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Arctic Ocean Sea Ice Draft, Bathymetry, and Water Properties from Nuclear-Powered Submarines

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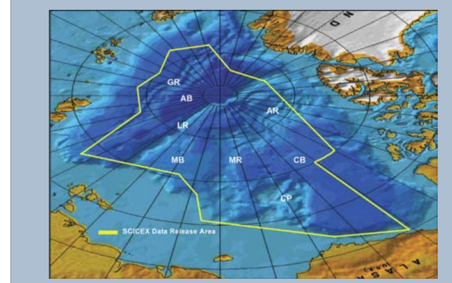
http://nsidc.org/scicex

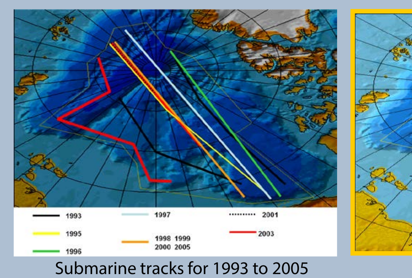
History

SCICEX was officially launched in 1994 after a feasibility test in 1993 in which civilian scientists joined U.S. Navy personnel on board nuclear-powered submarines to acquire scientific data. Between 1995 and 1999, five more such dedicated science cruises were completed. In 1998, due in part to a drastic reduction in the size of the nuclear submarine fleet, the Navy announced that they would no longer facilitate the dedicated scientific missions following the scheduled 1999 cruise. Since then, a modified approach has been taken, where some time is set aside for Navy personnel to collect unclassified scientific data during otherwise classified submarine exercises. These Science Accommodation Missions (SAMs) are facilitated by the Navy's Arctic Submarine Laboratory (ASL). As of 2014, there have been 13 missions, 6 of which were dedicated and 7 of which were SAMs. In 2009, NSIDC became the SCICEX data managers and host of the SCICEX web site.

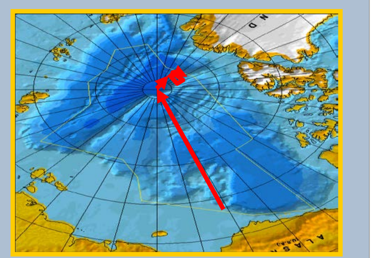
Cruise Title	Dates	Submarine(s)
SCICEX SAM 2014	15 March - 03 April 2014	USS New Mexico and USS Hampton
SCICEX SAM 2012	17 November - 20 November 2012	USS Topeka
SCICEX SAM 2011	12 March - 14 March 2011 and 30 March - 01 April 2011	USS Connecticut and USS New Hampshire
SCICEX SAM 2005	12 November - 20 November 2005	USS Salt Lake City
SCICEX SAM 2003	3 October - 25 October 2003	USS Honolulu
SCICEX SAM 2001	28 May - 4 June 2001	USS Scranton
SCICEX SAM 2000	17 October - 25 October 2000	USS L. Mendel Rivers
SCICEX-99	2 April - 14 May 1999	USS Hawkbill
SCICEX-98	1 August - 2 September 1998	USS Hawkbill
SCICEX-97	3 September - 2 October 1997	USS Archerfish
SCICEX-96	13 September - 28 October 1996	USS Pogy
SCICEX-95	26 March - 8 May 1995	USS Cavalla
SCICEX-93	23 August - 13 September 1993	USS Pargo



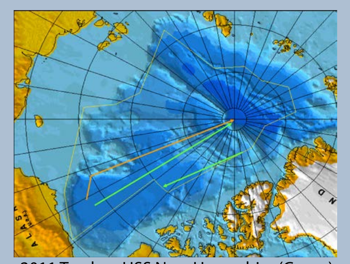
Data collection during a SCICEX SAM is restricted to the Data Release Area, outlined in yellow. The Navy has approved declassification and release of data in this region. Data release is further restricted to times when the submarine is operating at depths less than or equal to 244 m (800 ft) and speeds less than or equal to 25 kt.



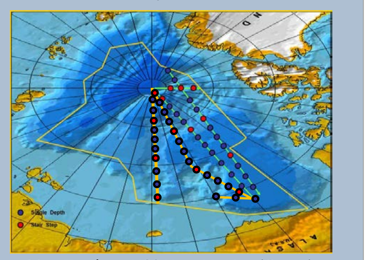
Submarine tracks for 1993 to 2005



2012 Topeka Tracks



2011 Tracks – USS New Hampshire (Green), USS Connecticut (Orange).



2014 Tracks – USS New Mexico (Green), USS Hampton (Orange)

Acknowledgments

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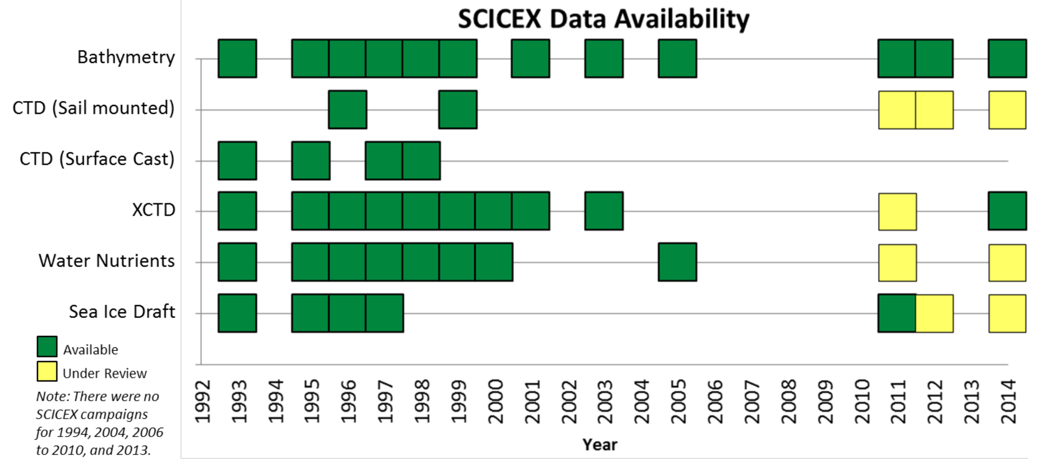
Register

For data updates and announcements at http://nsidc.org/scicex

The Submarine Arctic Science Program, SCICEX, is a collaboration among the operational Navy, research agencies, and the marine research community to use nuclear-powered submarines for scientific studies of the Arctic Ocean. Unlike surface ships, submarines have the unique ability to operate and take measurements regardless of sea ice cover, weather conditions, and time of year. This allows for a broad investigation of an entire ocean basin. The goal of the program is to acquire comprehensive data about Arctic sea ice, water properties (biological, chemical, and hydrographic), and water depth (bathymetry) to improve our understanding of the Arctic Ocean basin and its role in the Earth's climate system.

Data Access: http://nsidc.org/scicex/data_inventory.html



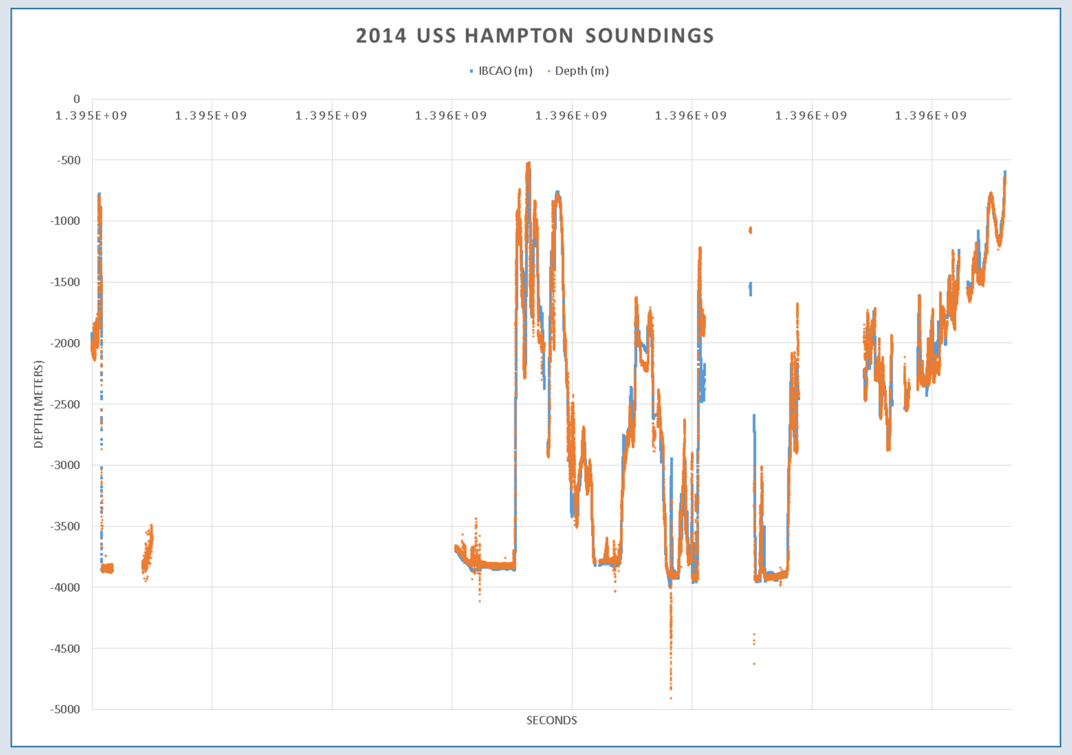
Bathymetry

Submarines have played a critical role in acquiring bathymetric data for the Arctic. SCICEX data contributed to the International Bathymetric Chart of the Arctic Ocean (IBCAO), and led to first-order changes in the mapped positions and depths of major bathymetric features. Knowledge of seafloor topographic features is important for studies of Arctic Ocean circulation, seafloor volcanism, and hydrothermal circulation, and has informed scientific ocean drilling.

Bathymetry is measured using the submarine's onboard fathometer. The SCICEX dedicated science missions systematically mapped portions of several major topographic provinces—Gakkel Ridge, Lomonosov Ridge, and Chukchi Borderland—that have been inaccessible to icebreakers because of perennial sea-ice cover (Edwards and Coakley, 2003).

Data acquired by the USS Hawkbill during the 1998 and 1999 SCICEX missions provided a base map for the 2001 Arctic Mid-Ocean Ridge Expedition (AMORE; Michael et al., 2003; Schlindwein et al., 2005) and the 2007 Arctic Gakkel Vents (AGAVE) expedition (Sohn et al., 2008).

Edwards, M.H. and B.J. Coakley. 2003. SCICEX Investigations of the Arctic Ocean System. Chemie der Erde - Geochemistry 63(4): 281-328.
Michael, P. J., C. H. Langmuir, H. J. B. Dick, J. E. Snow, S. L. Goldstein, D. W. Graham, K. Lehnert, G. Kurras, W. Jokat, R. Mühe, and H. N. Edmonds. 2003. Magmatic and Amagmatic Seafloor Generation at the Ultraslow-spreading Gakkel Ridge, Arctic Ocean. Nature 423: 956–961.
Schlindwein, V., C. Müller, and W. Jokat. 2005. Seismoacoustic Evidence for Volcanic Activity on the Ultraslow-spreading Gakkel Ridge, Arctic Ocean. Geophysical Research Letters 32, L18306, doi:10.1029/2005GL023767.
Sohn, R. A., C. Willis, S. Humphris, T. M. Shank, H. Singh, H. N. Edmonds, C. Kunz, U. Hedman, E. Helmke, M. Jakuba, et al. 2008. Explosive Volcanism on the Ultraslow-spreading Gakkel Ridge, Arctic Ocean. Nature 453: 1,236–1,238.



The image above shows the most recent bathymetry measurements from the USS Hampton acquired during the 2014 SCICEX campaign and how they compare with the IBCAO values.

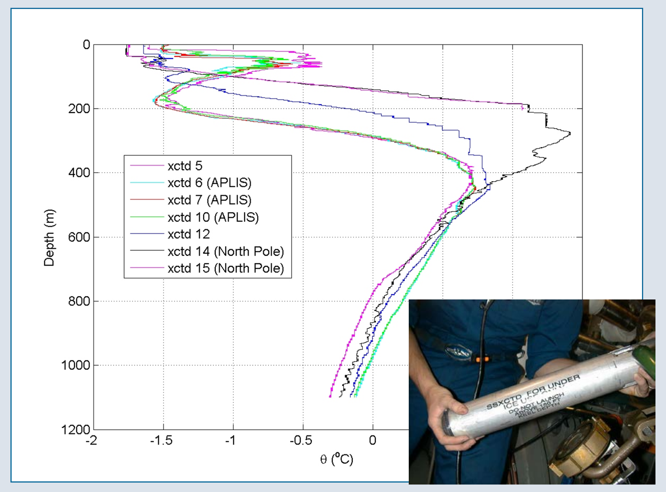
Conductivity, Temperature, Density (CTD)

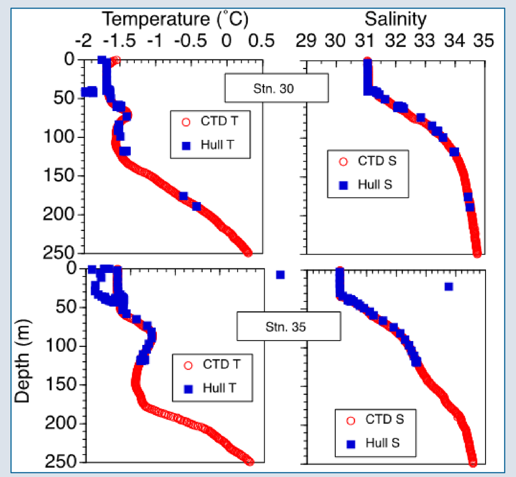
Hydrographic data provide definitive, synoptic evidence of upper ocean circulation pathways, and evidence of warming and penetration of Atlantic water as it propagates along basin peripheries and ridges. As the SCICEX data archive has grown, it has played a greater role in climate and modeling studies to validate model results of temperature and salinity distributions.

SCICEX has collected hundreds of measurements from CTD instruments mounted on the sail of the submarine or cast when the submarine surfaced, and from expendable CTDs (XCTDs) launched while the submarine is at depth. From 1995 to 1999, approximately 100 analog XCTDs were launched per cruise with an 85% success rate. The XCTDs are launched from the operating depth of the submarine, rise toward the surface, and then invert and profile downward, to a maximum depth of 1000 m. These data have been used as a point of comparison for numerical modeling studies to validate model results of temperature and salinity distributions, for example Karcher et al. (2003), and to evaluate the dynamical implications of mixing parameterization in Arctic regional models as in Zhang and Steele (2007).

The sail-mounted CTD provides a time series of measurements as the submarine moves through the water, at depth. The instrument used is a pumped CTD mounted in a free-flood space in the submarine sail, typically about 15 m (50 ft) above the keel depth, and plumbed to the exterior of the submarine. At present, Sea-Bird Electronics model SBE-19 and SBE-49 CTDs are the only units that have been approved for use.

Karcher, M.L., R. Gerdes, F. Kauker, and C. Koeberle. 2003. Arctic warming: Evolution and Spreading of the 1990s Warm Event in the Nordic Sea and the Arctic Ocean. Journal of Geophysical Research 108(C2), 3034, doi:10.1029/2001JC001265.
Zhang, J., and M. Steele. 2007. Effect of Vertical Mixing on the Atlantic Water Layer Circulation in the Arctic Ocean. Journal of Geophysical Research 112, C04S04, doi:10.1029/2006JC003732.





Top image: Temperature profile for 7 XCTDs from the 2011 SCICEX campaign.
Middle image: Photo of an XCTD being prepared for launch from the submarine.
Bottom image: Shows the comparison of sail-mounted CTD to surface cast CTD from the 1996 SCICEX campaign.

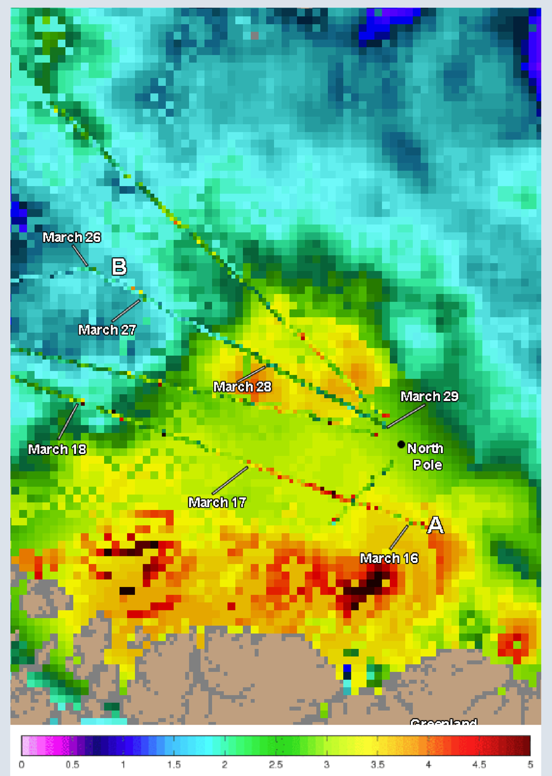
Sea Ice Draft

Profiles of sea ice draft obtained from submarines have provided an enormous wealth of data on ice thickness and how it varies over the Arctic basin. By comparing ice draft data collected by SCICEX with previously published data, scientists established that sea ice has thinned significantly within the Data Release Area between 1950–1970 and the 1990s.

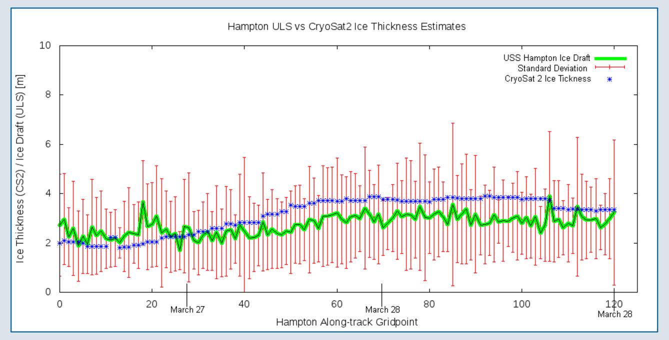
Ice draft measurements are collected using the submarine's upward looking sonar (ULS). A quick* comparison of 12.5 km averaged ULS sea ice draft data with a map of 25 km CryoSat-2 ice thickness data for March 2014** points to how submarine data can be used to better understand ice thickness fields from altimetry.

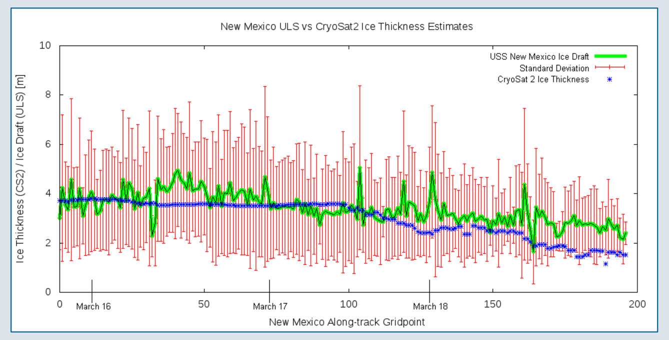
Here, investigators wanted to know if the submarine data would corroborate the large-scale under-ice topography suggested by the experimental Cryosat-2 product: thicker ice south and west of the Pole, and thinner ice between this area and the thick ice north of Greenland.

* This is exploratory work using ULS data that has not yet been processed by a SCICEX PI. There may be position errors and erroneous ice draft values. ULS ice draft values have not been converted to thickness.
** Available from NSIDC and described in "CryoSat-2 derived sea ice thickness and ancillary data for 2014" by Nathan Kurtz, NASA Goddard Space Flight Center



This image shows the ULS ice draft from the USS Hampton and the USS New Mexico during the March 2014 campaign overlaid on CryoSat 2 monthly-averaged sea ice thickness for March 2014. Track A is the USS New Mexico and Track B is the USS Hampton. The dates on the image above match the dates in the graphs at right.





These graphs compare the ULS ice draft from the USS Hampton [top] and the USS New Mexico [bottom] to the CryoSat 2 monthly-averaged sea ice thickness. The dates on the graphs above match the dates in the image at left.

~Images courtesy Scott Stewart for the U.S. National Research lab ArcticCAP project.

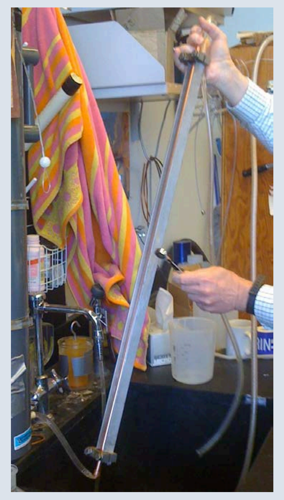
Ocean Nutrient Data

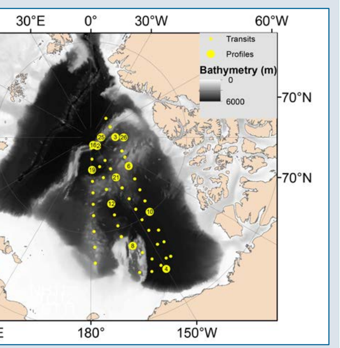
Chemistry data show that the rate of CO_2 uptake by the Arctic Ocean is twice the average for the global ocean, leading to acidification of the Arctic Ocean. Sensor estimates of chlorophyll and oxygen reflect the response of Arctic productivity to decreased sea ice extent during summer.

In March and April of 2014, the USS Hampton and USS New Mexico collected water samples across the western Arctic Ocean. Goals for this aspect of SCICEX include: a better understanding of freshwater flows, the determination of biochemical conditions such as the levels of nutrients and organic matter at the end of winter, and detection and quantification of the exchange of water between the peripheral shelves and the deep basins.

Water samples were collected from 53 locations. At 12 of these stations, a 6-depth profile was collected in the upper 250 m. Samples included nutrients, dissolved organic and inorganic carbon (DOC & DIC), particulate carbon and nitrogen, and a suite of geochemical tracers including ^{18}O, SF_6, $^3He/^3H$ and chlorofluorocarbons (CFCs). All profiles sampled the depth of the upper halocline (~33.1 salinity) that varied from a depth of 160-200 m in the southern Canada Basin to less than 60 m over the Lomonosov Ridge near the Pole.

The 2014 water samples are currently being processed and will be released in early 2015.





Top 2 images: Show different methods of processing the water samples.
Middle image: Shows a crewman collecting water samples from a makeshift lab on board a submarine.
Bottom image: Shows the water sampling locations for the 2014 SCICEX campaign.

CIRES

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