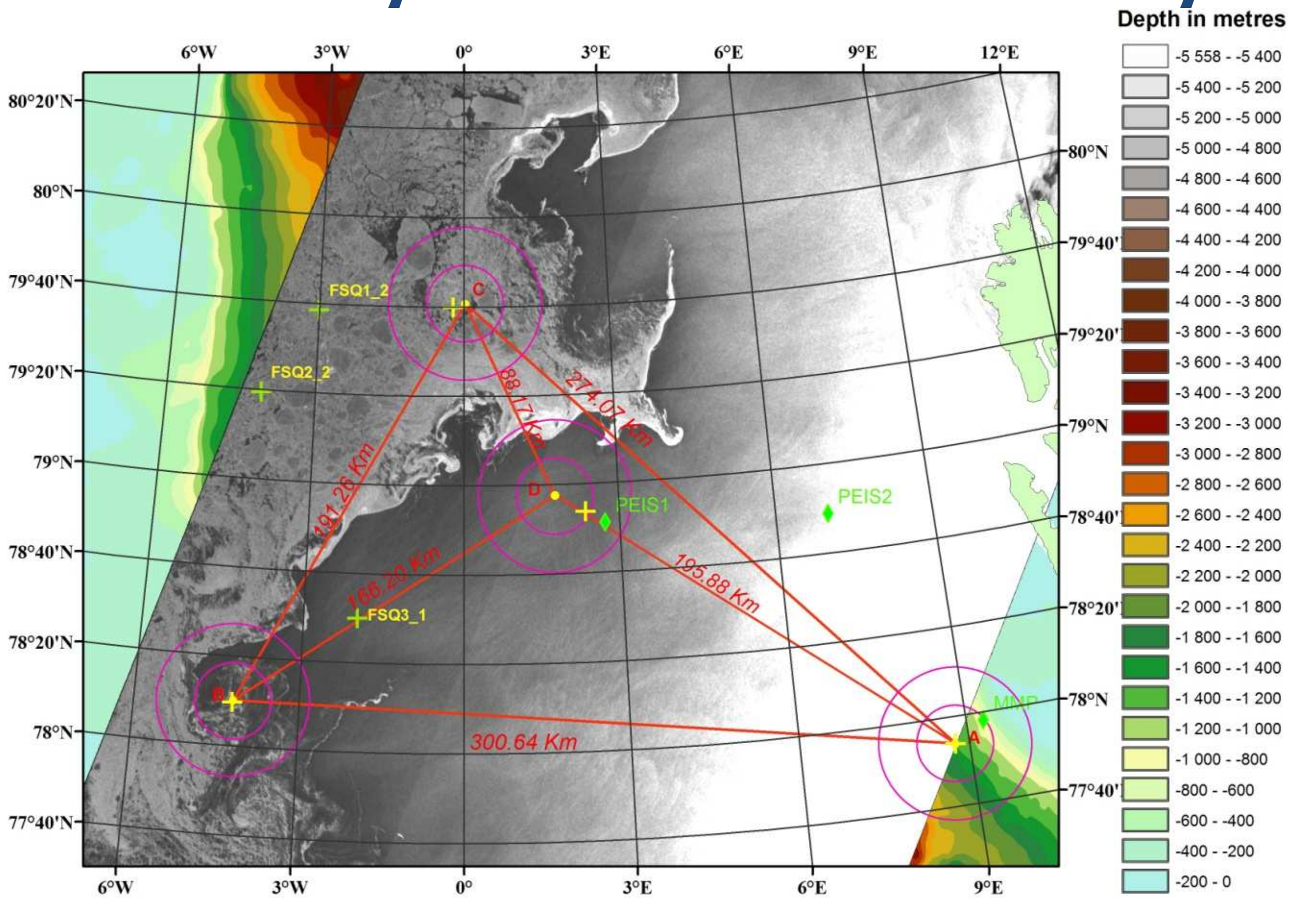
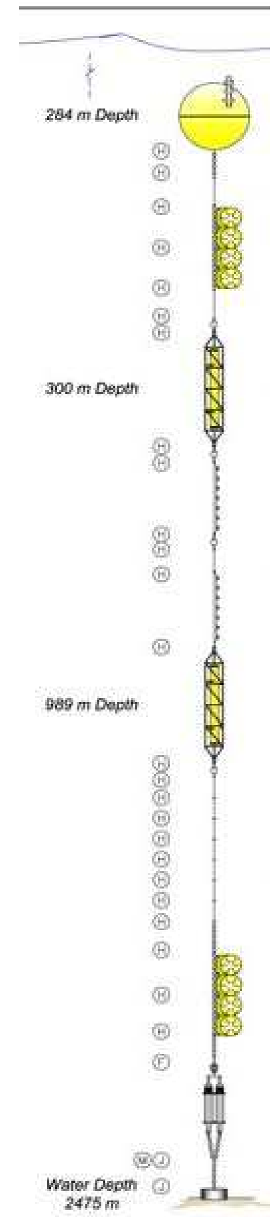


ASAR wide Swath image 1 October 2010, 11:16 UTC.



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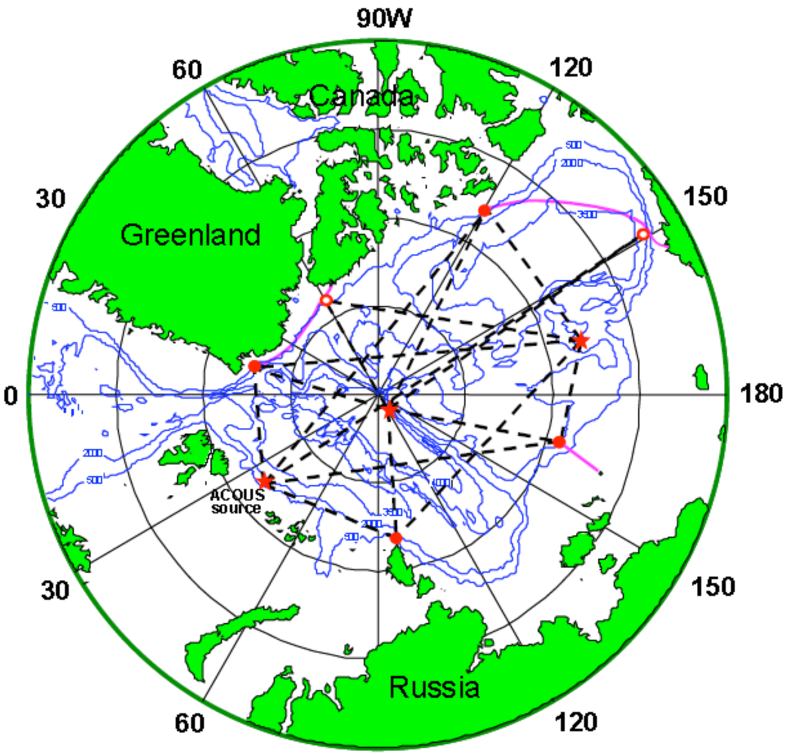
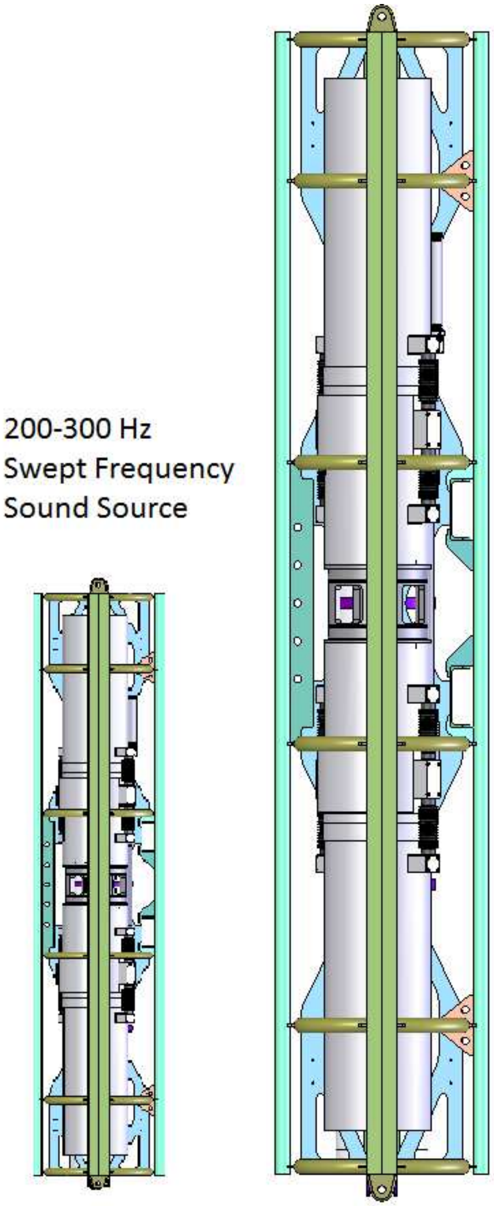
Basin Scale Low Frequency Navigation, Tomography, and Communications



70-100 Hz Swept Frequency Sound Source



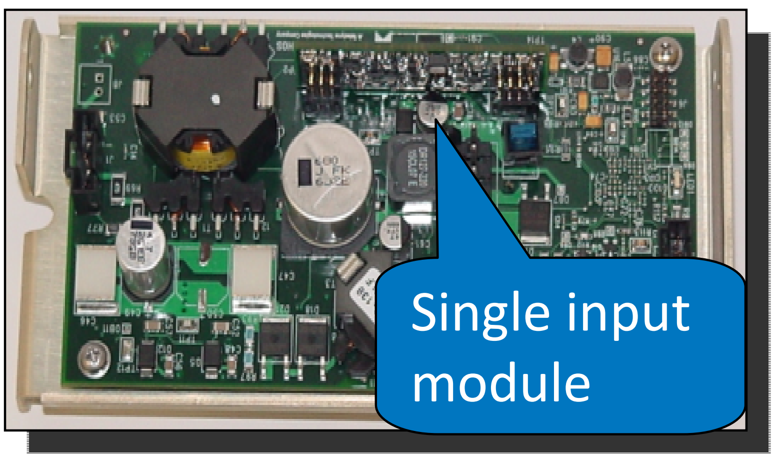
200-300 Hz Swept Frequency Sound Source

50 Hz 6 Hz Bandwidth 1500 m Depth Bubble Sound Source

Acoustic Navigation and Communications for High-latitude Ocean Research (Anchor) workshop
27 February – 1 March 2006 Applied Physics Laboratory
University of Washington Seattle, WA, U.S.A.

High Frequency Underwater Modem-Based Navigation Aids
Directional Acoustical Transducer (DAT)

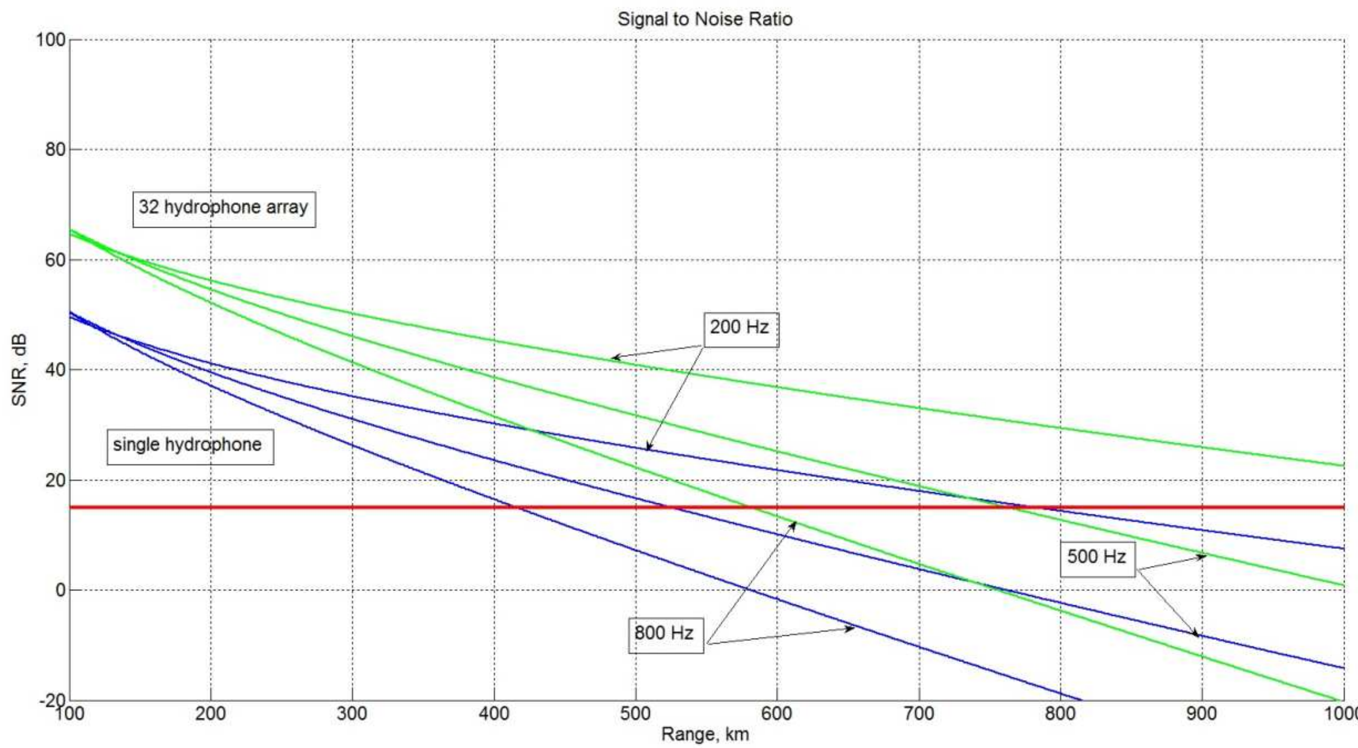
- Long Baseline (LBL)
- Extending LBL - Underwater GPS
- Ultras-Short baseline (USBL)



Underwater Long-Range Communications

694 Hz sound source for glider acoustic long range communications:
Weight - 6.75 kg in water.
Dimensions of carbon fiber tubing:
Diameter 20.4 cm
Length 47 cm pipe
Wall thickness 4 mm;
Acoustical actuator ITC1007;
Central frequency 694 Hz.
Bandwidth 20 Hz.
SPL 190 dB re 1 micropascal at 1 m, efficiency > 50%
Directivity gain 3 dB
Communication rate 10 b/s
Transmission of 100 bits -~10 sec

SNR calculated for data rate 10 b/s; and SPL transmitter 190 dB; Knudsen noise level



Joint Channel Estimation and Data Recovery for Long-Range Underwater Acoustic Communications. Errorless SNR 15 dB

Reference:
L.Freitag and M.Stojanovic, "Basin-Scale Acoustic Communication: A Feasibility Study Using Tomography M-Sequences,'' in Proc. IEEE Oceans'01 Conference, Honolulu, HI, November 2001.

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Under-Ice Communications 694 Hz

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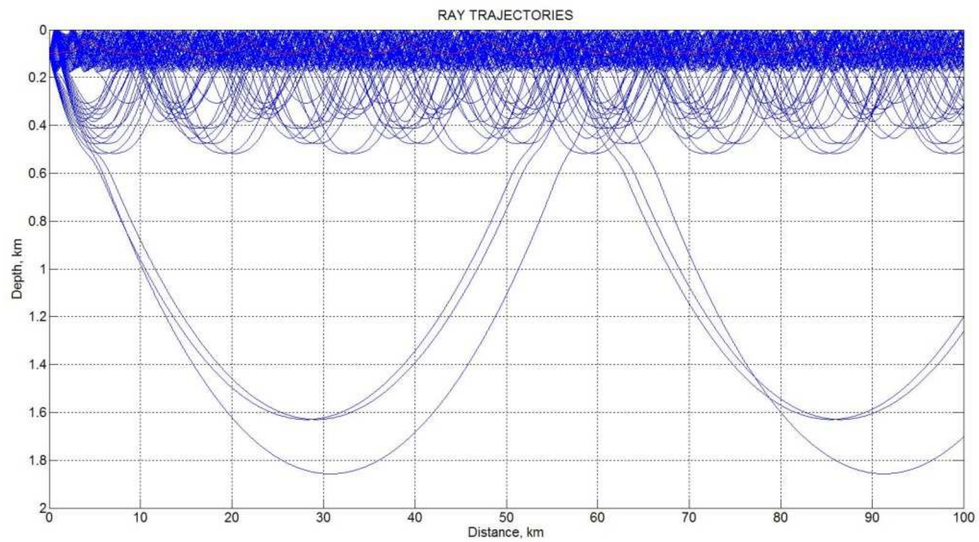
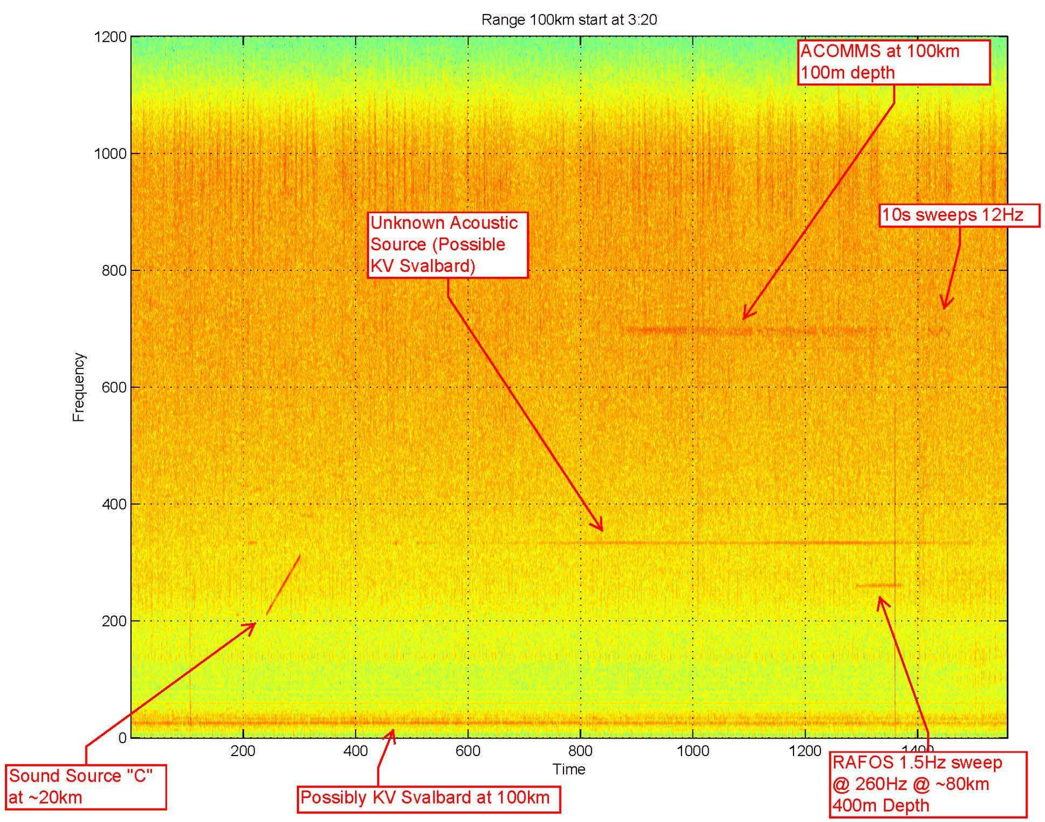
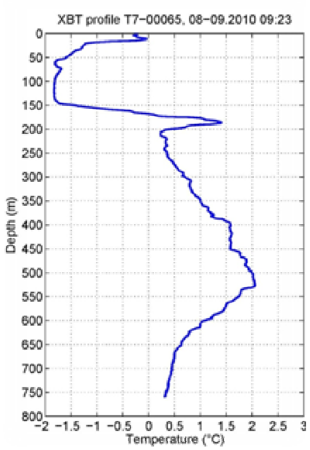


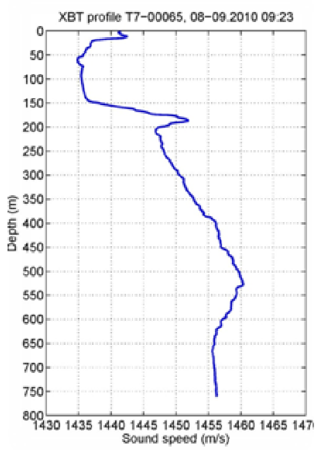
ACOMMS signal starts at 0822L (0622Z)

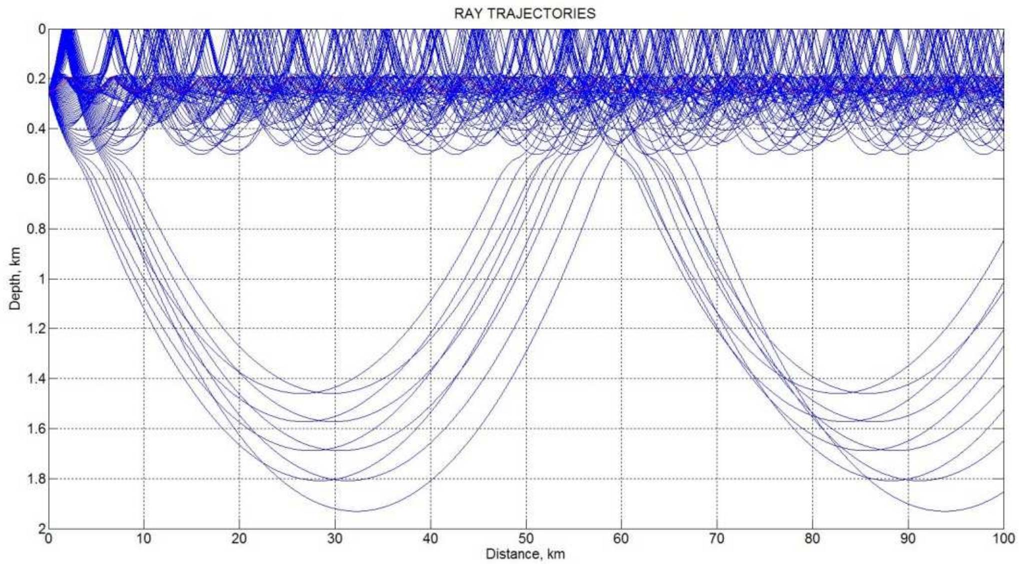


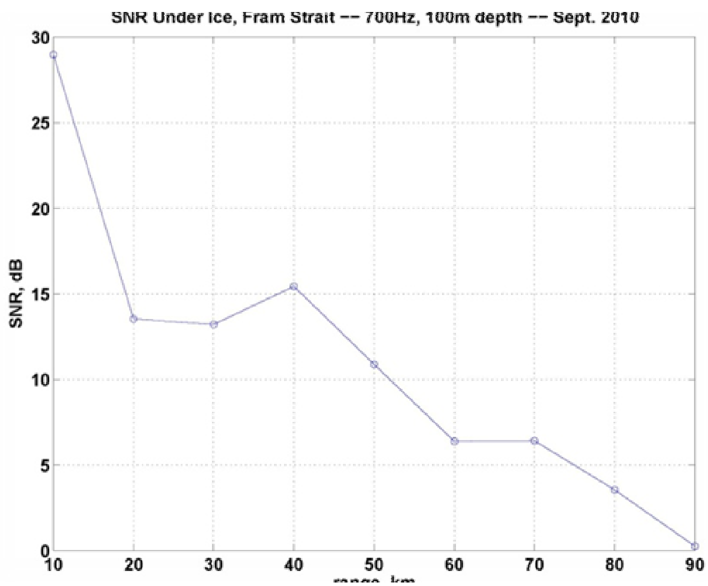
694 Hz sound source for glider acoustic
Sound pressure level SPL 186 dB re 1 micropascal at 1 m
Acoustical actuator ITC1007;
Central frequency 694 Hz.
Communications rate 10 b/s
Range - 100 km
Transducer depth -100 m
Receiver depth - 100 m
Record from one hydrophone (4 hydrophone array was used)

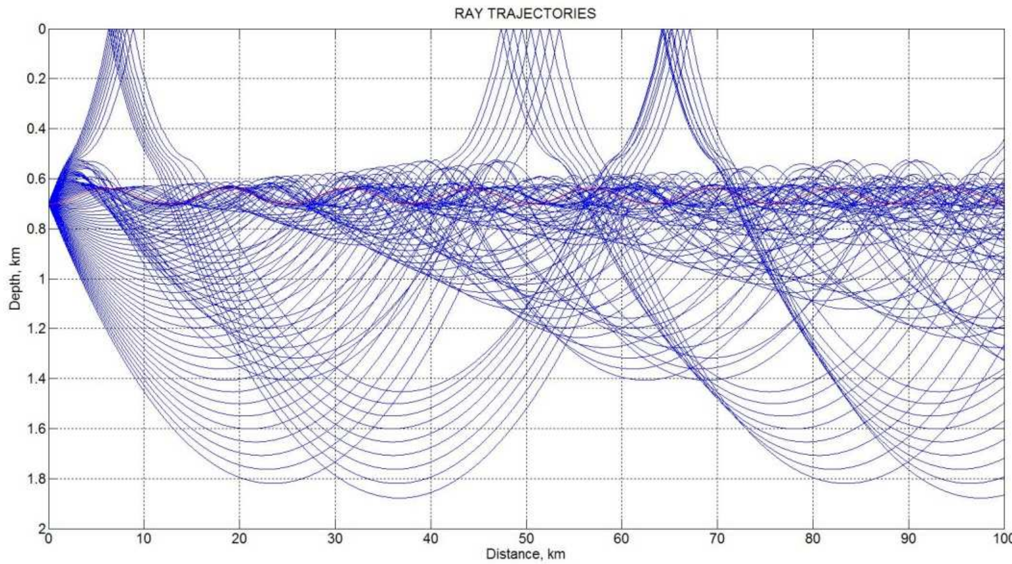
Under-Ice Sound Propagation











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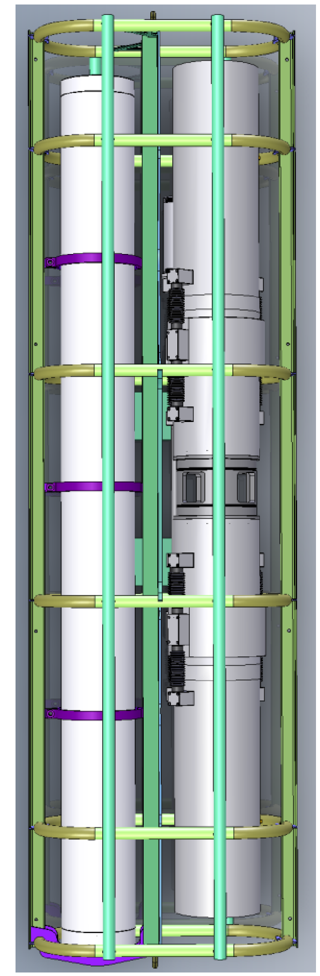
Signal processing for long-range communications

Deep space communications

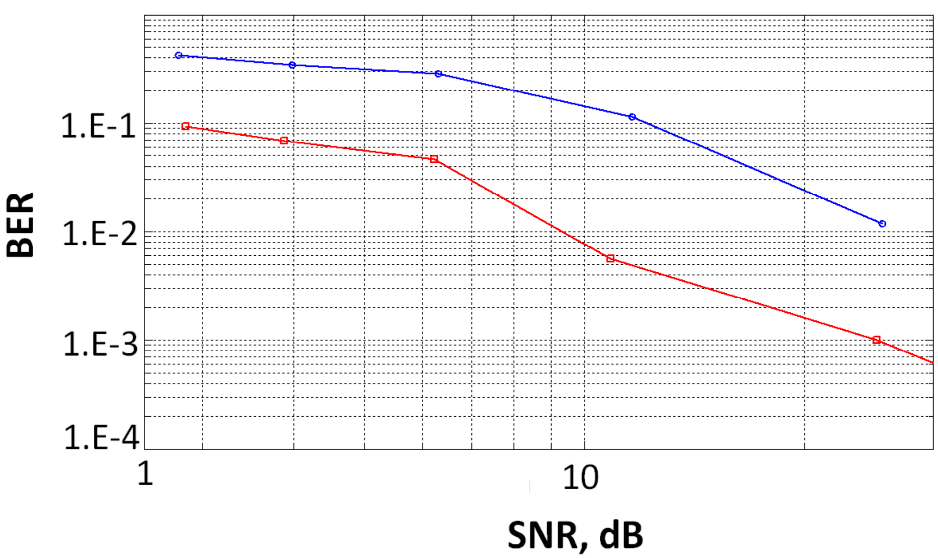
Long-range underwater acoustic communications

Algorithms for optimal signal processing

- **Joint Channel Estimation and Data Recovery**
  - **MAP**
  - **MLSD with pre-survivor processing**
  - **Sequential decoding**
- **Turbo decoding**



Comparison pre-survivor processing and dual loop selected pre-survivor processing



- ***Channel model***. 3 Raleigh paths with the standard deviation 0.5 1.0 and 0.5 with the delay equal the one single bit duration. 50 realization with 1024 bit bpsk signals.
- Pre-survivor processing was used only in 3 branches with maximum probability.

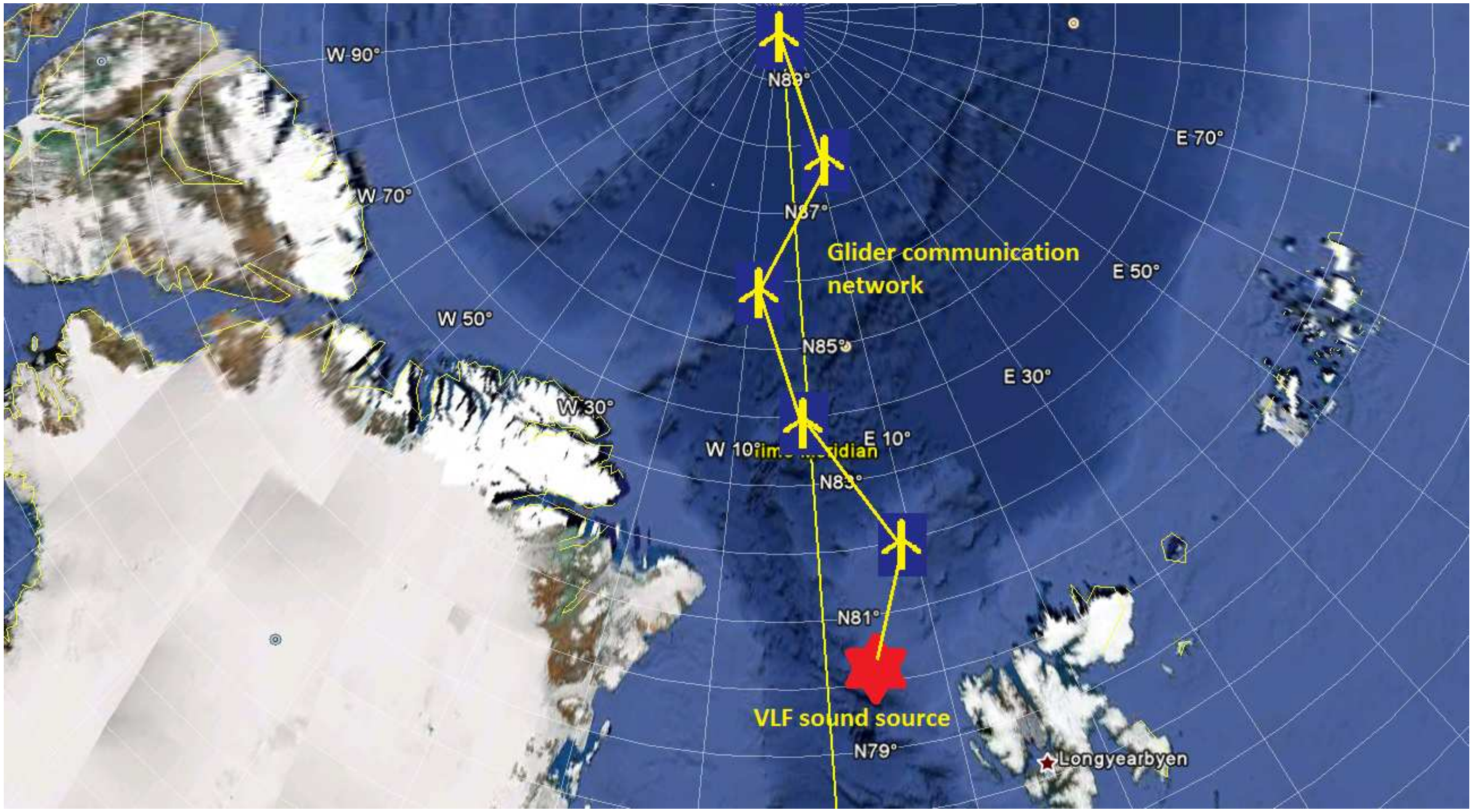
Glider Mission to the North Pole

Glider equipped to long term under-ice mission:

•Low frequency communications

•Networking

•Measurement directions (DAT) and distance (atomic clock) to VLF sound source and another glider



Conclusion

Teledyne Benthos ,Webb Research, TapTone, Gavia together with Woods Hole Oceanographic Institution suggest technology for long-range navigation and communications.
That technology allows in a nearest future start regular long-range under-ice glider missions including glider mission to the North Pole