The ONR High Latitude Dynamics Program

An Introduction

This article was prepared by Dennis M. Conlon, Office of Naval Research and Office of Polar Programs, National Science Foundation, and Thomas B. Curtin, Office of Naval Research.

The complete history of the Arctic Program lies in the scientific literature and in the numerous successful naval missions accomplished. Art Baggeroer, Andy Heiberg, Ken Hunkins, Leonard Johnson, Ned Ostenso, Norbert Untersteiner, and Willy Weeks contributed significantly to this article, which borrowed substantially from Thomas Curtin's 1998 article, "Historical Perspectives on the Arctic Program at the Office of Naval Research," published in Naval Research Reviews, *vol. L, no. 1.*

From a historical perspective, there have been three stages of the U.S. Navy's interest in the Arctic. The first stage was marked by exploration, driven by personalities like Robert Peary (first to reach the North Pole), Robert Byrd (first to fly over the Pole), Lincoln Ellsworth (with Roald Amundsen, first to fly over the Pole in a dirigible), and Elisha Kent Kane (multiple Arctic expeditions). The second stage was characterized by more focused investigations and classified operations, framed by the Cold War and the advent of the nuclear submarine. The Office of Naval Research (ONR) was established in 1946 at the beginning of this second stage, and it immediately began supporting research in the Arctic. The third and current stage, marked by waning military interest, began with the end of the Cold War.

At first, Arctic research at ONR was supported by the Environmental Biology Program, but after a few years it migrated to the Geography Programs before finally becoming an independent Arctic Science Program in 1954.* Singular among Federal research programs in any field, the ONR Arctic Program has been managed by just seven people spanning over fifty years. The tradition of proactive, involved managers was established early, as documented in one of the program's first publications:

> "The Office of Naval Research has many Arctic experts working on various phases of its Arctic research program. Several of these men have contributed to this pamphlet. Sir Hubert Wilkins has written a valuable introduction and Dr. Vilhjalmur Stefansson has compiled a useful bibliography on Arctic literature. The main article of the pamphlet was written by Dr. M.C. Shelesnyak, Head of the Environmental Physiology Branch, Office of Naval Research. Dr. Shelesnyak gathered material about the Arctic as United States Naval Observer with the Moving Forces, Canadian Army Winter Arctic Expedition, Operation Musk-Ox, in 1945. The expedition traveled by motorized, tracked vehicles 3100 miles across the Canadian Arctic prairies, Queen Maude Gulf, Coronation Gulf and southward from Coppermine to Port Radium, across Great Bear Lake and down through the bush country along the Alaskan–Canadian Highway to Edmonton. Dr. Shelesnyak's first-hand knowledge of the Arctic was further broadened by his experiences in traveling by dog sled from Coppermine N.W.T. to Cambridge Bay, Victoria Island, having left the Moving Forces to rejoin them later."†

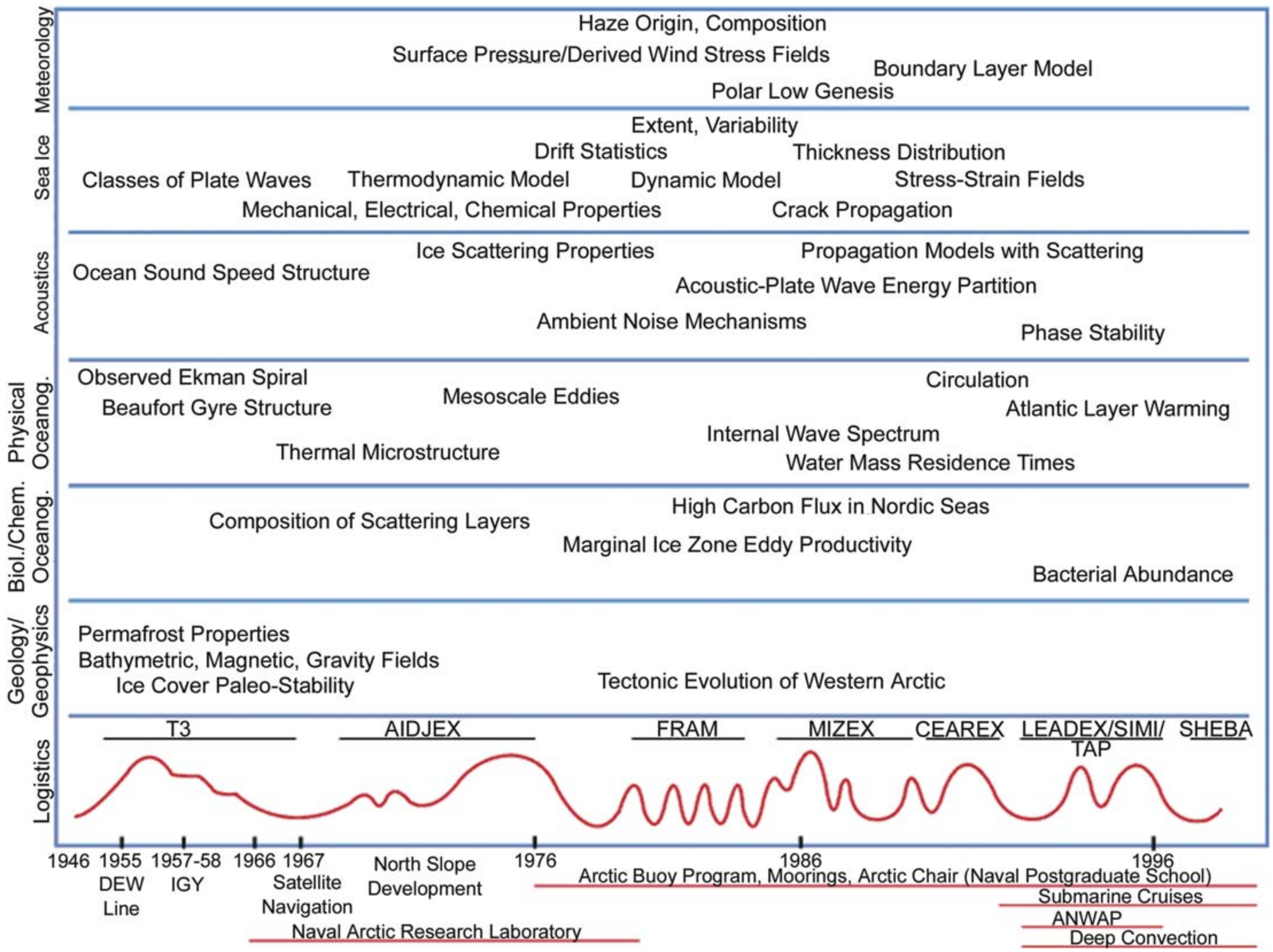
A very early initiative of ONR was building the Arctic Research Laboratory (later named the Naval Arctic Research Laboratory) near Barrow, Alaska, in 1947. With the construction of the USS *Nautilus*, the first nuclear-powered submarine, and its later transit of the Arctic Ocean, the importance of Arctic research was recognized at the highest levels of the Navy and the government. The perception of a growing threat from the Soviet Union sharply increased interest. At first, the concern was with Soviet submarines transiting the Greenland–Iceland–Faroe Gap to take up stations in the western Atlantic Ocean; later, the impetus for Arctic research came with the construction of the Typhoon Class, which could surface through the Arctic ice pack loaded with ICBMs.

Program managers of the Arctic Program since its inception at the Office of Naval Research.

1947–1954	M.C. Shelesnyak
1954–1970	M.E. Britton
1970–1975	R. McGregor
1975–1984	G.L. Johnson
1984–1994	T.B. Curtin
1994–1996	M. Van Woert
1996–2003	D. Conlon

* See Maxwell Britton (2001) The role of the Office of Naval Research and the International Geophysical Year (1957-58) in the growth of the Naval Arctic Research Laboratory." In *Fifty More Years Below Zero*, Arctic Institute of North America.

†Shelesnyak, M.C., and V. Stefansson (1947) Across the top of the world, A discussion of the Arctic." Office of Naval Research, Navy Department, NAVEXOS P-489, Washington, D.C.



A few of the major insights by discipline achieved over the years of the Arctic Program at the Office of Naval Research. The curve at the bottom shows the relative activity of ice stations.

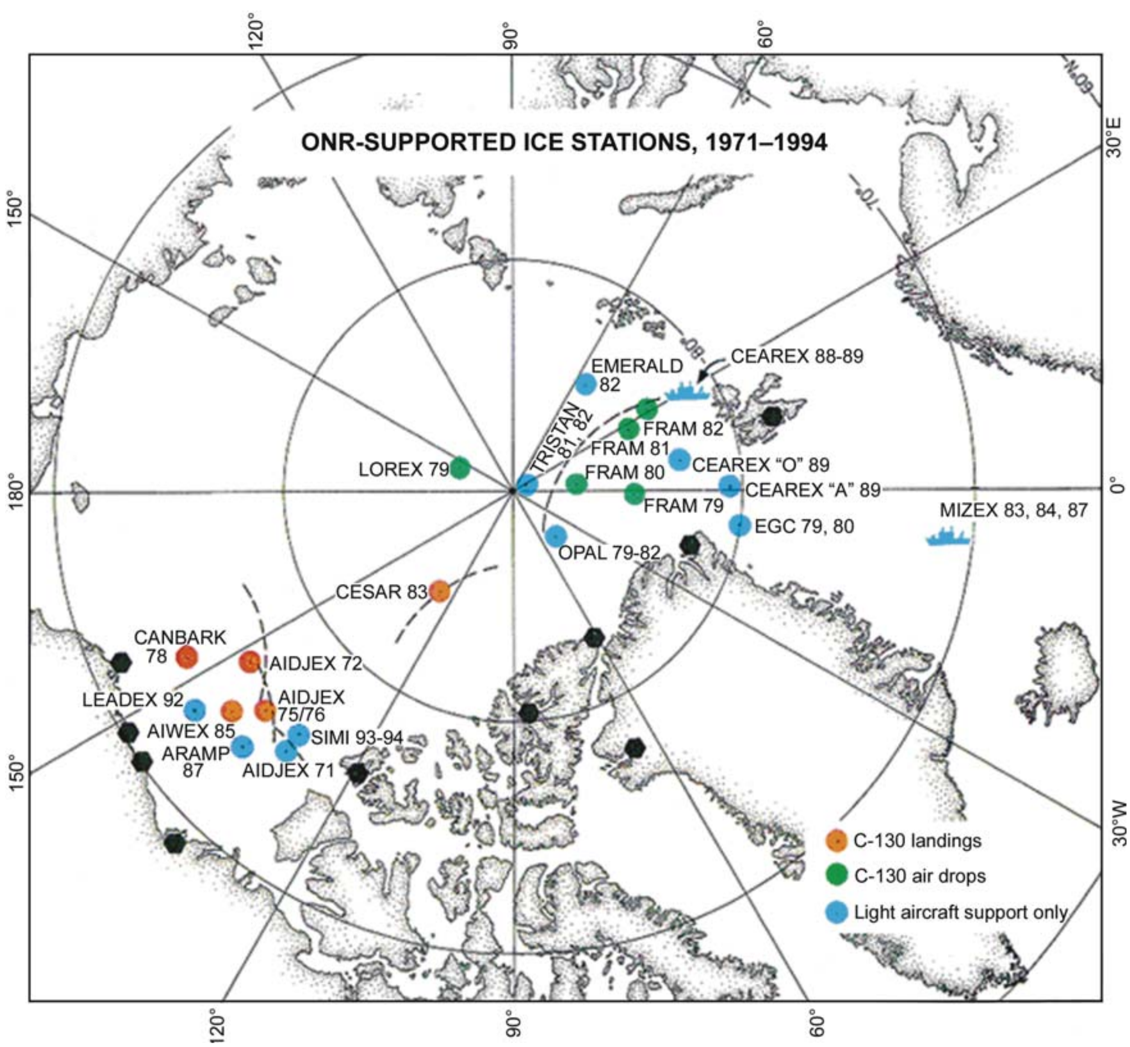
The Arctic Sciences Program became the leader in Arctic research in the Western world, paralleling the Soviet effort with its North Pole Stations and aircraft landings in the Arctic Seas, with the Arctic Ice Dynamics Joint Experiment (AIDJEX), a program largely stimulated by Dr. Norbert Untersteiner of the University of Washington. A veteran of the International Geophysical Year, Untersteiner convinced ONR to investigate how ice deforms in response to external stresses. The program began in 1970 with a pilot ice camp, and other efforts gradually built up to the peak effort in the summer of 1975, when four ice camps were built, surrounded by a constellation of data buoys that acquired data until the spring of 1976. During the following two decades, ONR initiated a series of large international field programs, including CANBAREX, FRAM I–IV (1979–1981), the Marginal Ice Zone Experiment (MIZEX, 1983-84, 1987), the Coordinated Eastern Arctic Experiment (CEAREX, 1987-88), the Leads Experiment (LEADEX, 1992), and the Sea Ice Mechanics Initiative (SIMI, 1993-94). Other major initiatives included Arctic Acoustics and Real-Time Environmental Arctic Monitoring (RTEAM).

The last major experimental effort supported by ONR was as a partner with the National Science Foundation in the Surface Heat Budget of the Arctic Experiment (SHEBA, 1997-98), in which the Canadian icebreaker *Des Grosselliers* was frozen into the pack ice and allowed to drift for 14 months. SHEBA focused on two feedback processes: ice–albedo feedback (increasing melt decreases albedo, further increasing melt) and cloud–albedo feedback (increasing melt increases clouds, increasing albedo and decreasing melt). Investigators were ferried on and off the SHEBA site, typically spending a few weeks performing research at one of several satellite structures surrounding the ship. Chief Scientists Richard Moritz and Don Perovich led an international team that developed a remarkable camaraderie during the year on the ice. According to Perovich, it was a common experience at mealtime to hear the words, "I saw the coolest thing today…."

Measures of the more than fifty years of research supported by the program are the associated cumulative scientific literature and the strategy and tactical procedures, both military and commercial, influenced by that knowledge. A comprehensive bibliography has not been compiled but would no doubt be impressive. These are a few of the major insights achieved over the years:

- Atmospheric circulation patterns and pollutant (haze) pathways are now well established.
- The mechanical, electrical, and chemical properties of sea ice, as well as its dynamics and thermodynamics over a hierarchy of scales, are known well enough to enable predictive models with some skill.
- The statistics of sea ice extent, variability, and drift, and to some degree its thickness, have been determined.
- The propagation of sound, at both low and high frequencies, including scattering and transformation into a rich class of plate waves, some of which were discovered initially in the Arctic, can now be modeled accurately.
- Ambient noise mechanisms have been established.
- The Ekman spiral, derived theoretically, was first observed in the Arctic, as was thermal microstructure.
- The ocean circulation, including water mass residence times and mesoscale eddy distributions, is now generally known.
- Unique aspects of the internal wave spectrum have been documented.
- The high primary productivity in the marginal ice zone has been quantified and its mechanisms elucidated.
- The Nordic Seas have been determined to be carbonate- (rather than silicate-) dominated, affecting global carbon sequestration.

Ice stations supported by the Office of Naval Research from 1971 through 1994.



- Near-surface bacterial abundance at high latitude is far greater than previously thought.
- The properties of permafrost are known and were used to great advantage in pipeline construction.
- Bathymetric, magnetic, and gravity fields have been mapped to useful resolution.

Understanding how much there is yet to be understood is always sobering. However, the contrast between the knowledge of the Arctic marine environment in 1945 and today gives an appreciation of how much has been accomplished.

Logistics has always been inextricable from science in the Arctic. Ice stations or camps have been central ways of doing business since Nansen pioneered the method with the *Fram*. During peak years, logistics costs typically ranged from $2 to 4 million, consuming 20–40% of the program budget. From the mid-sixties to the late seventies, many expeditions in the western Arctic were staged from the Naval Arctic Research Laboratory. Eastern Arctic stations were staged from Greenland or Norway. Since the Navy's divestiture of NARL to the North Slope Borough in the late seventies, there has been a slow but steady trend toward autonomous instrumentation. That trend is expected to accelerate in the coming years, with advances in microprocessor, navigation, and communication technology. Considering the number and diversity of people involved, the variability and extremes of nature, the remote and Spartan accommodations on the ice, and the invariably tight budgets, it is a notable tribute to the operations managers over the years that all have returned safely to analyze their data. One of the constants of experiments from AIDJEX on was the participation of Andy Heiberg of the Polar Science Center of the University of Washington; he has received awards from both ONR and NSF for his contribution to the logistics of Arctic research.

With the fall of the Soviet Union and the disappearance of an ICBM threat under the Arctic ice, support within the U.S. Navy for Arctic research began to decline, a process that accelerated in the late 1990s until the termination of the program in 2003. Ironically, it was the decline of a threat that also allowed the U.S. Navy to provide a nuclear attack submarine for Arctic research during the period 1993–2001, the SCICEX Program (described in detail in the article on p. 14, this issue).

Beginning in the mid-1990s, the decline in the program's funding was dramatic; in 1995 the Arctic Program funding was approximately $25 million (including a special $10 million appropriation for the Arctic Nuclear Waste Assessment Program, ANWAP), was managed by a staff of five program officers, and supported around 100 investigators. By 2003 the program was funded at less than $2 million, supported fewer than 30 investigators, and was managed by a single program officer. In fact, the impact on the field was far greater. In 1995 the average award of nearly $250 thousand paid for a significant fraction of the investigator's time and usually included a graduate student. Moreover, it was normal to be funding a major field effort every two or three years. By 2003 the average award of less than $70 thousand bought a month or two of the investigator's time, and field work was usually dependent on another agency's initiative.

Building on high-quality, multi-disciplinary investigations, key elements of the program, established at its inception and maintained for over a half century, were international collaboration, bold field experiments, development and use of innovative technology, and support of graduate students. The research community has lost a program to which they could come with innovative, risky ideas and pursue those ideas expeditiously in partnership with a fully engaged sponsor. In many ways, this engagement was the ONR paradigm envisioned by its founders.

What of the future for Navy interest in Arctic research? The simple answer is that the interest will be dictated by the need for missions in the Arctic, and future missions are difficult to predict. Dramatic environmental changes are clearly underway at polar latitudes, especially in the Arctic, and some projections predict economically useful openings of the Northern Sea Route and perhaps even the Northwest Passage. The need for enlightened leadership and a prescient investment strategy is acute.

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