

ACOBAR: The Fram Strait Acoustic System for tomography and navigation of gliders.

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Operational ocean monitoring and forecasting systems, such as MERSEA-IP, (2005-2008, <http://www.mersea.eu.org/>) and MyOcean (2008-2011), combine observations from different satellite remote sensing techniques and in-situ open ocean measurements (mainly Argo floats and moorings) with ocean circulation models through advanced assimilation techniques. In the Arctic Ocean, however, the internal water-masses, circulation and seafloor are largely unknown due to lack of observations. Development of an Arctic Ocean Observing System (AOOS) is still hampered due to significant lacks in technology and investment.

The objective of the two European projects DAMOCLES-IP and ACOBAR is to develop and test new technologies to measure ocean and sea ice to obtain new knowledge of the Arctic Ocean environment, and to contribute to the development of a future Arctic Ocean Observation System (AOOS). This includes the implementation of an ocean acoustic system for acoustic tomography and navigation of gliders in the Fram Strait. While tomography is superior to the glider technology in temporal resolution, the glider provide ocean data at a much higher spatial resolution. A region with strong mesoscale activity as in the Fram Strait requires both high temporal and spatial resolution of the observations. Therefore, our goal is to establish an integrated data and model system combining acoustic tomography, gliders, point measurements and ice-ocean modeling through data assimilation techniques to improve the accuracy of the heat, mass and freshwater transport estimates through the Fram Strait.

Acoustic tomography provides measurements of acoustic travel times between acoustic sources and receivers. Through inversion techniques, internal ocean temperature can be retrieved at an accuracy of 0.01°C over a 200 km distance (Munk et al. 1995, Dushaw et al, 2009 a). Acoustic tomography systems in Arctic regions have been developed and successfully tested in ice covered regions such as in the Greenland Sea Experiment in 1988-1989 (Worcester et al. 1993), in the 6 year long Labrador Sea tomography experiment (Avics et al., 2005), in the Trans-Arctic Acoustic Propagation Experiment (TAP) (Mikhalevsky et.al. 1999), and in the 14-month long ACOUS (Gavriliov and Mikhalevsky, 2006).

In OceanObs'99, key areas appropriate for tomography such as the Strait of Gibraltar and the Fram Strait were identified (Bold et al. 1999). The first step to develop and implement tomography observing system in the Fram Strait started under the DAMOCLES project (2005-2010). A source mooring and a receiver mooring were deployed for one year in August 2008 (Sandven et al. 2008). The two moorings are separated by 130 km and aligned along 78 30 N. In 2010, under the ACOBAR project, the Fram Strait acoustic system will consist of 3 acoustic transceiver moorings in a triangle configuration with a receiver mooring in the middle (Sagen et al. 2008a), see Figure 1. Each of the sources will produce broad-band acoustic signals for 3 D tomography and standard narrowband 260 Hz RAFOS signals for navigation purposes.

Because of the integral nature of the data, tomography is best employed in conjunction with numerical ocean models and data assimilation (ATOC 1998, Worcester et al. 2005, Dushaw et al, 2009 b). The acoustic travel times provide by definition spatially integrated temperature where meso- and small-scale variability is suppressed. In the same way, precise measurements of average current can be determined from the difference between reciprocal travel times produced by simultaneous transmission of acoustic pulses in opposite directions along an acoustic path. Assimilation of integrated ocean parameters derived from acoustic thermometry and tomography into ocean circulation models was originally recommended by Munk et al, (1995). Assimilation of acoustic travel times into the TOPAZ ocean data and model system is under development (Sagen et al 2008b).

Use of *gliders and floats* have recently become important platforms for oceanographic data collection. While floats drift passively with the current, gliders can be remotely steered by an operator via satellite communication when they are at the surface. Gliders have no propulsion and therefore low energy consumption, allowing operation for more than 6 months over a distance of more than 3000 km. (Griffiths et al. 2007). In ice-covered areas gliders and floats cannot rise to the surface to use satellite based navigation

(GPS) and data telemetry via IRIDIUM and ARGOS. In 2008 a glider operated for 2.5 months in the ice-free part of the Fram Strait (for more information visit <http://acobar.nersc.no>).

In order to operate underwater platforms in ice-covered regions, it is necessary to develop acoustic navigation and telemetry systems. The need for a mid frequency acoustic navigation system for gliders and floats in selected Arctic regions coincide to a large extent with the requirements for the acoustic tomography/thermometry system. The first under-ice operation of a glider using 780 Hz narrow banded RAFOS sources was done by Craig Lee (Applied Physics Laboratory, Seattle, USA) in the Davis Strait in 2008 (Dickson, 2008). A similar approach will be used in the Fram Strait using acoustic signals provided by the triangular net of acoustic sources under the ACOBAR project.

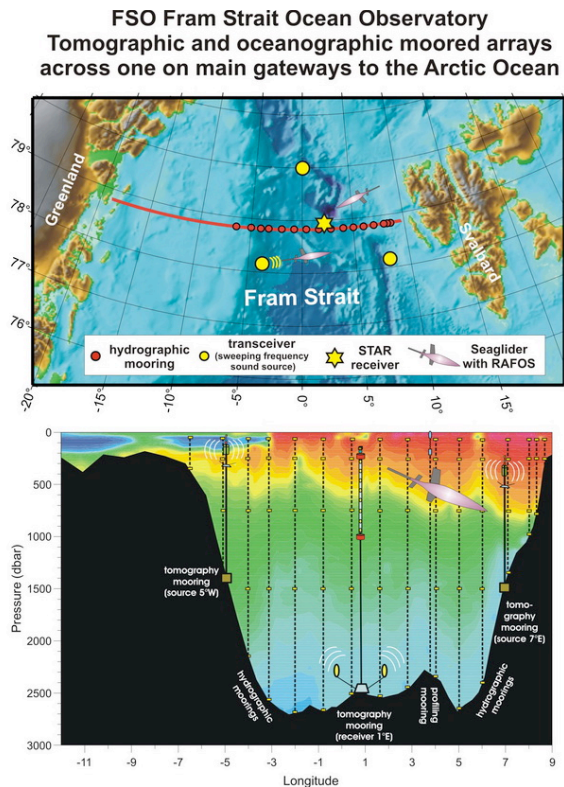


Figure 1 (to the left). The moored ACOBAR observatory (tomography and oceanographic) in Fram Strait (right panels). In addition to moored instrumentation, profiling gliders capable of under-ice acoustic navigation will be employed. The right lower panel shows positions of moorings overlaid on the temperature distribution in Fram Strait where red is warm water and blue is cold water.

References.

Avsic, Send and Skarsoulis, (2005) "Six years of tomography observation in the central Labrador sea," Proc. Int. Conf. Underwater Acoustic Measurements: Technologies & Results, Heraklion 2005.

Dickson (2008), The integrated Arctic Ocean Observing System (iAOOS) in 2008. A Report of the Arctic Ocean Sciences Board. Written by R.R. Dickson with inputs from iAOOS PIs

Dushaw, Au, Beszczynska-Möller, Brainard, Chiu, Cornuelle, Duda, Dzieciuch, Fahrbach, Forbes, Freitag, Gascard, Gavrillov, Gould, Howe, Jayne, Johannessen, Lynch, Martin, Menemenlis, Mikhalevsky, Miller, Munk, Nystuen, Odom, Orcutt, Tossby, Sagen, Sandven, Simmen, Skarsoulis, Stephen, Vinogradov, Worcester and Wunsch. (2009a). "A Global Ocean Acoustic Observing Network." Community White paper under

preparation for the upcoming OceanObs conference September 2009, Italy. See <http://www.oceanobs09.net/>

Dushaw, Worcester, Munk, Spindel, Mercer, Howe, Metzger, Birdsall, Andrew, Dzieciuch, Cornuelle, and Menemenlis (2009b). A decade of acoustic thermometry in the North Pacific Ocean, J. Geophys. Res., in press.

Hatun, Eriksen and Rhines (2007). 'Buoyant Eddies Entering the Labrador Sea Observed with Gliders and Altimetry', JPO, vol. 37, DOI: 10.1175/2007JPO3567.1.

Gavrillov, and Mikhalevsky (2006). "Lowfrequency acoustic propagation loss in the Arctic Ocean: results of the Arctic Climate Observations using Underwater Sound experiment," J. Acoust. Soc. Am., 119, 36943706 .

Munk (1995), Worcester, Wunsch (1995). Ocean Acoustic Tomography. Cambridge Monographs on Mechanics.

Mikhalevsky (1999), Gavrillov & Baggeroer. The Transarctic Acoustic Propagation Experiment and Climate Monitoring in the Arctic, IEEE Journal of Oceanic Engineering 24(2), 183-201.

Sagen, Sandven, Worcester, Dzieciuch, Skarsoulis (2008a). "The Fram Strait acoustic tomography system" "Acoustics '08, Paris". http://www.damocles.eu.org/artman2/uploads/sagen_et_al_paris08_final_2_.pdf

Sagen, Johansen, Marini, Lisæter, Bertino, Sandven (2008b) "Preparing for assimilation of acoustic data into a ice-ocean coupled model using EnKF", NERSC Technical report No. 299.

Sandven, Sagen, Haugen, et.al. (2008). "THE FRAM STRAIT TOMOGRAPHY EXPERIMENT 2008", NERSC Technical report No. 298, 19 December 2008.

Schauer, Beszczynska-Möller, Walczowski, Fahrbach, Piechura, Hansen (2008). Variation of Measured Heat Flow Through the Fram Strait Between 1997 and 2006,, Arctic-Subarctic Ocean Fluxes: Defining the Role of the Northern Seas in Climate, edited by R.R. Dickson et al., © Springer Science + Business Media B.V., 65-85.

Worcester, Lynch, Morawitz, Pawlowicz, Sutton, Cornuelle, Johannessen, Munk, Owens, Shuchman and Spindel (1993). Evolution of the large scale temperature field in the Greenland Sea during 1988-89 from tomographic measurements. Geophys. Res. Letter, Vol. 20, No. 20, pp. 2211-2214.

Worcester, Spindel (2005), North Pacific Acoustic Laboratory. J. Acoust. Soc. Am. 117 (3), Pt. 2.