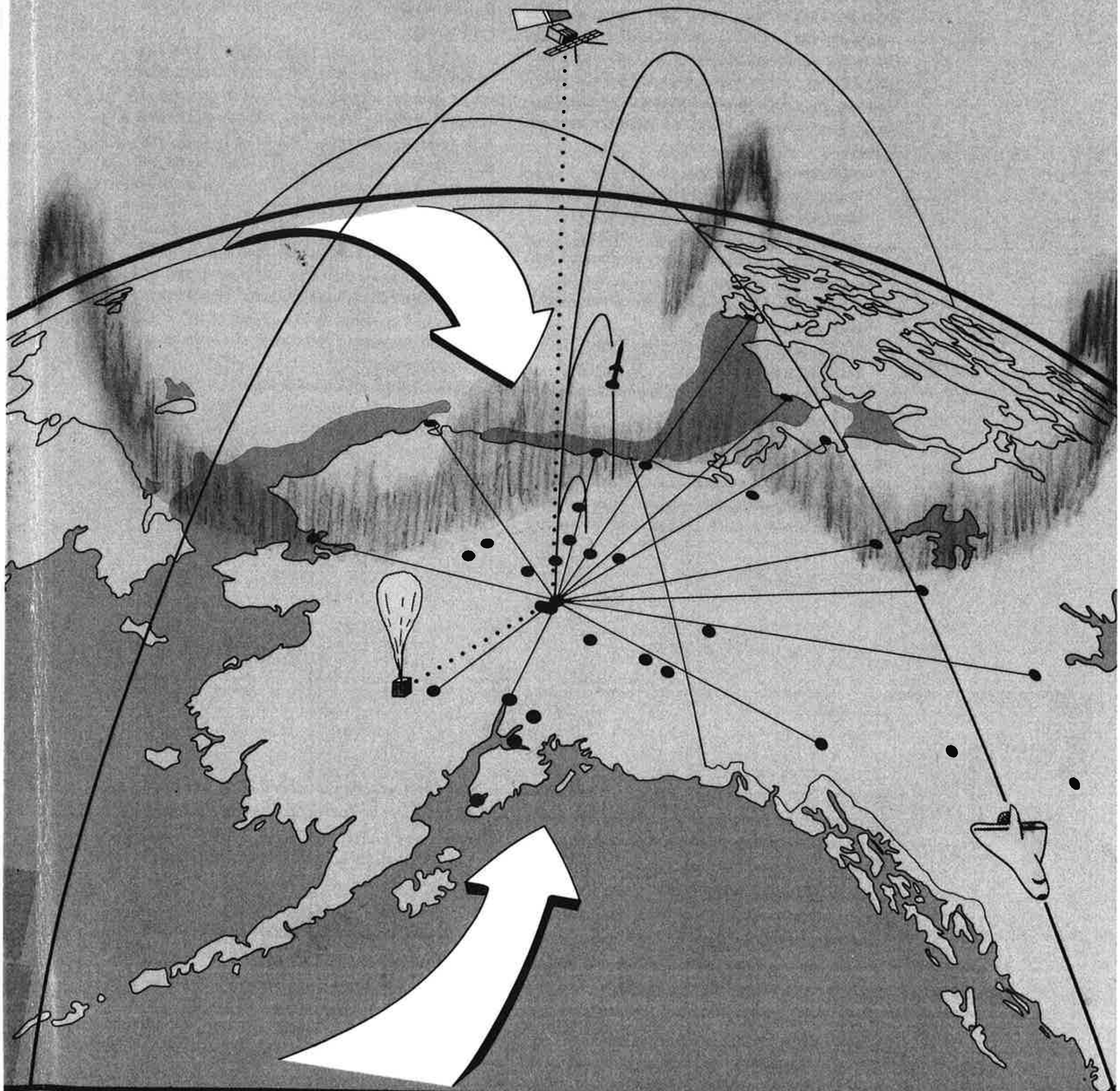
VOLUME 3

SPRING 1989

ARCTIC RESEARCH
OF THE UNITED STATES



INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee and the Arctic Research Commission. Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

- Reports on current and planned U.S. Government-sponsored research in the Arctic;
- Reports of ARC and IARPC meetings;
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector and other nations; and
- A calendar of forthcoming local, national and international meetings.

Arctic Research is aimed at national and international audiences of government officials, scientists, engineers, educators, private and public groups, and residents of the Arctic. The emphasis is on summary and survey articles covering U.S. Government-sponsored or -funded research rather than on technical reports, and the articles are intended to be comprehensible to a nontechnical audience. Although the articles go through the normal editorial process, manuscripts are not refereed for scientific content or merit since the journal is not intended as a means of reporting scientific research. Articles are generally invited and are reviewed by agency staffs and others as appropriate.

As indicated in the United States Arctic Research Plan, research is defined differently by different agencies. It may include basic and applied research, monitoring efforts, and other information-gathering activities. The definition of Arctic according to the ARPA is "all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain." However, areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

Issues of the journal will report on Arctic topics and activities. Included will be reports of conferences and workshops, university-based research and activities of state and local governments and public, private and resident organizations. Unsolicited nontechnical reports on research and related activities are welcome.

Front Cover

Existing and planned activities associated with the Poker Flat Research Range and the Geophysical Institute of the University of Alaska–Fairbanks. Unique among Arctic rocket facilities is the extensive land area downrange and the network of associated ground-based observatories, represented by black circles. The Poker Flat impact area is slightly larger than Indiana and is open to the Arctic coast, allowing almost unlimited suborbital and orbital flight towards the pole. A satellite downlink will allow real-time evaluation of data from observing platforms in near-earth space, including the space shuttle. Real-time communication and display of data from remote riometers, magnetometers and optical instruments at various field observatories, including the Alaskan–Canadian chain and part of the Canadian Canopus Network, will allow immediate evaluation of the constantly changing auroral atmosphere in support of rockets and high-altitude balloons. Measurements of upper atmospheric density and turbulence will support polar-orbital space shuttle operations. An extensive array of optical and radio instruments at Poker Flat will observe the properties of the Arctic atmosphere from the ground to the exosphere. In addition, the air-sampling station at this continental subarctic position will be expanded to include measurements of an array of background atmospheric constituents in the polar and Pacific air masses, which are extremely sensitive to global changes.

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Address correspondence to
Editor, *Arctic Research*
Division of Polar Programs, Room 620
National Science Foundation
Washington, D.C. 20550

Cooperation and Partnership

The Arctic Research and Policy Act of 1984 is five years old. The Interagency Arctic Research Policy Committee and the Arctic Research Commission have evolved together during this period, establishing an integrated Arctic research policy and producing numerous recommendations and reports. During that time, and often in coordination with the Committee or the Commission, the National Academy of Sciences, Arctic residents, and university and professional organizations also contributed statements and reports on U.S. Arctic research.

Positive results of these activities are beginning to emerge. For instance, in the first biennial revision to the U.S. Arctic Research Plan, to be submitted to the President in July 1989 and then to the Congress of the United States, three cooperative interagency programs are proposed and the first step towards establishing an Arctic social science program are outlined. (The full text of the revised Plan will appear in the fall issue of *Arctic Research*.) The success of the proposed research on oceans, atmosphere, land, resource, environments and people will depend on cooperation in planning and implementation among the Federal agencies, the State of Alaska, the people of the Arctic, the private and public sectors, and finally, other countries. New mechanisms for international cooperation are being developed among the countries and scientists involved in Arctic research. The international community is now on the verge of agreeing to a new organization to guide international Arctic research.

The last issue of *Arctic Research* summarized the Arctic research activities in twelve Federal agencies. This issue is different in several ways. It contains several invited papers that highlight some U.S. accomplishments in Arctic research and point towards future challenges and opportunities. To further demonstrate the broad, multidisciplinary nature of Arctic research and related activities and their support, numerous reports of past and current national and international conferences, workshops and activities are presented. Finally, this issue reflects a new enterprise of joint responsibility for the journal and Arctic research between the Interagency Committee and the Commission.

As we enter the last decade of this century, the Arctic will increase in importance on all levels—the environment, resources, people and national security. The next several years will be crucial to the success of ARPA itself. The challenges and opportunities and accomplishments rely on increasing cooperation and partnerships, both nationally and internationally.

ERICH BLOCH
Chairman of the Interagency Arctic Research Policy Committee
JUAN ROEDERER
Chairman of the Arctic Research Commission

International Marine and Atmospheric Arctic Science
Past–Present–Future

G. LEONARD JOHNSON, VERA ALEXANDER AND RUSSELL SCHNELL

This article is a general overview of the last ten years of international Arctic marine research in which U.S. participation has been significant. This includes research from aircraft, ships and ice stations. The U.S. has contributed scientifically to many international projects, but much of the seagoing logistics support has been provided by other nations since the U.S. has no truly ice-capable research vessels. In addition to the Soviet Union, three countries—West Germany, Sweden and, in the 1990s, Canada—have (or propose to have) the capability for deep penetration of the Arctic. These capabilities can support sophisticated multidisciplinary and international science programs. The U.S. remote sensing aircraft, including the NASA and NOAA DC-8, WP-3D and ER2 provide outstanding support. Satellite remote sensing is another capability with which the U.S. has made substantial contributions. This will intensify with the implementation of the new SAR capability through the ERS-1 satellite to be launched in 1990.

The Arctic is an international arena, and international cooperation has generally been the modus operandi. For the most part the cooperation has been fostered by the initiative and will of the Arctic scientific community and not by administrative decree. This grass roots support has resulted in strong scientific programs, which will be evident from the following sections.

Completed Projects

The Fram Expeditions: Arctic Ocean Studies from Floating Ice, 1979–1982

In May 1982, with the successful conclusion of Fram IV, the Office of Naval Research (ONR) completed the Fram series of observations from ice floe stations in the eastern Arctic. These expeditions were initiated each spring from 1979 to 1982. From its inception the Fram ice station program emphasized multi-disciplinary research by scientists of several nations. The stations were under U.S. management, with logistics coordinated by the Polar Research Center, University of Washington, under ONR contract. Danish scientists were involved through the Commission for Scientific Research in Greenland, Norwegians through the Norsk Polarinstitutt, British scientists through the Scott Polar Research Institute, and Canadians through the Bedford Institute of Oceanography. Each expedition emphasized a particular scientific discipline with supporting programs, as listed below (the priority discipline is listed first):

- Fram I (March 11 to May 5, 1979): Geophysics, hydroacoustics, oceanography, marine biology;
- Fram II (March 19 to July 5, 1980): Hydroacoustics, oceanography, geophysics;
- Fram III (March 14 to May 13 1981): Oceanography, geophysics, hydroacoustics, marine biology; and
- Fram IV (March 15 to May 11 1982): Hydroacoustics, geophysics, physical oceanography.

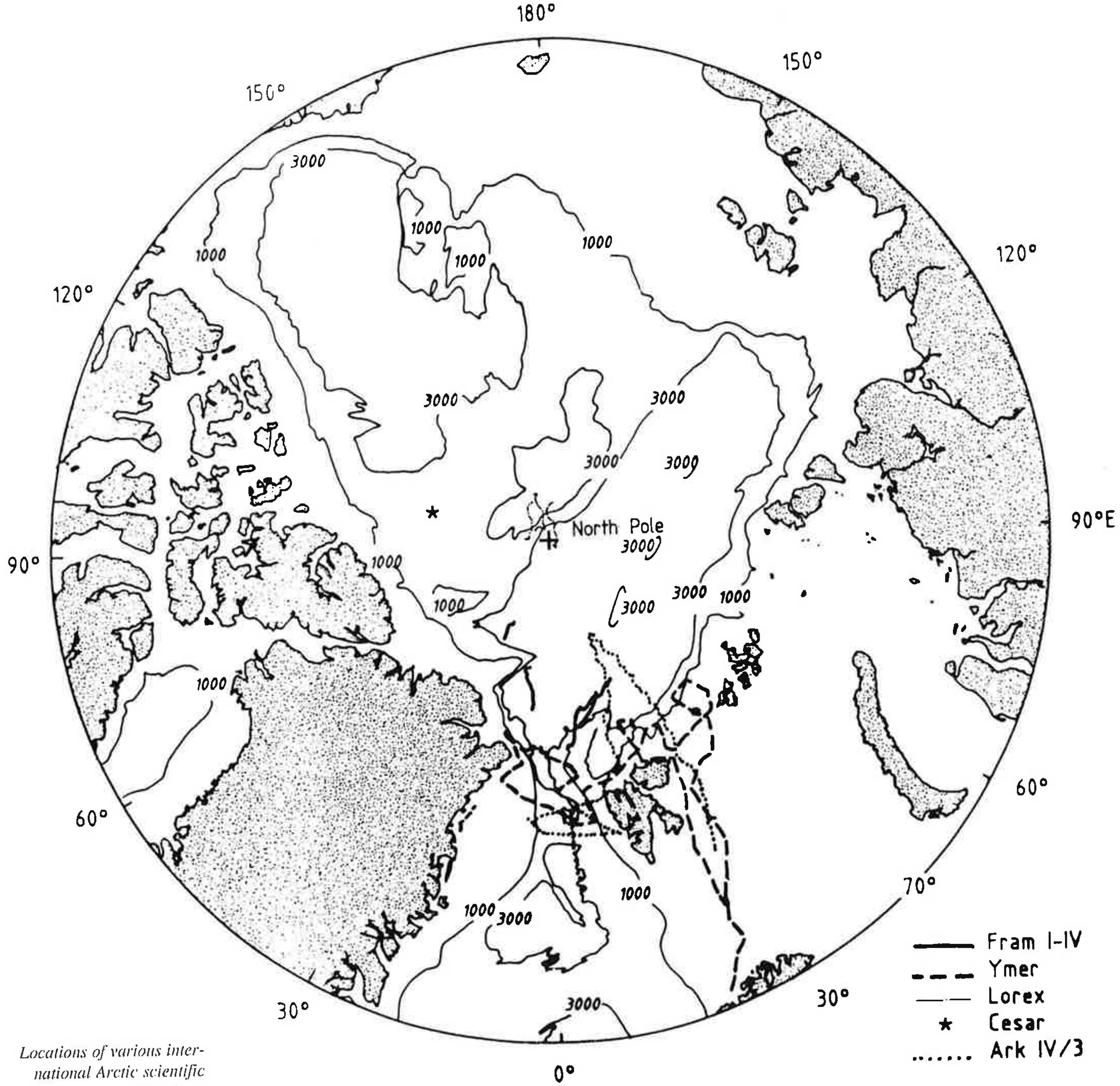
Fram IV was part of a coordinated program celebrating the centennial of the First International Polar Year, 1882–83.

A major finding of the Fram expeditions was that the oceanic crust in this area is about 3 km thick, which is less than half the thickness of normal oceanic crust. Fram I data from the main axis of spreading suggest that the inner floor of the rift valley narrows as the rate of spreading decreases.

Though oceanographic conditions in the Eurasian Basin area have been studied intermittently since the time of Nansen, the Fram program used modern instruments for the first time to obtain continuous profiles of salinity, temperature and currents through the full depth of the water column. The region of the polar frontal boundary between outflowing Arctic cold surface water and inflowing Atlantic water in Fram Strait was of special interest. Significant amounts of heat and salt are transferred through this strait; fluctuations in the flow affect the weather of Greenland and Iceland and may influence long-term climatic changes. Water samples collected from all Fram stations were analyzed for tritium and the helium 3 isotope. The results suggest that Nansen Basin water below the upper mixed layer is a mixture of Atlantic water and fresh water from the Siberian rivers. Derived tritium values suggest that the fresh water component in the Eurasian Basin is approximately 11 years old.

Data were collected for modeling the distribution and movements of sea ice and estimating the volume of ice exported through Fram Strait and down the east coast of Greenland. The inherent

G. Leonard Johnson is Director of the Geo-Acoustics/Arctic Division at the Office of Naval Research, Arlington, Virginia 22217. Vera Alexander is Director of the Institute of Marine Sciences at the University of Alaska, Fairbanks, Alaska 99775. Russell C. Schnell is Director of the Arctic Gas and Aerosol Sampling Program; he is located at the Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder 80309.



Locations of various international Arctic scientific expeditions.

properties of the ice were also studied, for example, its flexure due to surface and internal waves. Waves with periods of 30 seconds and amplitudes of about 3 mm were detected, as well as much longer waves of 9-minute period and higher amplitude.

Samples were taken on Fram I to investigate the chemical composition of the air, specifically to identify pollutants and if possibly trace their origins. Augmenting data from Greenland, Svalbard and Canada, they strongly suggest that much of the pollution aerosol in the Arctic atmosphere is derived from the Soviet Union. The smelter complex at Noril'sk is an identifiable contributor of high levels of nickel, cobalt and chromium.

On Fram I, biologists from the Zoological Museum of Copenhagen conducted a successful biological program of deep-water studies. Nine species of Isopoda (Crustacea) were reported from the Pole Abyssal Plain and the Nansen Ridge (the Arctic mid-ocean ridge) northeast of Greenland at depths between 2300 and 4000 m. These were the first isopods to be recorded from the deep polar seabed. Six of the species were previously undescribed. Fram I was also used by biologists of the Norsk Polarinstitutt for a polar bear tagging program. Four bears were tranquilized and fitted with collars carrying radio transmitters, making it possible to track their movements by satellite. After a month two of the bears had moved eastwards to Svalbard and Franz Josef Land, one remained in the same general area, and one moved south. At times the bears must have traveled over 40 km per day, often moving against the general drift of the ice. The biologists now believe that polar bear populations from Svalbard and east Greenland mix more freely than was previously assumed.

The metabolism of deep-water organisms is thought to be fueled both by food particles falling from the surface layer and by organic matter included within the water masses during their formation. On Fram III, biologists from the University of Maine investigated the relative importance of these two components under the high Arctic ice pack. Their results indicated that, although surface productivity in the ice field is generally low, the rain of organic material from the surface is still the major source of energy for deep-water organisms.

Lomonosov Ridge Experiment (LOREX)

The central and longest ridge in the Arctic is the Lomonosov, which passes close to the North Pole. The Lomonosov Ridge has been the subject of speculation since it was discovered during the winter of 1948–49 by Russian scientists, who named it after the 18th century Russian scientist, poet and grammarian. A major multi-disciplinary international polar expedition to investigate the nature and origin of Lomonosov Ridge was led by the Department of Energy, Mines and Resources of Canada in the spring of 1979.

This ridge is an aseismic submarine mountain range that extends over a distance of 1700 km from the continental shelf off Ellesmere Island to the continental shelf off the New Siberian Islands and forms the border between the Eurasian and Amerasian basins.

Lomonosov Ridge is generally accepted as being a continental splinter rifted away from the Barents Shelf, based on constraints from plate reconstructions. Seismic reflection and refraction data collected on ice station LOREX support this theory. A single-channel high-resolution seismic profile across the Lomonosov Ridge displays a saw-tooth asymmetrical feature with a thin veneer of sedimentary cover. Refraction data along the strike of the ridge measured two layers: a 5-km-thick upper crustal layer with a velocity of 4.7 km/s and a small velocity gradient underlain by a lower crustal layer with a velocity of 6.6 km/s, also with a small velocity gradient. Mantle velocities of 8.3 km/s were reached at a depth of about 27 km. Physical oceanographic measurements represent the first modern deep sea data from the central Arctic basin, which yielded water mass dating and evidence of currents scouring the ridge.

Canadian Expedition to Study the Alpha Ridge (CESAR)

The geological origin and age of the Alpha Ridge and its sedimentary cover have long been the subject of controversy regarding the tectonic evolution of the Arctic Ocean and its paleoenvironmental history. A major multidisciplinary international polar expedition to investigate the nature and origin of the Alpha Ridge was led by the Department of Energy, Mines and Resources of Canada in the spring of 1983. The geological aims of CESAR were to collect data that would help clear up the following problems:

- The tectonic origin and age of the Alpha Ridge;
- The lithostratigraphy and depositional history of the overlying sediments; and
- The paleoceanographic and paleoclimatic evolution of the Arctic Ocean.

A reversed 210-km-long crustal refraction line was shot along the crest of the Alpha Ridge. The sedimentary sequence varies in thickness up to 1 km and has a high velocity gradient. The basement material on which the sedimentary cover was deposited has a velocity of 5.3 km/s. This velocity is typical of oceanic layer 2. Dredged material from the exposed basement of the ridge was a weathered alkaline volcanic rock consistent with this interpretation. The velocity structure of the layer below this ranged from 6.45 to 6.8 km/s, with both positive and negative velocity gradients. At depths of 20 km a laterally consistent velocity of 7.3 km/s was measured. The measured depth of the crust-mantle is 38 km. The thick crustal structure, morphology, heat flow, magnetics and rock type of the Alpha Ridge resembles the Late Cretaceous plateaus of the Pacific Ocean. The velocity depth profile of the Alpha Ridge is similar to Iceland: a modern oceanic plateau.

Quantitative studies of the relation between foraminiferal assemblages, temperature and salinity will permit firm conclusions to be drawn regarding the Late Cenozoic paleoceanographic history of the Arctic Ocean. However, the CESAR core data suggest the following:

- Contrary to the Ewing–Donn theory of Arctic glaciation, there is no evidence for ice-free intervals in the central Arctic Ocean during the past million years;
- Late Pleistocene decreases in total foraminifera probably reflect dilution of surface water salinity by increased runoff; and

- Low total abundances and high ratios of benthic to planktonic foraminifera in the Late Pliocene sediments probably reflect increased carbonate dissolution on the seafloor.

One core was especially interesting in that it dated from Late Cretaceous to Eocene and recorded warm, temperate oceanic conditions during that time.

Ymer-1980

The first ship to sail through the Northeast Passage was the *Vega,* with A.E. Nordenskiold as expedition leader. Nordenskiold left Sweden in 1878. In a lecture to the Royal Society of Naval Sciences in 1976, Commander Bertil Daggfeldt proposed an expedition aboard the *Ymer,* a large Swedish icebreaker, following in the tracks of the *Vega* over to the Bering Strait, back through the Canadian archipelago and south of Greenland—a worthy centennial commemoration of Nordenskiold's great voyage.

The expedition took place in 1980; because of geopolitical considerations, the ship's track was shortened to the Fram Strait region and north and east of Svalbard. The prime scientific objectives were to study

- The chemistry of the Arctic atmosphere, particularly the pollution caused by industrial activities in temperature latitudes;
- Marine biology, with emphasis on the evolution of species in the Arctic Ocean; and
- Marine geology, particularly the bottom sediments along the route to establish the extent of former glaciations and past climatic variations.

The expedition was truly international, with 119 scientists engaged in the fieldwork. Of these, 76 were Swedish scientists and 43 were non-Swedish, coming from Norway, Denmark, Finland, Great Britain, Germany, Luxembourg, the U.S. and Canada.

The expedition found that marine life was quite abundant over the shelf. Every trawl and bottom dredge contained a great number of sea cucumbers, starfish and sea spiders. There were differences in shelf fauna between stations north and south of Kvitoya (White Island). There were many more small crustaceans on the exposed northern flank than to the south of the island, where echinoderms and soft corals were more common. At greater depths the number of species, as well as the number of individuals, decreased rapidly just outside the continental slope. At a depth of 3920 m on the flat abyssal plain, life was sparser than expected—few species and few individuals. A species of sea cucumber and some sponges were dominant, but there were also some tubicolour polychaetes and one species of small sea anemone. It appeared that benthic life is infrequent on the bottom of the deep Arctic basin (and probably more so than in any other ocean).

A large number of CTD casts, water samples and current meters enabled the first delineation of the West Spitzbergen current as it sinks beneath the surface polar waters to form an intermediate warm, salty layer.

The chemical oceanographers found fewer pollutants than anticipated. Heavy metals, such as copper, zinc, cadmium and lead, appeared in very low concentrations. One reason might be that very small zooplankton, living on phytoplankton, take up the heavy metals, which then reach the bottom sediments as faecal pellets and thus do not stay in the water. The new snow collected on ice floes in the Arctic Ocean had a lead content that was lower than even that of central Greenland (the source of the lead is high-octane gasoline burned in North America and Western Europe). About 30,000 analyses were made from the 2500 water samples collected during the expedition.

Piston cores revealed a much higher sedimentation rate than had previously been recorded for the Arctic. The sedimentation rate in the eastern Arctic appears to be about twice that of the western Arctic.

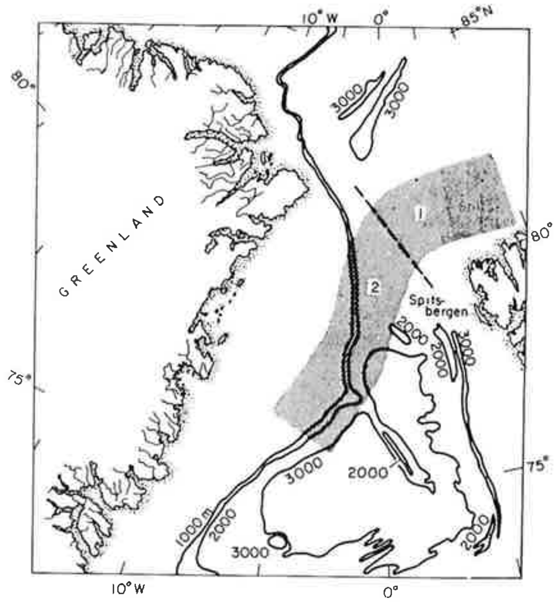
Marginal Ice Zone Experiment (MIZEX)

The overall objective of the Marginal Ice Zone Experiment was to gain a better understanding of the mesoscale physical and biological processes by which ice, ocean and atmosphere interact in the region of the ice edge.

MIZEX West 82/83

The program goal was to better understand the physical oceanographic, meteorological and sea ice processes that dominate the midwinter Bering Sea marginal ice zone. Specific objectives were

- To understand the oceanographic frontal systems associated with the ice edge, as well as the interactions among these and the ice cover;
- To understand the sea ice rheology within about 100 km of the ice edge;
- To characterize an ice balance for the marginal ice zone;
- To determine the role of ocean wind waves and swell in breaking up and driving ice floes;
- To explore the means by which ice bands are formed;
- To document modifications of the atmospheric boundary layer over the marginal ice zone; and
- To improve parameters needed for modeling marginal ice zone processes.



Location of MIZEX field efforts in Fram Strait and the Greenland Sea. Area 1 was the primary focus of the effort in 1983–84, and area 2 was the focus in 1987.

These objectives were approached through an international program involving participants from Science Applications International Corporation, NOAA's Pacific Marine Environmental Laboratory, the University of Washington, the Jet Propulsion Laboratory, NASA's Goddard Space Flight Center, the U.S. Geological Survey, the U.S. Army Cold Regions Research and Engineering Laboratory, and Scott Polar Research Institute.

Data were collected on physical oceanographic, sea ice and meteorological conditions using three vessels, which operated in the marginal ice zone during February and March 1983, and moored current meters, which were deployed from October 1982 to May 1983 in locations bracketing the midwinter ice edge. Additional data on sea ice distribution were obtained from the AVHRR sensors on the NOAA satellite and by overflights using instrumented aircraft. These aircraft also obtained meteorological data.

The scientific results of this program included detailed physical descriptions of the ice-edge frontal system. This front is present in the vicinity of the ice edge only in winter and has an associated northwestward current of 10–15 cm/s. The baroclinicity that leads to frontal formation is caused by the input of meltwater from the ice. The frontal location represents a balance between southward-moving ice that melts along the ice edge and northward-flowing water from the north Pacific across the Bering Shelf. In addition to this regional and mesoscale description, small-scale processes were clarified. Surface waves were shown to affect ice movement along the edge and to play a role in the development of ice banding. The effects of ice in damping out waves were further quantified. New data were acquired on the rate of ice floe melting and the development of the atmospheric boundary layer under varying conditions of wind and temperature.

MIZEX East 83/84

Summer field experiments began in June and July 1983 on a limited scale. The full-scale field experiment was conducted between May and July 1984. The Fram Strait region between Svalbard and Greenland was chosen because this area is crucial for the study of energy interactions across the ice margin; most of the heat and water exchange between the Arctic Ocean and the rest of the world is through this strait. MIZEX 84 was the largest coordinated, international Arctic research program conducted in the marginal ice zone, integrating the resources and expertise of 11 nations. MIZEX 84 operations used seven ships, eight remote-sensing and meteorological aircraft, and four helicopters to support a multidisciplinary team of over 200 scientists and technicians. Scientists, equipment and support came from Canada, Denmark, West Germany, Finland, France, Ireland, Norway, Sweden, Switzerland, the U.K. and the U.S.

Five prominent ice-edge eddies in Fram Strait on the scale of 30–40 km were observed over deep water within 77°N to 79°N and 5°W to 3°E. The use of remote sensing, satellite-tracked buoys, and in situ oceanographic measurements showed the presence of eddies with orbital speeds of 30–40 cm/s and lifetimes of at least 20 days. Ice ablation measurements made within one of these ice–ocean eddies indicated that melting, which proceeded at rates of 20–40 cm/day, is an important process in determining the ice-edge position. These studies give new insight on the formation, propagation and dissipation of ice-edge eddies.

Sequential remote-sensing images of the Fram Strait marginal ice zone played a key role in elucidating the complex interactions of the atmosphere, ocean and sea ice. Analysis of a subset of these images covering a one-week period provided quantitative data on the mesoscale ice morphology, including ice-edge positions, ice concentrations, floe size distribution and ice kinematics. The analysis showed that, under light to moderate wind conditions, the morphology of the marginal ice zone reflects the underlying ocean circulation.

A major component of the Fram Strait MIZEX was the investigation of air–sea–ice interactions, processes and circulation patterns found behind the local ice edge and on scales greater than 10 km (mesoscale and large scale). Neutrally buoyant floats, ice-tethered cyclesondes and helicopter-based measurements were used to obtain uniquely integrated and consistent views of the mesoscale ocean features beneath the ice cover of Fram Strait. Within the vicinity of the Yermak Plateau, three distinct regions of mesoscale motion were observed that coincide with the shallow topography of the plateau.

It is estimated that 84% of the ice exiting the Arctic Basin through Fram Strait during June and July 1984 was multiyear ice and that a large percentage of this ice is ridged or otherwise deformed. While freeboard and thickness data, together with salinity measurements on cores, usually sufficed to distinguish between first-year and multiyear floes, preliminary identification could usually be made on the basis of snow cover measurements, because the snow cover is much thicker on multiyear ice. Age estimates of multiyear floes, based on petrographic and salinity characteristics of cores, did not exceed 4–5 years for any of the floes that were observed exiting Fram Strait.

MIZEX East 87

Winter MIZEX 87 was conducted during March and April 1987 in the Fram Strait and Greenland Sea area. Two Norwegian ships, R/V *Hakon Mosby* and the ice-strengthened R/V *Polar Circle* with a helicopter, and the German R/V *Valdivia* participated in the experiment. In addition, flight operations were carried out by two Canadian SAR aircraft and a Norwegian P3.

Winter MIZEX 87 investigations were based on the need, demonstrated by summer MIZEX results, to understand the atmosphere–ice–ocean processes responsible for the advance of the winter ice edge, and the effects on acoustics and electromagnetic remote sensing, under different conditions than in summer. MIZEX 87 had the following primary goals:

- To provide the first comprehensive oceanographic mesoscale data set with emphasis on fronts, ice–ocean eddies, deep convection and internal waves in the winter marginal ice zone vital for ocean and acoustic modeling;
- To demonstrate the remote-sensing capabilities of synthetic aperture radar (SAR) for detecting and tracking winter ice–ocean eddies, discriminating ice types, and determining ice concentration and ice kinematics;
- To provide mesoscale meteorological data for the winter marginal ice zone;
- To provide a unique data set on ice and surface gravity wave interactions in winter;
- To provide ambient noise data integrated with environmental data to improve our understanding of ambient noise generation by geophysical processes; and
- To obtain a unique data set on biological activity of the winter marginal ice zone and during the onset of light.

The unique opportunity to receive downlinked SAR images of the investigated area enabled a real-time study of the evolution of meanders and ice–ocean eddies in the marginal ice zone. Under moderate wind conditions, the sea-ice motion is a good indicator of the upper ocean circulation. One of the highlights of this experiment was the observation of numerous vortex pairs along the ice edge. A vortex pair starts as a local set that develops into two counter-rotating eddies. A typical vortex pair along the ice edge is 30 km long. Their lifetimes are difficult to estimate, but the ice signature indicates that they can be as short as 3–4 days.

The mesoscale thermosaline and velocity structure off the ice edge in Fram Strait between 75–79°N and 4°W–4°E was studied by the *Hakon Mosby*, which collected 50 sections, combining towed undulating CTD (SeaSoar), standard CTD casts and Acoustic Doppler Current Profiler (ADCP) observations. Complex mesoscale thermohaline structures were occasionally observed with SeaSoar. Most striking were the manifestation of several narrow, well-mixed chimney-like features with widths of 5–10 km and vertical thicknesses of more than 250 m. The near-uniform densities in these chimneys were 0.07 sigma-theta less than the average density of 28.09 sigma-theta of the deep water below 1500 m. The thermohaline structure gives the impression of upwelling of intermediate water of Atlantic origin.

The large-scale circulation and hydrography in the Greenland Sea and Fram Strait was surveyed by the *Valdivia* along five sections. These covered the area between 71° and 79°N and between the polar pack ice and the shelf break of the Barents Sea in the east. The most prominent finding was the close coupling of the circulation and the boundaries between different water masses with the bottom topography. Buoys, released on either side of the Greenland fracture zone only 30 km apart, followed very different circulation regimes. One buoy moved northward in the West Spitsbergen Current/Boreas Gyre along the western flank of the Knipovitch Ridge, while the other two looped around the Greenland Gyre, completing half a circle in five months.

In general, the marginal ice zone is a region with a high atmospheric drag coefficient, with the lower values over the interior ice and the open ocean, which would imply higher wind stress in the marginal ice zone. However, this assumes that the surface wind speeds are constant, which is not realistic. Because of the rougher and more stable (cold) surface, the surface wind speed was less over the ice. The result was that the pattern of wind stress in the marginal ice zone was very complicated and does not have a typical pattern for all conditions. Factors that affect the height of the inversion also affect the surface wind speed and must be considered when modeling wind stress. For example, the movement of ice is affected by clouds, since clouds affect the surface wind speed.

Preliminary analysis of the SAR data indicates the following:

- SAR imagery can be used to differentiate between first-year ice, multi-year ice and many stages of young ice;
- SAR imagery can be used to detect surface expressions of eddies, both in the open ocean and within the ice pack;
- SAR imagery permits the tracking of ocean waves, both outside and propagating approximately 100 km into the ice pack; and
- SAR imagery shows internal wave features beneath the ice packs.

Phytoplankton biomass and photosynthetic response were also measured as part of the biological program of MIZEX 87. Surface chlorophyll-a concentrations averaged 0.022 mg/L. These concentrations are extremely low, indicating that phytoplankton growth had not proceeded significantly by the time of the study (March–April).

Arktis Expedition (ARK IV/3)

The expedition began in Tromso on 4 July 1987 and ended in Hamburg on 2 September 1987. Fifty-seven scientists and technicians from 19 institutions in 8 European and North American countries joined forces to carry out a complex program of oceanographic, meteorological, biological and geoscientific studies. The *Polarstern* succeeded in penetrating the eastern Arctic ice pack as far north as 86° 11′N, farther than any surface ship dedicated to scientific research. It also represented the first modern, mobile, surface research platform with sophisticated equipment to reach a central Arctic area and the first oceanographic transect into the basin interior.

The Arctic Ocean is one of the last poorly investigated and poorly known deep-sea areas of the world ocean. *Polarstern* for the first time collected detailed and precisely positioned bathymetric and gravimetric data from the continental margin north of Svalbard, the adjacent abyssal plain, and the southern and northern flanks of the Nansen–Gakkel Ridge, as well as from its central valley.

Basement rocks were sampled in the central part of the ridge. In one box core, large pieces of hydrothermally and possibly tectonically altered basalts covered by a thin sediment layer were collected. They represent the only sample of undisturbed basement rocks from the entire Eurasian Basin; they are also the only sample from very young oceanic crust of the world's slowest-spreading midocean ridge. Heat flow was found to be extremely high in the central part of Nansen–Gakkel Ridge median valley.

Planktonic and benthic organisms respond in composition and quantity to a major boundary between Atlantic and Arctic water masses close to 83–84°N. This boundary is located far north of the southern border of the ice pack, but it is clearly reflected in planktonic and benthic foraminiferal distributions, productivity and copepod assemblages. The boundary appears to separate the shelf-influenced southern part of the basin from the northern, deep-Arctic environment.

The first transect of oceanographic stations into the central Eurasian Basin allowed important hydrographic and chemical traits of water mass structure and distribution to be defined. The core of the Atlantic waters entering the Arctic follows the continental margin north of Svalbard, forming a well-developed boundary current. The CTD data for the top and intermediate layers of the water column show the expected distribution of cold and fresh polar surface layers, increasing in thickness towards the north to approximately 200 m. The relatively warm and salty Atlantic signal is reduced from 1.9°C north of the Barents shelf break to approximately 1.2°C over the Nansen–Gakkel Ridge.

The only previous study of Freons in the Nansen Basin indicated the presence of significant levels of Freon. Perhaps the most surprising finding of the ARK IV/3 section was the discovery of a large pool of water in the center of the Nansen Basin (below 3000 m) with no detectable F-11, F-12 and methyl chloroform but containing carbon tetrachloride. This indicates that the deep water is at least several decades old.

Much of the investigated ice is very "dirty," containing considerable but variable amounts of clayey and silty sediment of unknown origin. Most of the dirty ice cores seem to be multi-year ice. Extreme material accumulation, affecting up to 70% of the surface, was associated with regions where surface melting was extensive, covering 25–40% of the ice surface. At almost all sites with dirty ice, material formed small aggregates. These aggregates sometimes accumulated in meltwater depressions in black layers up to 1 cm. In some cases, round to elongate cohesive sediment accumulations, called mudballs, were found in holes in meltwater ponds and on the ice surface. These mudballs were 1–3 cm in diameter and consisted mainly of clay- and silt-sized material. Similar features were also observed in seafloor sediment samples, both in surface sediments and accumulated in deeper layers.

Some major features of the northern Bering Sea and the Chukchi Sea.

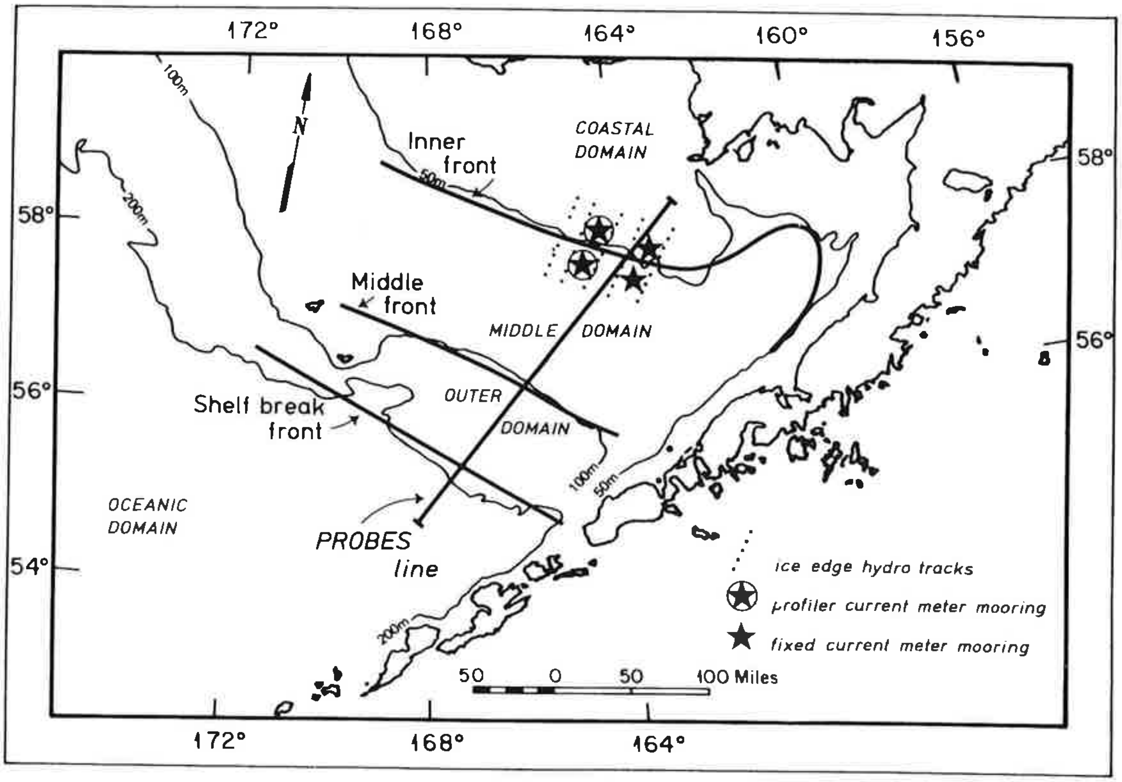
Cooperative Soviet–American Cruise to the Chukchi and East Siberian Seas

This cruise, aboard the Soviet whale-hunting ship *Razyashchii* in September and October 1980, was a cooperative research effort between the United States National Marine Fisheries Service and the Tinro Institute of the U.S.S.R. Its aim was to assess the whale populations in the western Chukchi and East Siberian seas. The cruise emphasized survey work, which required maximum coverage of the area. There was little opportunity for detailed oceanographic work. Additional biological information was limited to one benthic dredge, one vertical plankton tow, four water samples, and salinity and temperature measurements in the upper 10 m.

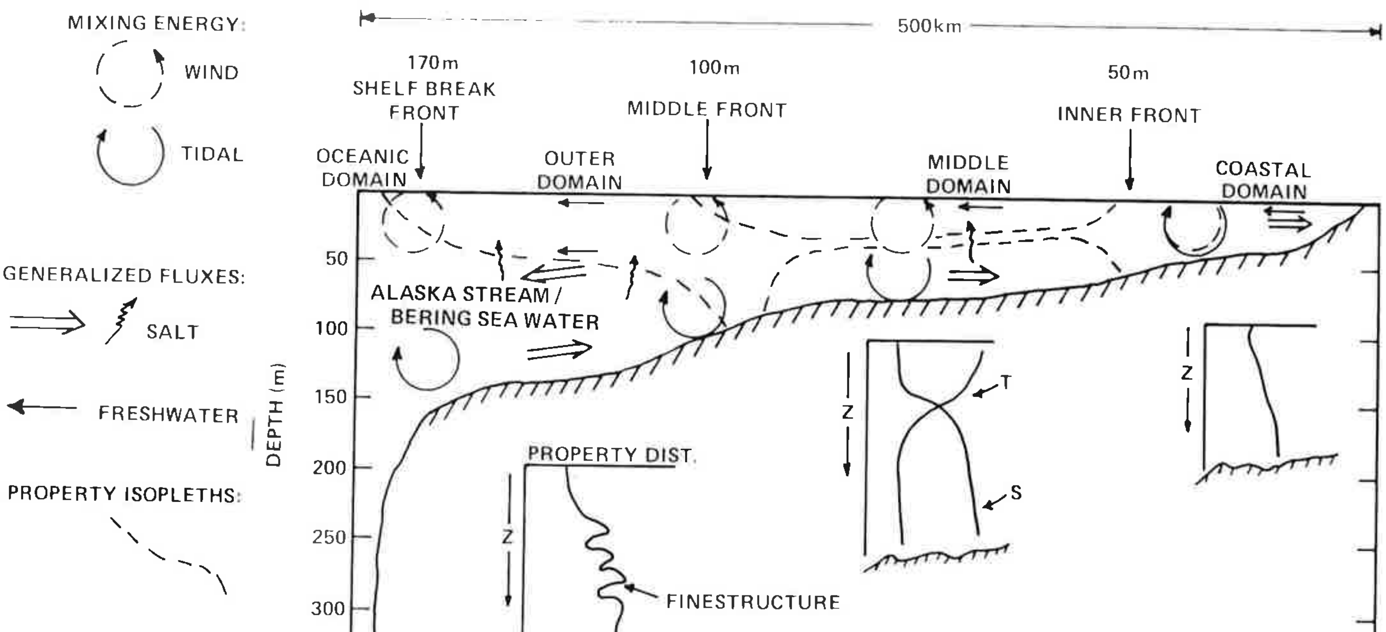
Salinity and temperature in the upper 10 m dropped from east to west along the Siberian coast, with the lowest salinities and temperatures (25.7–29.0%; –1.2°C) in the East Siberian Sea and the highest (30.2–33.8%; 4.4°C) in the eastern Chukchi Sea and in the Bering Strait area. These changes were generally associated with increasing concentrations of ice. Chlorophyll and phytoplankton cell counts were highest in the Bering Strait area (2.63–0.97 mg/L of chlorophyll; 1.5×10^5 to 1.7×10^5 cells/L) and dropped westward. The majority of the phytoplankton were diatoms of the genera *Chaetoceros, Leptocylindricus, Nitzschia* and *Thalassiosira*. Nutrient concentrations were low except in the Bering Strait area. Zooplankton concentrations were low at all stations, with the calanoid populations consisting mainly of *Pseudocalanus* and *Oithona*. Meroplankton were common, with especially high levels in the Chukchi Sea, where bivalve and polychaete larvae made up as much as 49% of the catch. Benthic communities varied, especially the crustacea, which were correlated directly with gray whale abundance. Gammaridean amphipods, the dominant forms, occurred only in areas with silty, muddy bottoms. Ninety percent of the stomach contents of a 13-m-long female gray whale consisted of *Ampelisca macrocephala*. Although bowhead whales were sighted in large numbers around Cape Vankarem, no unusually high concentrations of plankton were detected in the area. Although this was just one brief cruise, the results seems to confirm that a food chain based on benthic detritivores dominates in areas that support gray whales.

Processes and Resources of the Bering Sea Shelf (PROBES)

PROBES was an international, multi-institutional project supported by the National Science Foundation. It addressed the ecosystem of the southeast Bering Sea shelf using an interdisciplinary approach. The main program started in 1976 and included studies of water circulation and mixing, nutrient dynamics, primary productivity and phytoplankton, upper trophic level ecology (emphasizing pollock) and ecosystem analysis and synthesis. The program involved scientists from the U.S., Denmark and Holland, as well as Japan-



The major subdivisions of the southeast Bering Sea in the region of the PROBES investigation.



Cross-shelf properties of the southeast Bering Sea.

ese scientists from the National Institute for Polar Research. Scientists from the Ocean Research Institute, Tokyo University, and other Japanese universities collaborated in planning the program.

New understanding of the ecological consequences of various hydrographic regimes across the shelf emerged, in particular, the different allocation of the products of primary production between the outer shelf and the middle shelf region. The waters of this shelf are highly structured and consist of discrete domains divided by three oceanographic fronts. These fronts are zones of enhanced biological activity, and the patterns of phytoplankton and zooplankton growth, biomass and species composition are organized in relation to them. The middle front, in particular, is a zone of enhanced biological activity; it separates the benthic-dominated food web of the middle shelf from the pelagic-dominated region of the outer shelf. The program was completed in 1982, and the results of PROBES have been synthesized in a special volume of *Continental Shelf Research*.

Arctic Gas and Aerosol Sampling Program (AGASP)

AGASP-I

AGASP was conceived in 1982 with the aim of determining the characteristics of Arctic haze (air pollution) above the Barrow, Alaska, Geophysical Monitoring for Climatic Change (GMCC) baseline station. The original plan was expanded to cover the Arctic Basin and to broaden participation to a wide range of scientists interested in the Arctic atmosphere. AGASP offered to acquire funded flight hours on a NOAA WP-3D, mount each scientist's instruments on the aircraft, and pay field expenses if the participating scientists would agree, in exchange, to analyze and publish their findings in a group effort.

A core group of participating scientists developed a research program with the following objectives:

- To determine the spectra, optical properties, chemical composition, distribution and trajectories of Arctic haze aerosols;
- To determine the concentration and distribution of Arctic haze trace gases;
- To determine the concentration, flux and gradients of atmospheric CO_2 in relation to important Arctic sources and sinks;
- To measure both in-situ and surface-observed radiative effects of the haze; and
- To document the existence of, and conduct stratospheric gas and aerosol measurements in, polar tropopause folds.

Additionally, these measurements would provide new inputs for models of the climatic effects of Arctic haze.

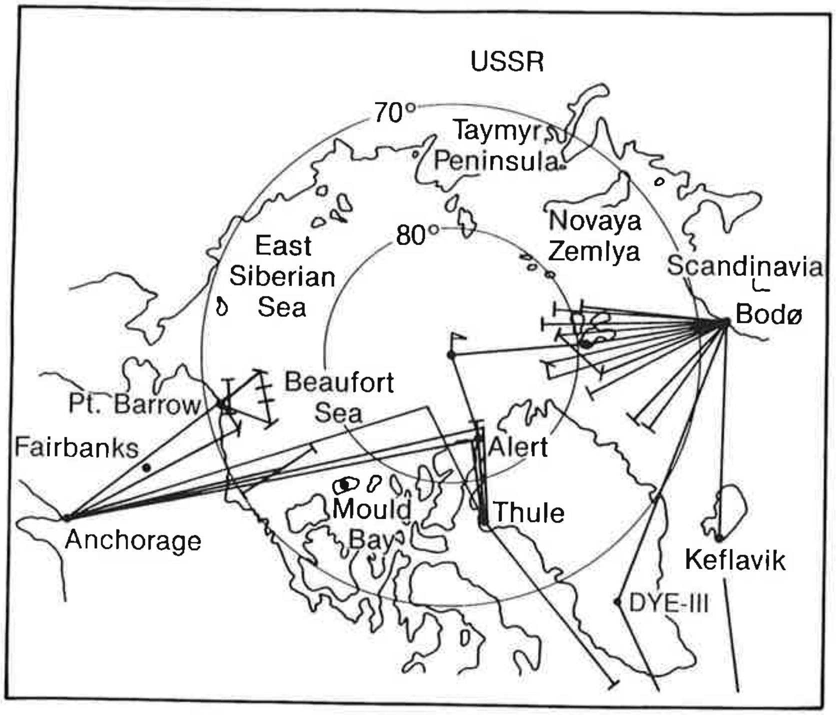
Through contacts with colleagues in the Atmospheric Environment Service (AES) of Canada and the Norwegian Institute of Air Research (NILU), the AGASP group arranged for complementary and coordinated ground measurements at the baseline stations at Alert, Northwest Territories, and Ny Alesund, Svalbard. In addition, Dr. Brynjulf Ottar, Director of NILU, agreed to undertake extensive airborne haze research with the NILU Piper Navajo in the Norwegian Arctic at the same time as the WP-3D operations.

In the spring of 1983, 35 separate measurement programs representing scientists from 17 research institutions were flown for 144 research flight hours on 12 missions, covering the non-Soviet Arctic from bases in Anchorage, Alaska; Thule, Greenland; and Bodo, Norway. The NILU Piper Navajo flew missions out of Svalbard, conducting profiles over the Ny Alesund baseline station.

The results of the AGASP-I program were published in *Geophysical Research Letters* (May 1984) and *Atmospheric Environment* (December 1985). These papers, bearing authorship from Canada, United States, Norway, West Germany, Great Britain and Denmark, showed that the spring Arctic troposphere contained high concentrations of anthropogenic gases and aerosols, mainly of Eurasian and Soviet origins. These pollutants were advected across the Arctic in distinct layers, on time scales of 10 days or less, over path lengths of up to 10,000 km, with little diffusion or mixing. In-situ radiation measurements indicated that the haze layers had an appreciable effect on the flux of solar radiation reaching the ground in the high Arctic. The aircraft profiles above the baseline stations showed that concentrations of the pollutants at the surface were often much lower than concentrations aloft.

A highlight of the Arctic haze program was the 1985 International Symposium on Arctic Air Pollution sponsored by the State of Alaska and hosted by the Scott Polar Research Institute (United Kingdom). Along with North American, Nordic and European scientists, the symposium was addressed by an Eskimo elder whose hunting existence could be adversely affected by Arctic air pollution. A book based on the symposium contains results of research on Arctic air pollution and health and ecological issues, discussions of inter-

The National Oceanic and Atmospheric Administration WP-3D Orion research aircraft used in the Arctic Gas and Aerosol Sampling Program. This aircraft is capable of 10- to 12-hour research missions with a range of more than 3000 nautical miles.



Flight tracks from AGASP I, II and III.

national Arctic air pollution cooperative research programs, and position statements by government leaders and Arctic Native peoples.

AGASP-II

A second AGASP field program was developed along the lines of the first by previous investigators wishing to pursue unanswered questions and new participants wishing to study different aspects of polar air pollution (see *Arctic Research of the United States*, Spring 1988, p. 39). As in AGASP-I, working-level field scientists developed the program on an ad hoc basis without a formal lead agency or central funding source.

The NOAA WP-3D was joined in this program by the University of Washington C-131 research aircraft and the National Aeronautical Establishment of Canada Twin Otter. The C-131 carried a downward-looking aerosol lidar to study haze distributions. The WP-3D flew missions from Alaska to Greenland and joined the C-131 and the Twin Otter in comprehensive studies tied to the Canadian baseline station at Alert. The Twin Otter was based in Alert, and the C-131 and WP-3D in Thule, Greenland, for the joint flights. Intensive ground measurements were conducted at the Alert, Barrow and Ny Alesund baseline stations in support of the aircraft measurements.

Highlights from AGASP-II include

- The discovery of the photolytic destruction of ozone by bromine in the Arctic troposphere;
- The tracking of a major haze event from central Europe, across Scandinavia and the Arctic basin, to Alaska, and on toward Alert;
- Observations of active SO_2-to-H_2SO_4 conversion in the haze 8000 km from the SO_2 source;
- Lidar profiles of the fine detail of up to 25 successive Arctic haze layers stacked one above the other; and
- The detection of ice crystal plumes rising from open leads high into the troposphere.

The overall results of this program are being published in 45 papers appearing in dedicated issues of the *Journal of Atmospheric Chemistry* and *Atmospheric Environment*, both due to be published by mid-1989.

Polar Lows

There has been significant progress in recent years in the understanding of Arctic atmospheric processes. This progress has resulted from cooperative international programs. Polar or Arctic lows are small storms (about 300 km in diameter) that develop in a few hours and often have winds of hurricane force. Reports of research findings over the past few years on these storms were presented at an international meeting in Madison, Wisconsin, in March 1988. The papers have been compiled and will soon appear as the first published volume on the topic. This volume will serve as a reference text on the origin, evolution and characteristics of these intense storms. Progress in the understanding of the physics of the storms has led to numerical models that have predictive capability.

The major research needs are to develop early detection capabilities, find observational and data assimilation methods to initialize numerical models, understand the generation physics, and develop prediction techniques that can be nested in larger area models or operate on a small computer. Progress has been made, but before these dangerous storms can be routinely detected and predicted there is a need for more ambitious research programs.

Ongoing Projects

Greenland Sea Program (GSP)

The GSP is a program of observations and modeling of air–sea–ice interaction and polar biology. The results will be used to tie seasonal and interannual sea ice variations to the large-scale dynamics of the atmosphere and ocean. The Greenland Sea chosen because it is a key component of the advective–convective system that links the Arctic Ocean and the North Atlantic and because of its large signals in all components of the air–ice–ocean system, its comparatively large data base and its accessibility.

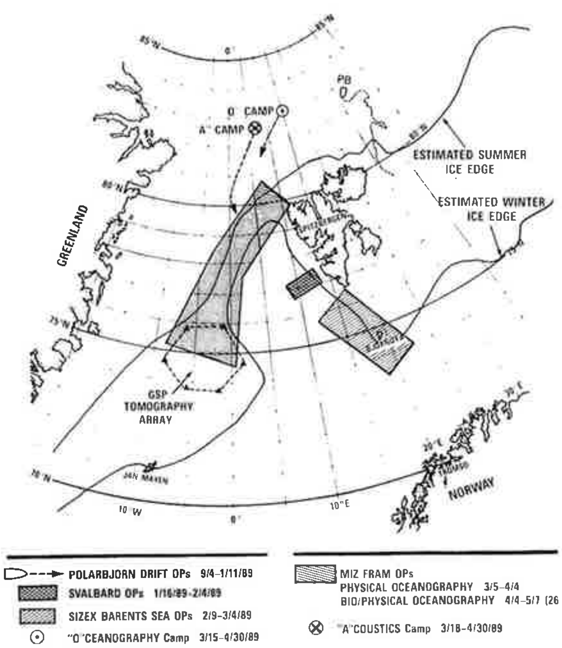
The plan has five major elements, all closely linked:

- A study of the seasonal and interannual variability of the sea ice cover;
- A study of ventilation and convection of the deep water;
- A study of the ocean circulation and mixing;
- A study of atmospheric energetics; and
- A study of biological processes as they interact with air, the sea and ice.

The primary region of study is bounded by Fram Strait to the north, Spitsbergen and the Mohn Ridge to the east, the Greenland–Jan Mayen Ridge to the south, and Greenland to the west. Measurements will also be made well north of Fram Strait to monitor the fluxes into and out of the Greenland Sea, on the Yermak Plateau and south along the east Greenland coast down to the Denmark Strait. The Greenland Sea Project began in 1987; it will continue for at least five years.

The Arctic Ocean Science Board is the organizer of both the logistics and the scientific program. Contributions to the program in all of its elements are expected from at least seven countries: Canada, Denmark, West Germany, France, Iceland, Norway and the U.S. Other contributions are likely. Program direction comes from an international group of scientists, each of whom is a principal investigator for an element of the program. Staff support for this group is provided by an international project office in West Germany.

Although initial data sets have not yet been completely analyzed, some important conclusions are emerging. There appear to be three separate gyres in the Greenland Sea. The volume of water transport along the edge of the major gyre is on the order of 10 Sv. There was substantive convection in 1988 but not in 1987. Clearly there is substantial interannual variability in the circulation of the Greenland Sea.



Location of the CEAREX experiments.

Coordinated Eastern Arctic Experiment (CEAREX)

CEAREX consists of several phases, the first of which began when the Norwegian charter vessel *Polarbjorn* was allowed to freeze into the ice northeast of Svalbard in October 1988 (see *Arctic Research of the United States,* Fall 1988, cover). This spring there were marginal ice zone and open water investigations, as well as two ice camps north of the Fram Strait. Participants are from Canada, Norway, West Germany, Great Britain and the U.S. The Office of Naval Research is the U.S. sponsor, with interagency participation by NASA, NOAA and NSF.

The scientific objectives of CEAREX are to understand the structure and function of mesoscale and small-scale (10 km to 1 m) processes in the Arctic Ocean exchange of momentum, heat and biomass and to understand the associated acoustic coherence and ambient noise fields. From September 1988 through May 1989, a number of coordinated investigations were staged from ships, ice camps and aircraft.

During Phase 1 the sampling base was the *Polarbjorn* frozen into the central pack ice north of Svalbard during the early winter. Phase 2 investigated the East Spitsbergen front dynamics west of Svalbard during midwinter from the *Polarbjorn.* In Phase 3 the *Polarbjorn* was joined by the R/V *Hakon Mosby* and SAR-equipped aircraft to study the marginal ice zones of the Barents Sea and northern Greenland Sea. Finally, in Phase 4, oceanography and acoustics ice camps, as well as aircraft with SAR and meteorological sensors, were deployed north of Fram Strait while the *Polarbjorn* pursued eddy tracking in the Fram Strait marginal ice zone.

Building on the MIZEX results, the evolving dynamics of marginal ice zone and sub-ice eddies was addressed, including their role in the mean circulation and in the net seasonal biological productivity. The air–ice– ocean momentum flux was studied through detailed measurements of atmospheric and oceanic boundary layer structure, together with ice floe stress and deformation fields. Below the boundary layer the partition of energy in the upper ocean among internal waves, mixing and dissipation was investigated. The mechanisms of ambient noise generation in interior pack ice were isolated, and the causes of temporal and spatial variability in low-frequency coherence were evaluated.

Arctic Radiation and Chemistry (ARC) Experiment (AGASP III)

As a component of CEAREX, a NOAA WP-3D equipped with gas and aerosol measuring equipment, an aerosol lidar and a wide range of radiation and energy-flux measuring instruments flew polar missions north from Bodo, Norway, in March and April 1989. These flights were coordinated with surface measurements conducted at the CEAREX ice camps and satellite flyovers. The central scientific objectives of the ARC program are:

- To determine the Arctic radiation budget in spring, with particular attention to surface reflectance, air chemistry and aerosol physics under cloud and cloud-free conditions;
- To measure the properties of Arctic aerosols and gases, with particular reference to Arctic haze and its composition, sources and transport; and
- To understand the sensitivity of surface fluxes to radiative and surface roughness properties in enough detail to model regional air–ice–ocean energy exchanges.

Inner Shelf Transfer and Recycling in the Bering and Chukchi Seas (ISHTAR)

ISHTAR is a multi-disciplinary, multi-university ecosystem study designed to test the hypothesis that interannual changes of atmospheric forcing on water transport through the Bering Strait result in a two-fold to four-fold difference in the flux of nutrients from the shelf break of the northwestern Bering Sea, the primary production north of St. Lawrence Island, the burial of carbon in Chukchi Sea sediments, the amount of energy passed up the food web, and the chemical properties of the Arctic Ocean water transported south. The project began in 1983 with a pilot cruise, and the first full field season was in 1985. The project continues through 1990. Scientists from the U.S., Denmark and Belgium have been involved in the project from its inception, and during the field seasons of 1987 and 1988, Japanese scientists from the National Institute for Polar Research, Tokyo, participated by deploying moorings for measuring plant pigment fluorescence and particle flux (sediment traps).

From east to west in the northern Bering Sea, the major water masses are the Alaska Coastal Water, the Bering Shelf Water and the Anadyr Water. The latter two are physically similar, but both are distinct from the relatively warm, low-salinity Alaska Coastal Water. It is the front between the Alaska Coastal Water and the Bering Sea Water that is most distinct. The Alaska Coastal Water is extremely unproductive, with only a single phytoplankton bloom following ice breakup. The Bering Shelf Water, on the other hand, supports very high phytoplankton biomass and production and is cold, nutrient-laden water that originates to the south in the region of the continental slope. In 1988, for the first time, ISHTAR had the opportunity to work in Soviet waters of the northwestern Bering Sea after the R/V *Washington* made a port call at Provideniya to pick up a Soviet scientist.

Marine Mammal Research

Much of the United States marine mammal research in the Bering and Chukchi seas has been conducted aboard Soviet research vessels as part of a U.S.–U.S.S.R. Marine Mammal Project, under the Agreement on Cooperation in the Field of Environmental Protection, Area 5, Project 6, "Marine Mammals." Most of the marine mammals that inhabit U.S. waters in the western Arctic reside in ice-covered waters. While not a multinational research program, this collaboration has been invaluable in providing access to ice-covered seas. Meetings for the exchange of information are held every 18 months, alternating between the U.S. and the U.S.S.R.

U.S./U.S.S.R. Bering Sea Study

A series of joint U.S. and U.S.S.R. cruises have been undertaken to the Bering Sea on the *Akademik Korolev*, also under the 1972 bilateral agreement. The first cruise took place in 1977, the second in 1984, and the third in 1988 (see *Arctic Research of the United States*, Fall 1988, p. 90). The principal objectives are to study the ecosystem structure and function of the Bering Sea and to determine the Bering Sea's capacity for assimilating pollutants. Collaborative efforts have evaluated the simultaneous effects of varying nutrient and toxicant concentrations, and experiments have studied the effect of nutrient regimes on the intensity of PCB bacterial degradation in cold waters.

Canadian Ice Island (Hobson's Choice)

The Ward Hunt Ice Shelf calved several ice islands in 1983, the largest one (9 × 5 km with a thickness of 43–45 m) was tagged with an Argos buoy on 11 August 1983. In September 1984 the Canadian government funded the Polar Continental Shelf Project (PCSP) to start building research facilities on the ice island. The field camp has been occupied intermittently since then and has now drifted southwest along the coast to south of Meighen Island. There are facilities for geological, geophysical, meteorological and oceanographic research. This research platform is open to scientists of all nations through the PCSP, and there has been international participation.

The project has yielded several important biological oceanography results:

- The annual production of particulate organic carbon on this polar margin appears to be an order of magnitude lower than that predicted from global carbon budgets;
- Blooms of diatoms occur in both summer and winter seasons; and
- Measurable levels of organochlorine pesticides and PCBs are present.

The geophysical data suggest the margin is a passive rifted one with a 15-km-thick sequence of sedimentary strata. A prominent unconformity appears to separate the Upper Cretaceous–Tertiary strata from Lower Cretaceous and older strata and is similar to that of the Beaufort Sea; it could contain significant resources. From geological data, siliceous demasponges were found to form reef mounds on the inner continental shelf. They show a depth zonation that suggests a relative sea level rise of 20–600 m during the last 400–1000 years.

Future Projects

International Arctic Polynya Project

A comprehensive interdisciplinary study of Arctic polynyas is being planned under the auspices of the Arctic Ocean Sciences Board. Plans call for simultaneous study of three polynyas: the Northeast Water on the East Greenland Shelf, the North Water in Baffin Bay and the St. Lawrence Island Polynya in the Bering Sea. Polynyas play an important physical role in air–sea exchange, ice formation and deep water formation. At the same time, they are important to Arctic marine ecosystems, although very little is known of their biology. The plan includes closely integrated physical oceanographic, meteorological, chemical and biological research designed to understand the interactions within a polynya, as well as the downstream consequences. Each site is to be the focus for an international team, with coordination and joint synthesis among the teams.

The Transpolar Expedition (TRAPOLEX)

TRAPOLEX is intended to be a multidisciplinary investigation of the interior of the Arctic Ocean, sponsored by the Alfred Wegener Polar Institution. The plan is to enter the Makarov Basin via the Laptev Sea. The Swedish icebreaker *Oden II* and the German icebreaker *Polarstern* may, however, work together as a team in 1991 for a deep penetration north of Franz Josef Land. It is uncertain which expedition will occur or whether the two will be merged.

The scientific objectives are to study

- The paleoceanographic development from temperate restricted basins (more than 40 mya) to glacial environments (less than 5 mya);
- The tectonic evolution of the Arctic deep sea basins;
- The distribution of water masses in the Nansen, Amundsen and Makarov basins;
- The origin, transport and transformation of sea ice and regional variations; and
- Transport and deposition paths and rates of continental-derived aerosols through air masses over the Arctic Ocean.

Nansen Arctic Ocean Drilling

The tectonic and paleoenvironmental history of the Arctic Ocean Basin and adjacent extensive continental margins are poorly understood. The primary goals of this research are to develop a satisfactory understanding of

- The climatic and paleoceanographic evolution of the Arctic region and its effects on the global climate, the biosphere and the dynamics of the world's ocean and atmosphere; and
- The nature and evolution of the major structural features of the Arctic Ocean Basin and circum-Arctic continental margins.

The only feasible approach to satisfy these requirements is a program of long coring and drilling. An international committee consisting of representatives from West Germany, Norway, the U.S., Canada, Sweden and Denmark has been formed. The U.S.S.R., Japan, France and Great Britain have been invited to join. The initial field work will be giant piston cores during TRAPOLEX, possibly using a gattling gun drill.

Publications

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Window on Space over the Western Arctic

The Poker Flat Research Range

CARLA A. HELFFERICH, CHARLES S. DEEHR, NEAL B. BROWN AND DOREEN FITZGERALD

Carla A. Helfferich, Charles S. Deehr, Neal B. Brown and Doreen Fitzgerald are all from the Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775-0800.

Poker Flat, the world's largest overland rocket range, is based 30 miles north of Fairbanks, Alaska, and extends to the coast of the Arctic Ocean. The only high-latitude rocket range on U.S. soil, the Poker Flat Research Range has an impact zone larger than Indiana. The range is an important facility for maintaining the highest level of auroral research, for national security support, for observing global climate, and for support in the National Science Foundation's program on Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR).

Poker Flat is owned and operated by the Geophysical Institute of the University of Alaska–Fairbanks under contracts with the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center, Wallops Flight Facility. The range has also received contracts from the Defense Nuclear Agency, the U.S. Air Force Geophysics Laboratory, the National Oceanic and Atmospheric Administration, and the National Science Foundation.

Since the first launch 20 years ago, more than 220 high-altitude rockets have been launched from Poker Flat. Among the records set during these two decades are the heaviest parachute-recovered payload (2300 pounds), the heaviest vehicle (5985 pounds) to an altitude of 113 km, and a payload recovery far exceeding that of launch facilities with impact areas at sea. The current apogee record for a Poker Flat launch is 1400 km.

The range is located on land owned by the University of Alaska. Permission to let expended rocket motors and payloads fall on the designated 14-million-acre impact zone extending north and north–northeast to the Beaufort Sea is secured periodically from the Bureau of Land Management, the U.S. Fish and Wildlife Service, the State of Alaska Division of Lands, the Doyon Ltd. Native Corporation, and other entities. The Federal Aviation Administration reviews requested rocket flight zones and coordinates airspace operation during launches; the Alaska Department of Transportation authorizes range personnel to stop traffic on the nearby Steese Highway during launches. Soviet authorities are informed shortly before each launch via NORAD in Colorado Springs.

As the Poker Flat facility begins its third decade of service, it must modernize to be effective, because vital scientific support is lacking. In accordance with the recommendations of the *U.S. Arctic Research Plan* and the U.S. Arctic Research Commission, a plan is being developed for a major upgrade of Poker Flat. Features include

Poker Flat Research Range flight zones.

Partial List of Range Users (1969–1988)

United States:
Advanced Research Projects Agency
Aerospace Corporation
Air Force Geophysics Laboratory
Cornell University
Defense Nuclear Agency
Florida Atlantic University
Geophysical Corporation of America
Geophysical Institute, Unersity of Alaska–Fairbanks
Lincoln Laboratory, MIT
Los Alamos Scientific Laboratory
National Aeronautics and Space Administration
National Oceanic and Atmospheric Administration
onal Science Foundation
Pennsylvania State University
Sandia Corporation
Science Applications Inc.
Space Data Corporation
Rice University
United States Air Force, Space Division
United States Air Force, BMO
United States Army, BMD
University of California at Berkeley
University of California at San Diego
University of Colroado
University of Denver
University of Michigan
University of Minnesota
University of New Hampshire
University of Rhode Island
University of Houston
University of Washington
University of Wisconsin
Utah State University

Foreign:
Denmark
Japan
Sweden
United Kingdom

improvements in ground- and space-based support, launch facilities, range support and background atmospheric indicators of global climate change. A unique feature of the modernized range will be a network of Alaska village observatories, providing important synoptic data to the range command center, as well as educational and job opportunities to the villages.

History of Poker Flat

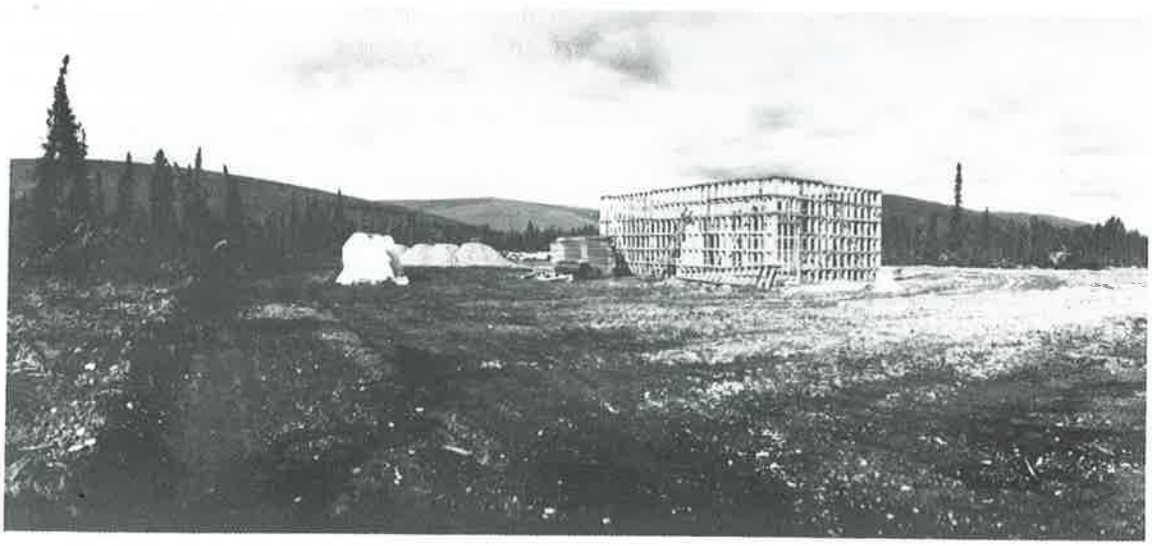
Auroral studies began on a small scale at Fairbanks as early as 1929; 20 years later, the Geophysical Institute, authorized by an act of Congress, was under construction. Auroral studies were a major part of the institute's program, and by the 1950s, American scientists were interested in using sounding rockets as a major means for studying the aurora.

By 1956 North America's first northern sounding-rocket range had been built at Ft. Churchill, Manitoba, as a joint U.S.–Canadian venture. Ft. Churchill was an important facility, but it had some disadvantages. Its chief problem was that only some kinds of auroral forms occur there, and only certain kinds of experiments can be performed. Nevertheless, the Canadian site was valuable to many experimenters. Among them, in the 1960s, was Neil Davis of the Geophysical Institute. After one campaign there, he conceived the plan for an Alaska research range. By 1964 NASA was interested enough to commission Davis to find the best sounding-rocket launch site in Alaska.

His first choice lay on the southern boundary of the quiescent auroral zone, the best vantage point from which to study the aurora. It was in a sparsely populated area from which rockets could be launched without interfering with major highways or population centers, yet it had easy access to a highway connecting it with the amenities and transportation facilities of Fairbanks. The site could also be integrated with the University of Alaska, where the Geophysical Institute had achieved a distinguished record of auroral and other relevant high-latitude research. Numerous ground-based observation sites that could support sounding rockets already existed throughout Alaska, and most of them were under the auspices of the institute. Because mammoth gold dredges had once operated near this now-bare tract, old electric power lines, standing since the 1920s, could easily be refurbished.

NASA might have ignored Davis's survey and the selected site, but distant international developments began to play a role. The early 1960s had witnessed the race between the U.S.S.R. and the U.S. in atomic weapons testing, and the Defense Atomic Support Agency (DASA) had gone all out in purchasing launchers, missiles, ships and aircraft to monitor nuclear tests. By 1966 the test ban treaty was ready for signing, and DASA needed a new way to do its research. The barium clouds created by chemical releases from sounding rockets resemble atomic bomb debris, and DASA grasped this opportunity to work with—in effect—simulated bombs. Aurora scientists suddenly had access to surplus launchers, boosters, money, new facilities and friends in the military.

There was still no Alaska launch facility, and there might never have been one except for an accident in Greenland. A major series of barium-release experiments sponsored by the Department of Defense was scheduled for Thule, Greenland, in the spring of 1968. Just before the launches an American B-52 with nuclear weapons aboard crashed off the coast near Thule. The Danish parliamentary elections were in progress, and "ban-the-bomb" sentiment was at its peak. Public indignation, mixed with political prudence, dictated that no U.S. weapons-related experiments be held on Danish protectorate territory.



Initial construction at Poker Flat—a rocket assembly building—in the fall of 1968.

Assembling the first rocket launcher, in the winter of 1968.

DASA was left with six barium-release rockets and a crew, ready and waiting, but no launch site. Fort Churchill was unsuitable; after the Greenland accident, no one would consider anything but American soil for a launch. At the urging of Neil Davis, who enlisted the help of Peter Haas of DASA, Robert Frosch of the Advanced Research Projects Agency (ARPA, and especially Lt. Col. Mike Dowe, also of ARPA), the site survey was reconsidered. It was agreed that the location near Chatanika, north of Fairbanks, could house a so-called minimal launch facility, designed specifically for the mission bumped from Greenland, SECEDE III. It was rescheduled for March 1969.

Minimal though it may have seemed to Federal officials, building the launch facility stretched the Geophysical Institute's resources to their limits. The first task was to obtain the necessary permissions: a long-term lease for 7000 acres from the State, permission for airspace use from the FAA, and permits from the Bureau of Land Management for rocket impacts on Federal lands. Finally, in July 1968, construction began.

Eldon Thompson, Larry Sweet, other institute staff, Army and Air Force personnel, and technicians and scientists from Space Data Corporation began with a budget of $90,000—a meager sum since they were starting from scratch. The site was called Poker Flat, in honor of nearby Poker Creek and the Bret Harte short story "The Outcasts of Poker Flat."

Construction continued throughout the fall and winter. In March the DASA and ARPA crews arrived with their six barium-release rockets. They found a rail-type launcher, complete with a 60-ft A-frame movable cover, a corrugated aluminum rocket assembly building, and a trailer to house scientific equipment and personnel that was shielded from the launch pad by a fortress of what the crew called Alaska cement (55-gallon drums filled with ice). An array of storage and single-purpose portable structures and tents completed the picture. Poker Flat was open for business.

The Defense Department had envisioned it to be highly limited business. Once SECEDE III was complete, they planned to pack up and move away, leaving Poker Flat to return to scrubby black spruce forest.

Davis had other plans. The SECEDE experimenters needed ground support for their payload observations, and they requested stations at Fort Yukon, Bettles, Tok and Ester Dome—a fair expanse of interior Alaska. Davis agreed that the stations would be provided, on one condition. He also had a rocket experiment planned, a NASA-funded launch to make auroral measurements from Ft. Churchill, but Davis wanted to make the launch from Poker Flat.

Thus it was seven rockets, not six, that lifted off from Poker Flat during the spring of 1969. Radio stations throughout Alaska carried the live countdown of the first launch, and thousands of Alaskans hurried outside to catch a glimpse of the first barium release. The Department of Defense had what it wanted. They packed up and left, even rolling up the communications cables that had linked the range headquarters to Pedro Dome, where communications had been established to the temporary control center for SECEDE III at Fort Wainwright near Fairbanks. With a budget of less than $500, Davis, Thompson and Sweet saw that the grounds were kept up while they tended to their duties at the institute. They even managed to install a communications system at Poker Flat, built entirely with surplus military equipment.

Because the launch facility had shown itself to be workable and scientifically useful, the institute wouldn't let it be abandoned. To forestall any possibility of premature closing, the first two full-time range employees were hired, launch officer Carroll Coe and windweighter Jim Wolff. Institute scientists also put together their own payload experiment, to which Jim Heppner of NASA/Goddard added three barium-release rockets. Remarkably, a second launch season took place.

By the summer of 1970 the U.S. research community was convinced of Poker Flat's value. But the facility was not prepared for sudden popularity: 13 sounding rocket launches were scheduled between November 1970 and March 1971. With this show of support, construction had to begin again.

A second launcher was installed; permanent telemetry and radar stations were established, with the long-term loan of a portable Sandia telemetry station and the NASA Very Long-Range Tracking (VERLORT) radar, which had been used early in the manned space flight program and was capable of tracking a rocket to the moon.

NSF funded construction of a 40- by 40-ft blockhouse to shelter most major functions: range and payload control, telemetry and windweighting. Other improvements included new roads, better on-site communications, a microwave link to Pedro Dome for both telephones and scientific data, and several wooden storage and work buildings.

The 1971 construction season was even more hectic. After several years of negotiations, including one memorable visit to the range by a site selection committee whose members were greeted by a freshly cleaned moose carcass hanging from one of the launchers, an 88-ft-diameter incoherent scatter radar was installed a mile from the launch site. Operated by SRI International, this radar provided valuable data for years in conjunction with optical, radio and rocket techniques. It was moved to Sondrestrom, Greenland, in 1982.

To provide more prelaunch data, ground support instrumentation was upgraded at the Fort Yukon and Ester Dome field sites by Hugh Anderson of Rice University and Neal Brown of the institute. Two new launcher support buildings were built, and protective, heated clamshell covers were installed to keep rockets and payloads from freezing while they awaited launch. Communications at the site and between the range and field sites were improved. To ameliorate the poor rocket-storage situation (rockets were being stored in boiler-heated tents), a 30- by 40-ft rocket assembly and storage building was erected.

Poker Flat had become a big business, employing 18 people full time—mostly for construction and scientific instrumentation—during the summer of 1971. It now needed an overall coordinator more than a scientist with a wild idea. Davis had seen the range through, but he had visions of returning to science. In the fall of 1971, Neal Brown was named the first full-time Poker Flat range supervisor.

Brown started work in the spring of 1972, just in time to oversee the biggest year yet in range construction. The budget was $1.2 million, the staff numbered 50, and the launch support capa-

The A-frame rocket launcher cover, built in the winter of 1968.

bility effectively doubled. Two new launchers were built, both specially designed and funded by the Defense Nuclear Agency to accommodate the complex payloads charged with liquid helium needed for project ICECAP (Infrared Chemistry Experiment Coordinated Auroral Program).

The old A-frame launcher cover was demolished with carefully placed explosives. In keeping with the Flat's traditional spirit, 90% of its materials were salvaged and recycled, mainly into a new payload assembly building, a 2500-square-ft structure with a class-100 clean room for assembling dust-sensitive payloads. A warm-storage warehouse went up, as did a partially buried rocket storage bunker. All aspects of range communications were improved, and three television camera systems were installed for launch pad surveillance.

Assembling rocket motors onto the launcher for a Talos–Sergeant launch in 1978.

The scientific capacity also improved. The telemetry system was expanded from P-band to include S-band with autotrack. Too large and sophisticated to fit in the blockhouse, it was relocated in the new payload assembly building. A 260-ft-high instrumented meteorological tower was installed; along with a minicomputer, this helped with windweight calculations for launches. Another invaluable addition was an all-sky, low-light-level television camera for determining auroral and launch conditions. With the suspension of NASA rocket operations at Point Barrow, the Tone Ranging Trajectory System, which tracks rocket paths by radio waves, was moved to Poker Flat. A final 1972 improvement was the Meteorological Rocket Network Facility, another pad with three launchers for smaller rockets (Lokis, Super-Lokis and Arcas) used to collect wind and temperature data, and still more technical and scientific support capability.

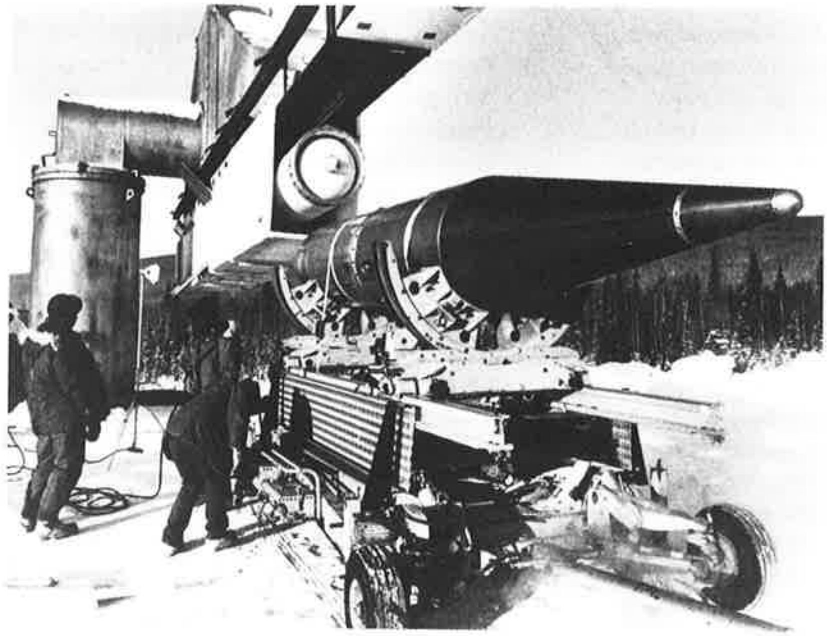
By this time the basic facility was essentially complete. The next major addition was in 1974, when construction began on the Poker Geophysical Observatory. It would house riometers, magnetometers and other instruments used in routine institute experiments, plus all-sky cameras and meridian-scanning photometers to support rocket launches.

Since then various significant additions have appeared. The University of Rhode Island installed air sampling equipment in 1979, a program that continues with funding to the University of Alaska–Fairbanks. NOAA, in conjunction with the Environmental Protection Agency and under the auspices of the World Meteorological Organization Global Ozone Research and Monitoring Project, in 1984 installed and began operating an automated Dobson ozone spectrophotometer meteorological measurement station at Poker Flat. This station is part of a global array of similar stations collecting data on the status of stratospheric ozone.

Radar equipment continues to be important. Site preparation for NOAA's Mesospheric–Stratospheric–Tropospheric (MST) radar began at Poker Flat in 1978. This experimental radar measured the upper-atmospheric wind direction, speed and turbulence. It began gathering data in 1979, gradually coming up to full power over the next few years. During the summer of 1986, site preparation and construction got underway for a stratospheric–tropospheric radar funded by Federal agencies and the State of Alaska through scientists at the Geophysical Institute. Completed in the fall of 1987, it has a 150-ft-diameter spherical dish with a 120-ft tower.

The range now incorporates rocket assembly and launching capabilities, along with telemetry receiving stations and ground-based diagnostics needed for launch decisions for space, aeronomy and atmospheric science experiments. The ground-based instrumentation allows auroral activity, magnetic storms, ionospheric perturbations and other space disturbances to be monitored as they happen. The facility now incorporates eight rocket launchers up to 20,000 pounds; S-band and P-band telemetry; 100-m precision radar and transponder tracking; and 200-m optical beacon tracking.

The Poker Flat location offers several advantages: overflight and landing rights on a large land area; economical, fail-safe payload recovery; easterly launches as far as the Alaska–Canada border; northerly launches with no downrange limit; a safe polar-orbit satellite launch track; a complete meteorological rocket launch, track and data facility;



Poker Flat personnel preparing a rocket for launch in 1981.

an extensive network of Geophysical Institute observatories; university academic and research facilities; access to nearby military and civilian air fields; and range operators with the experience of many launches behind them.

Poker Flat also plays a supporting role in research on the ground. The Caribou–Poker Creeks Research Watershed, cooperatively established in 1970 by Federal and State agencies and the University of Alaska, lies north of the Chatanika River within the prime booster impact area. The area is managed by the U.S. Forest Service's Institute of Northern Forestry. Users look to Poker Flat for occasional support, and cooperation and coordination between range and watershed personnel is continuing.

Some Results from Poker Flat

Rocket experiments at Poker Flat fall into three categories: ballistic tests of rocket systems, single experiments on the high-latitude upper atmosphere, and series of experiments involving single or multiple techniques that are refined over several years. The last of these is by far the largest category. Fully half of the large rockets flown at Poker Flat carried payloads designed on the basis of experiments flown previously. These experiments, or series of experiments, have also been by far the most productive in terms of scientific results.

One of the more important results involved the discovery and mapping of vertical electric fields and field-aligned currents associated with an auroral arc. Predicted from auroral television data, the low-altitude portion was observed with rocket-borne magnetometers in the early 1970s, and the morphology beyond 10,000 km was studied by using shaped-charge barium by the mid-1980s. These results were of key importance to the theories of the formation of auroral arcs and the acceleration of auroral primary electrons. Correlation with plasma drift measurements by the Chatanika incoherent scatter radar were also made to increase the scale of the measurements.

Among the optical measurements, both the ultraviolet and the infrared portions of the aurora's spectrum have been measured. The results have related the spatial extent of these emissions to the visible aurora. In addition to the barium releases, chemicals such as lithium, water and aluminum have been used to map neutral and ionized winds. In the lower atmosphere the Meteorological Rocket Network provided neutral wind, temperature and density measurements as ground truth for SAGE and SAM satellites, among others.

One of the more extensive programs has been the tracing of field lines and production of aurora emissions with rocket-borne electron accelerators. The aurora created by these electron beams has been observed immediately under the rocket and after the beam has traveled to the conjugate region in the southern hemisphere and back.

Among the successful single shots was a measurement of the ozone depletion due to X-rays from the aurora. Others include the measurement of the UV oxygen energy transfer in an optically thick medium and noctilucent cloud studies.

The increasing sophistication of the experiments conducted at Poker Flat has demanded that range facilities improve accordingly.

Future Development

As the Geophysical Institute prepares to enter a new century, there is a heightened interest, both national and international, in the Arctic. The U.S., through the International Geosphere–Biosphere Program, the Arctic Research Commission, and the Interagency Arctic Research Plan, has identified vital needs for improved knowledge of space and the upper atmosphere as a component of the Earth as a system.

Thus the institute expects sounding rocket programs to remain an important component of experimental research because rocket programs can support various scientific needs: cost-effective studies of plasma processes in space; studies of solar-variability-controlled energy depositions in the upper atmosphere and their downward flow through the middle atmosphere; and studies of the behavior and dynamics of minor constituents such as ozone in the Arctic upper atmosphere for global studies. The upper atmosphere studies are proposed by the NSF programs CEDAR and GEM (Geospace Environmental Modeling) and the international Solar–Terrestrial Energy Program. One of the four items in *Findings and Recommendations of the U.S. Arctic Research Commission* is that the U.S. should "upgrade the only high-latitude sounding rocket launch facility on U.S. soil and related logistics systems to support expected needs in upper atmosphere research in the Arctic."

Responding to the identification of specific needs, the Geophysical Institute has proposed a major upgrade to develop the existing range into a national space and environmental research facility that can support the U.S. Arctic research effort. The institute plan calls for redeveloping the range payload assembly and launching facility for modern guided and ballistic sounding rockets. This entails rebuilding launch pads and providing an improved, refitted payload assembly building. Launching more-powerful rockets requires strengthening the blockhouse building to ensure safety of the facility and personnel. Longer rail launchers are required for better control over unguided rockets.

Also planned is the integration of the range command center and the optical observatory within a new structure. The observatory is the source of information essential for launch decisions and is the hub of communications to networks of downrange and cross-track stations that telemeter their data for collation and assembly at Poker Flat. It would be equipped to serve the next generation of rocket and balloon experiments, as well as ground-based observers.

It is also important to integrate an air sampling station with the data-handling capability of the research range. This will create a center for expanded efforts to measure stratospheric and tropospheric ozone, greenhouse gases and Arctic aerosols. This station in continental boreal tundra would provide sensitive indications of processes leading to global climate change.

The planned installation and upgrades include

- A satellite receiving and command network to interrogate and command satellite observations of near-Earth space in real-time to establish magnetospheric conditions;
- Incoherent Scatter Radar, an instrument for measuring the spatial distribution of ion density and velocity;
- Resonant Scatter Lidar, an optical radar to measure the density and temperature of certain ions and neutral atoms as a function of altitude between 70 and 110 km, with a possible extension to 150 km;
- Rayleigh Scatter Lidar, an optical radar to measure the density and temperature between the ground and 70 km;
- High-speed imaging systems of auroral phenomena, both at the observatory and in the downrange area;
- An improved meridian-scanning photometer system for real-time quantitative measurements of auroral brightness and position;
- An imaging riometer to delineate areas of high-energy electron and proton precipitation;
- A magnetometer network for real-time quantitative measurements of the location of auroral electrojets leading to atmospheric heating, etc.;
- An optical interferometer network for measuring mesospheric and thermospheric, neutral and ionized wind fields;
- An air-sampling station to expand the capability for measuring stratospheric and tropospheric ozone, greenhouse gases and Arctic aerosols; and
- A village observatory network to incorporate rural Alaskans in near-Earth space research.

Through the Geophysical Institute, the University of Alaska has pioneered the Poker Flat facility, which is unique in the United States. Poker Flat's past has been distinguished, and the institute looks ahead with high hopes to future accomplishments.

Publications

Readers may obtain further information on some of the research described in this article from the following publications:

Poker Flat Research Range: A ten year history, by N.B. Brown: Geophysical Institute, Annual Report 1978-79, University of Alaska–Fairbanks, p. 15–33, 1980.

A new understanding of the aurora, by T.N. Davis and D.W. Swift: Geophysical Institute, Annual Report 1976-77, University of Alaska–Fairbanks, 1977.

United States Arctic Research Plan, by the Interagency Arctic Research Policy Committee, NSF 87-55, 1987.

National needs and Arctic research: A framework for action, by the U.S. Arctic Research Commission: Report to the President and the Congress of the United States, 1986.

Statement of goals and objectives to guide United States research: Findings and recommendations of the U.S. Arctic Research Commission, by the U.S. Arctic Research Commission, 1988.

What we have learned from the fireworks: Advances in plasma and magnetospheric physics, by E.M. Wescott: Research Report 1985–87, University of Alaska–Fairbanks, 1989.

The dynamic aurora, by Syun Akasofu: Scientific American, May, p. 90, 1989.

Alaskan Groundfish

The Importance of Research to a Major American Industry

GRANT THOMPSON AND WILLIAM ARON

Grant Thompson is a fishery biologist at the Alaska Fisheries Science Center, and William Aron is Center Director, National Marine Fisheries Service, NOAA Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington 98115-0070.

During the past ten years, a major American industry has developed in the water off Alaska, where fishermen are harvesting vast quantities of groundfish (fish living on or near the ocean bottom). It is difficult to overstate the explosive growth and the economic significance of this industry. From virtual nonexistence prior to the passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, American groundfish operations in Alaska have blossomed into an industry whose annual product value was estimated at $1.4 billion in 1986, with the potential of reaching as high as $2.2 billion in the near future. By 1988 this industry's exponential growth had resulted in a total catch of 2.1 million metric tons (t) and an ex-vessel value (the amount fishermen are paid for their unprocessed catch) of $414 million.

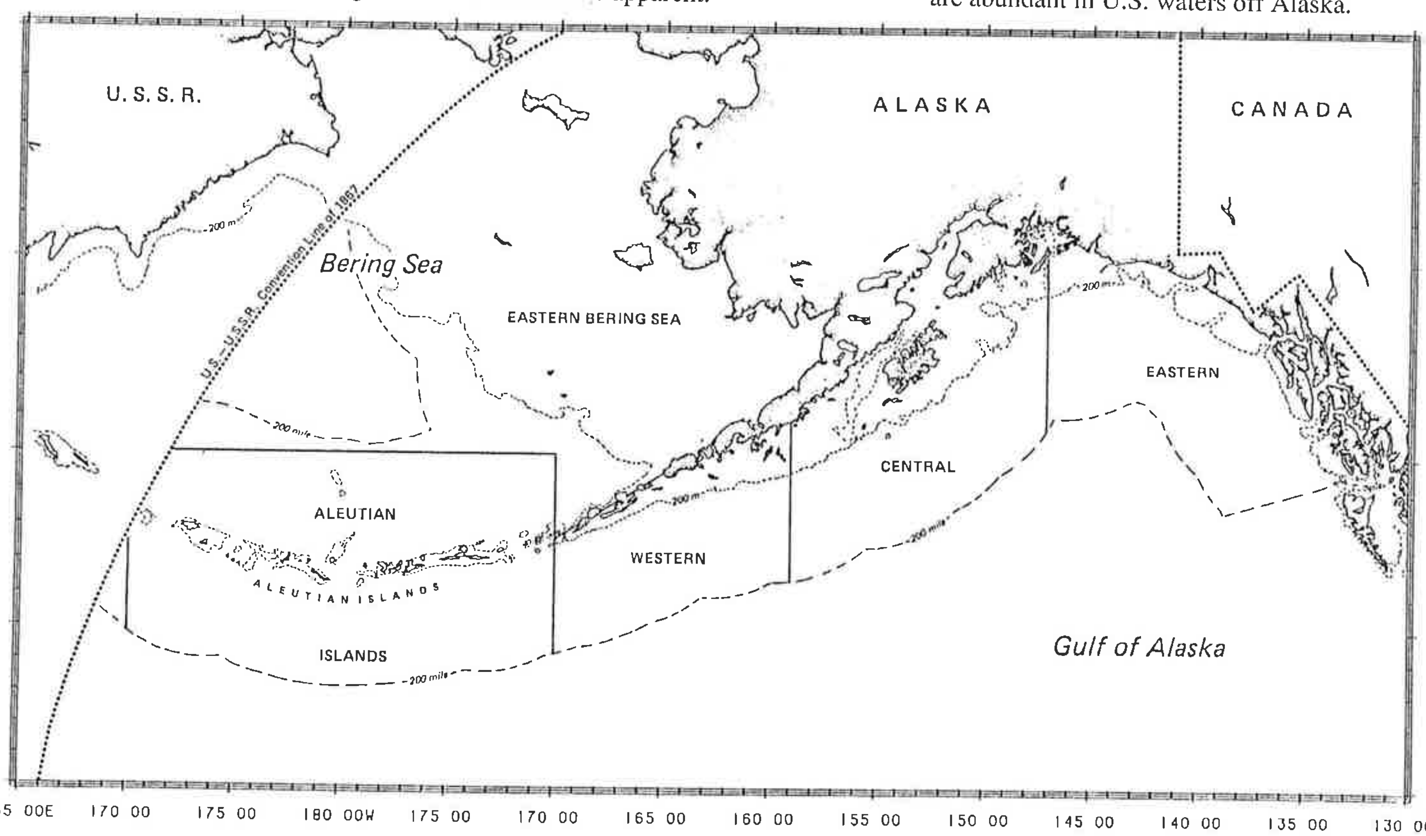
At a national level the Alaskan groundfish harvest was substantial enough to account for 26% of the total U.S. domestic fishery harvest. With the domestic harvest of Alaskan groundfish increasing by nearly 60% between 1987 and 1988, its national significance is even more apparent.

For continued success this major industry needs a predictable and abundant resource base. Responding to this need, however, is not simply a matter of ensuring the livelihood of a few fishermen. Rather, a major segment of the coastal economy has become dependent on the continued success of the fleet. For example, the total personal income resulting from Alaskan groundfish harvests exceeded the total product value by an average ratio of about 8:5 during the years 1981–1987.

In addition to generating substantial flows of both cash and product, the Alaskan groundfish fishery also represents a major capital investment. The magnitude of this investment is difficult to determine, but the trawl fleet alone represents a capital investment of about $760 million. The investment in the overall fishery is much higher, since it also includes the longline fleet and shoreside facilities engaged in processing, repairs and maintenance, storage, transportation and marketing.

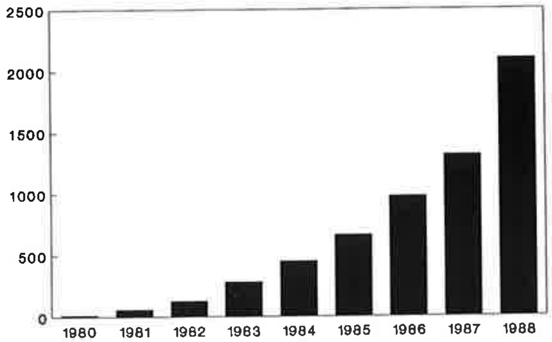
Simply put, then, the situation in the Alaskan groundfish fishery is as follows:

- A number of commercially valuable species are abundant in U.S. waters off Alaska.

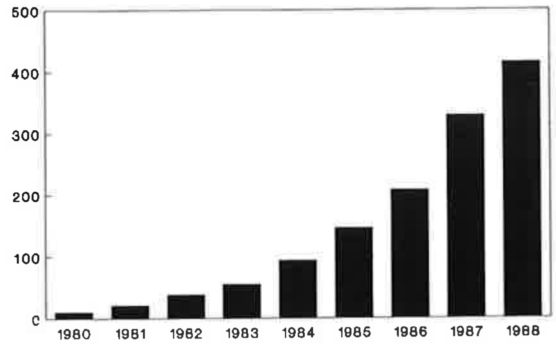


Exclusive economic zone off Alaska. Waters within 200 miles of shore (dashed line) are managed by the U.S. The names in small capital letters denote fishery management areas established by the North Pacific Fishery Management Council.

Catch of the Alaskan groundfish fishery (in thousands of metric tons).



Ex-vessel value of the catch (in millions of dollars).



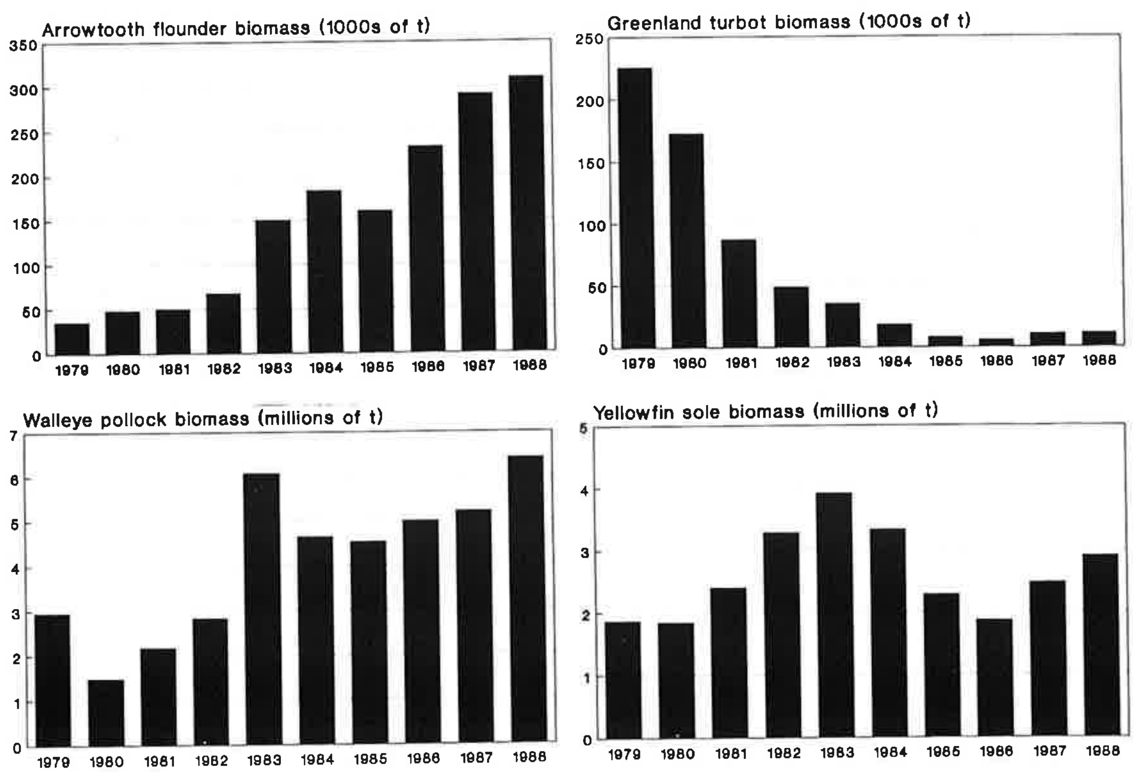
- Intense capitalization of fishing and processing capacity has been necessary to harvest the available yields from these stocks.
- Continued, predictable abundance of the fishery resource will be required to maintain a high-volume flow of the product and to safeguard the economic viability of the fishing, processing and other affected sectors of the economy.

Groundfish Population Trends

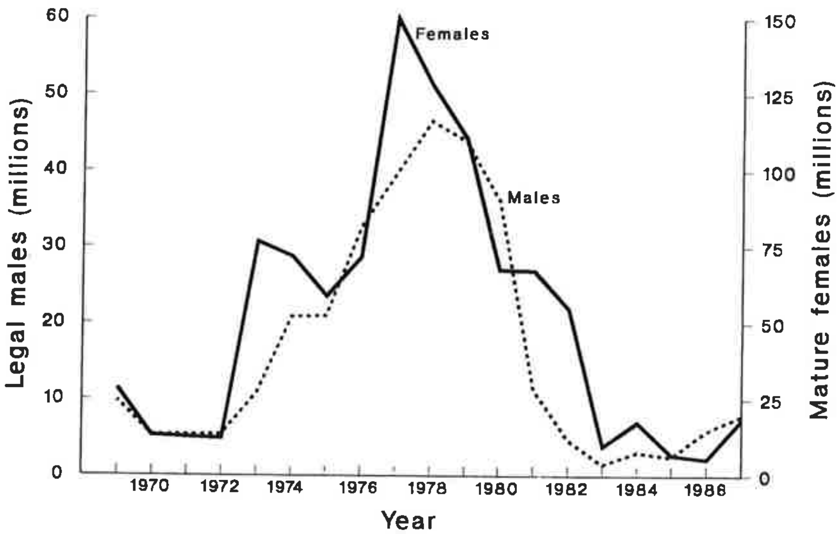
Although the abundance of the overall groundfish resource has not been a serious problem during the past ten years, research surveys conducted on the eastern Bering Sea continental shelf reveal that the abundances of individual stocks typically change significantly over time. For example, the biomass of arrowtooth flounder (*Atheresthes stomias*) increased from 35,000 t in 1979 to 309,000 t in 1988, representing an average gain of over 27% per year. Meanwhile, the biomass of Greenland turbot (*Reinhardtius hippoglossoides*) decreased from 226,000 t in 1979 to 11,000 t in 1988, an average decrease of nearly 29% per year.

The population of walleye pollock (*Theragra chalcogramma*) has been more erratic, decreasing from 2.9 million t in 1979 to 1.5 million t in 1980, increasing to 6.1 million t in 1983, decreasing to 4.5 million t in 1985, and increasing to 6.4 million t in 1988. The up-and-down trend in the biomass of yellowfin sole (*Limanda aspera*) has been even more pronounced, increasing from 1.9 million t in 1979 to 3.9 million t in 1983, decreasing again to 1.9 million t in 1986, and then increasing to 2.9 million t in 1988.

What accounts for these trends? There is no simple answer. While some observers attribute changes in stock abundance to changes in fishing pressure, this view is often inadequate or even incorrect. A case in point is the Alaskan red king crab (*Paralithodes camtschatica*). This species supported a large fishery that grew rapidly during



Biomass trends of selected species on the eastern Bering Sea continental shelf, as determined by Alaska Fisheries Science Center bottom trawl surveys. (Note the vertical scaling differences between plots.)



Abundance of adult red king crabs in the eastern Bering Sea.

the 1970s. Although fishing activities escalated throughout the decade, crab numbers increased until about 1978, when the stock took a dramatic downturn. Just as the stock's early increase was apparently unrelated to fishing, its subsequent collapse may not be attributable entirely to fishing; while the fishery took only males, both male and female abundances declined at about the same rate during the collapse.

Understanding Biological Variability

Explaining biological variability remains a central task of fishery scientists concerned with eastern Bering Sea groundfish. Although there are many ways to approach the problem of stock variability, one way is to view changes in stock size as adjustments toward some equilibrium level. In this view, the concept of biological variability is given meaning: stock size does not simply change, it changes toward an equilibrium level. This suggests objectives for continued research into biological variability; one of the most crucial objectives is to discover what factors determine the equilibrium levels toward which a particular stock might be tending.

Hypotheses about the determinants of equilibrium stock size may involve both physical and biotic factors. It is highly probably that equilibrium stock size is determined at least in part by the state of the physical environment (temperature, salinity, upwelling, surface currents, etc.). Equilibrium stock size might also be determined in part by biotic factors, involving interspecific dynamics, intraspecific dynamics, or both.

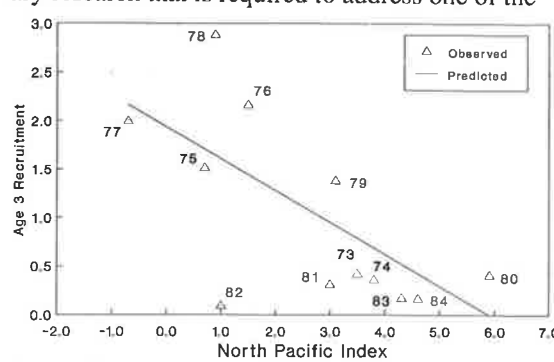
These hypotheses are potentially both complex and far-reaching in their implications. For example, if one accepts the hypothesis that equilibrium stock size is at least partially determined by the physical environment, this implies the existence of not one, but a family of curves relating present stock size to future recruitment. Thus, estimating the maximum sustainable yield from a stock becomes a problem of finding the optimal level of fishing in an environment that is subject to change.

There is a crucial need to move these considerations out of the realm of theory and begin to understand how they affect actual resources. One example of this type of research is the Fisheries–Oceanography Coordinated Investigations (FOCI) program being conducted by NOAA. In their investigation of Gulf of Alaska pollock (a stock that exhibits considerable variability in year-class strength), FOCI scientists are using a multidisciplinary approach to examine the implications of interactions between the physical environment and the pollock resource. Specifically this group seeks answers to the following questions:

- What meteorological, oceanographic and biological conditions correlate with historical year-class success?
- Are there interannual variations in transport that affect larval concentrations, and are there interannnual differences in prey and predators that affect larval growth and survival?
- How do small-scale physics, food availability, growth and predation affect mortality?

Although the FOCI program has not proceeded far enough to produce firm conclusions, there have been a number of interesting preliminary findings. Among these is the discovery of a correlation between the number of young pollock recruiting to the fishery and an index measuring the strength and position of the Aleutian low-pressure area. This tentative relationship is supported by an argument with considerable intuitive appeal: the low-pressure index could be expected to affect storm conditions, which in turn would affect currents, which in turn might critically influence the transport of pollock eggs and larvae.

Although it is too early to decide whether FOCI will be fully successful, the program is at least a step toward the type of integrated, multi-disciplinary research that is required to address one of the



Relationship between recruitment of age 3 Gulf of Alaska pollock and the North Pacific Index, a measure of the strength and position of the Aleutian low-pressure area.

most pressing needs of the Alaskan groundfish fishery: understanding biological variability. FOCI begins to address this need by opening the lines of communication between fishery biologists and oceanographers, allowing each group to tap the scientific resources of the other.

Thresholds and Fishery Management

Concern about stock variability has led fishery managers to pay particular attention to the question of overfishing, that is, "How much fishing is too much?" The MFCMA, for example, expressly prohibits overfishing, which is defined in NOAA's newly proposed fishery management guidelines as "a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis." This definition is significant in that it gives credence to an important hypothesis: if a stock is fished sufficiently hard, not only will it be reduced below the level needed to produce MSY, but even its long-term capacity to produce MSY will be jeopardized and it may be unable to return to the MSY-producing level.

Within this general definition, NOAA's proposed guidelines call for each fishery management plan to identify an empirical definition of overfishing for each stock or stock complex covered by that plan. The guidelines anticipate that many of these definitions will be expressed in terms of scientifically established "threshold" biomass levels, that is, minimum stock sizes below which fishing will be prohibited.

The proposed requirement to specify threshold levels (or a similar overfishing benchmark), if adopted, will require a major research effort into the biological variability in fishery systems. Coordinated investigations involving a number of scientific disciplines will be needed to determine the mechanisms that might contribute to stock collapse, whether they involve physical oceanography, community ecology or single-species population dynamics.

Conclusion

This discussion of biological variability, its possible causes and its implications for fishery science and management illustrates the complexity of fishery systems such as the Alaskan groundfish fishery and the need for greater understanding of such systems. At present, however, fishery science is left with more questions than answers.

For example, what are the causes of the rapid rise of arrowtooth flounder and simultaneous collapse of Greenland turbot? Is the relationship between these two abundance trends causal or coincidental? Can the up-and-down abundance trends of walleye pollock and yellowfin sole be understood as anything other than random fluctuations? What are the roles of fishing and the natural environment in determining stock variation? Do threshold levels of abundance exist, levels below which depletion becomes irreversible? Success in answering these questions is not merely an academic exercise. The future of one of the most important fisheries in U.S. waters may depend on it.

Publications

Readers may obtain more information on some of the research described in this article from the following publications:

Trends in the groundfish fisheries off Alaska 1976-1987, by R.T. Baldwin and J.D. Hastie: Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, Seattle, Washington 98115, in prep.

Atmospheric forcing of interannual variability in the northeast Pacific Ocean: Connections with El Nino, by W.J. Emery and K. Hamilton: Journal of Geophysical Research, vol. 90, p. 857–868, 1985.

Managing Alaska groundfish: Current problems and management alternatives, by D.D. Huppert: Fisheries Management Foundation and Fisheries Research Institute, University of Washington, Seattle, Report FMS-FRI-001, 1988.

Ecology of aquatic systems, by W. J. Liss and C.E. Warren: Fisheries Management (R.T. Lackey and L. A. Nielsen, Ed.), John Wiley and Sons, New York, p. 41–80, 1980.

Fisheries of the United States, 1987, by B.K. O'Bannon (Ed.): National Marine Fisheries Service, NOAA, 1988.

A mechanism for density-dependent survival of larval fish as the basis of a stock-recruitment relationship, by J.G. Shepherd and D H. Cushing: Journal du Conseil Internationale pour l'Exploration de la Mer, vol. 39, p. 160–167, 1979.

FOCI: Fisheries–Oceanography Coordinated Investigations—A study of the biological and physical parameters that determine recruitment into U.S. fisheries, by U.S. Department of Commerce: NOAA, Seattle, WA 98115, 1988.

Nonstationarity of production relationships in exploited populations, by C.J. Walters: Canadian Journal of Fisheries and Aquatic Sciences, vol. 44 (suppl. 2), p. 156– 165, 1987.

The intelligent investor's guide to Alaska's groundfish fishery, by C. Wiese and P. Burden: Pacific Fishing, September, p. 46–57, 1988.

Arctic Engineering in the 21st Century

BEN GERWICK

Ben Gerwick is Professor of Civil Engineering at the University of California at Berkeley, member of the U.S. Arctic Research Commission, and former chairperson of the National Research Council's Marine Board.

The long-term development of the Arctic appears inexorable. We can predict with some confidence that there will be a significant increase in facilities and operations for exploration of energy and petrochemical resources, for minerals, for tourism, for scientific observation and experimentation, for transportation, for fisheries, and for improvement in the living standards and health of the Native populations. Superimposed on these are the needs of national security. There seems to be general concurrence, nationally and internationally, that these developments are to be carried out with minimal adverse disruption to the environment.

Yet we all have faced the difficulty, if not impossibility, of translating such broad objectives into tangible specifics. What are the research needs to enable the engineering disciplines to fulfill their tasks in the year 2000 and beyond? What specific educational thrusts are needed to prepare engineers now entering universities for the demands of the 21st century?

At the outset it appears important to define the objectives of engineering and engineering research in the Arctic. A possible statement is: "To provide efficient, safe and economical methods for constructing and operating facilities in the Arctic to develop the natural resources and to carry out a full spectrum of activities — scientific, military, health and educational — with minimal adverse effects on the Native culture and the environment." With special relevance to Arctic science, this objective includes the provision of platforms, power, communications and logistics to support scientific endeavors.

There are several possible approaches to predicting the direction of Arctic engineering 30 years hence. It's a frightening task because we're all aware of our inadequacies in prediction.

We can, for example, take the historical approach. Let's consider the situation 30 years back, in the late 1950s. It was an era of high construction activity throughout Alaska, due primarily to the Cold War. There were remote radar stations, military bases, airfields, roads and housing to build. Our engineering and construction capabilities were primitive. The roads, which were just gravel placed over tundra, were subject to frost heave and subsidence. The embankments failed in sudden slumping, and buildings sagged as the permafrost degraded. Pipelines were laid directly on the tundra. Surveying techniques were archaic by today's standards, and roads laid out in the winter became raging streams in summer. Cat trains were our most effective winter supply method, still burning wood under the diesel tanks to keep them from freezing. Communications were interrupted for days at a time by magnetic storms. Garbage, sewage and empty oil drums were cast onto the adjoining land.

In that era, how could we have even begun to predict an Alaska pipeline elevated on thermally stabilized piles, prefabricated modules for Prudhoe Bay weighing several thousand tons, the fisheries of the Bering Sea, satellite navigation and the global positioning system, and synthetic aperture radar?

An important lesson in the development over the last 30 years is that satellite technology, so critical for the Arctic, was just in its infancy, and there were no Arctic missions in mind at all.

We can also remember the old adage: "We are too optimistic in our predictions for next year but grossly underestimate the long-term future."

A second approach is to list those areas in which we are currently involved and for which we recognize the need for improvement. This is the approach that many of us have undertaken on behalf of national, professional and academic organizations. Recently the National Science Foundation sponsored a workshop called "Arctic Engineering Research—A Strategic Plan" at Hanover, New Hampshire, seeking to develop a program not only for the NSF but also for the Interagency Working Group on Engineering and Technology and for the Arctic Research Consortium of the United States (ARCUS); the former comprises those agencies within the Federal Government having active Arctic interests, and the latter is made up of universities with Arctic involvements (see p. 53).

Based on these and similar recent studies, we can identify a number of specific areas that offer significant opportunities and potential benefits. This list represents a logical extrapolation from present capabilities through identified constraints to relatively clear objectives. The time frame is consequently short: these represent a program for the next decade.

Here are the principal topics:

- Construction engineering technology to reduce the costs and time associated with Arctic construction. As long as facilities cost 2–10 times as much in the Arctic as in the "lower 48," Arctic development will be stunted.

- Coastal and river engineering, particularly the erosion and ice ride-up that threaten coastal communities. Of special interest is the long-term effects of global warming, with a potential sea level rise in the Arctic of 1 m or more. This appears to pose the threat of massive flooding of low-level coastal and delta areas during periods of high river discharges.
- Materials for use at low temperatures, with special attention to impact, fatigue endurance and service as moisture barriers and insulation.
- Stabilization of embankments, roadway fills and pavements against frost heave, permafrost degradation and cracking.
- Facilities and infrastructure, including utilities (waste treatment, water supplies and power).
- Surface means for remotely determining subsurface geotechnical properties.
- Sea ice and its interaction with structures, especially in the shear and pack ice zones.
- Year-round mining in the Bering Sea and winter relocation of drilling platforms in the Beaufort Sea.
- Submarine tankers carrying oil to the East Coast.
- Gas liquefaction plants.

These are needs we clearly see today, the directions for Arctic engineering research in the 1990s. Such an approach, however, typically fails to see the truly significant breakthroughs: the dramatic and revolutionary advances that periodically shape developments, especially in unique environments like the Arctic.

Inherent in this approach is the rather arrogant assumption that there will be an inexorable growth, a "manifest destiny" to bring to the Arctic the urban civilization of the temperate zones: the cities, the industrial plants and the tourist centers. Robert Service dreamed "of cities leaping to stature, of fame like a flag unfurled. As I pour the tide of my riches in the eager lap of the world."

This approach fails to recognize the Arctic for what it is: a unique environment, physically, ecologically and culturally.

The third approach appears to evolve from the previous two: the historical and the extrapolative. If they do not provide a meaningful guide for the long term, then perhaps we ought to learn from them that it may be not so much our present needs that will determine the future as it will be the new technologies, developed independently of the Arctic environment, that engineering will adapt and transform to both serve and spawn new Arctic developments. What are these new technologies that today lie on the horizon? Several appear to offer exciting possibilities:

- Biotechnology, already employed on a trial basis in the Arctic, for road, slope and embankment stabilization. Can it also convert waste or algae to power, to be stored in batteries for use at remote sites?
- Microtunnelling, already used extensively in crowded urban environments and under coastal surf zones. Can it be adapted to permafrost? Will new insulating and heat-tracing technology permit insertion of piping into these horizontally drilled holes?
- Clathrate production. The gas potential that is bound up in these complex molecules of frozen water and gas far exceeds that in conventional petroleum deposits.
- Structures of frozen ground and perhaps plastic-reinforced ice, permanently cooled by thermopiles.
- Plastic modules, with integral insulation and moisture barriers, capable of being deployed by air and readily erected into a variety of building structures, completely outfitted for use.
- Robotics. Perhaps the most exciting possibility of all will come with remotely controlled mechanized operations, carried out by industrial robots that are unaffected by the cold, and monitored by satellite and electronic transmission. One can visualize robotic mining equipment extracting coal from the Brooks Range, processing it automatically, transporting it by slurry pipeline for self-loading onto ice-breaking tankers, while other robotic machinery restores the topsoil and treats it to accelerate the restoration of tundra.

Offshore and onshore, oil and gas production facilities will operate unmanned. Perhaps man will then not have to construct mammoth communities at every Arctic site. Instead of large industrial complexes and facilities typical of the temperate zones, robots and automated equipment may carry out the long-term development of the Arctic. We already see efforts in this direction with the proposed oil production facilities in the Arctic National Wildlife Refuge—one-third the size of those at Prudhoe Bay.

If robots can do the essential tasks safely, economically and efficiently, oblivious to the cold, then man's intervention can be minimized. It need not unduly disrupt the environment nor adversely affect the Native ways of life.

The adaptation and development of emerging technology for Arctic use will require advanced multidisciplinary engineering and technology, directed both to applied research and the development of pragmatic, workable systems. As each development takes shape, it will facilitate the introduction of others, and these may synergistically create a radically different system.

The surges in engineering and construction in the Arctic in the past have always been episodal events, as so vividly described in Mitchener's latest book, *Alaska*. They have been driven by furs, gold, war and oil. Each period of frantic activity has been followed by a period of stagnation, that is, up until now. That Arctic interest has continued as strong as it has, despite the collapse of oil prices, is truly remarkable, an illustration of how developmental breakthroughs can ultimately become self-generating.

Thus we see the vision of an Arctic in the 21st century in which the hand of civilization and development is technological in character, exploiting the resources of the Arctic in a kindly way, without despoiling the environment.

This is the challenge for Arctic engineering in the 21st century.

Status of Federal Arctic Research Logistics Coordination

CHARLES MYERS AND RICHARD PERMENTER

One of the responsibilities of the Interagency Arctic Research Policy Committee (IARPC) is to "...promote Federal interagency coordination of all Arctic research activities, including logistical planning and coordination" [Section 108(a)(9) of the Act]. In response to this mandate, the IARPC convened a Logistics Working Group in June 1988. The working group is chaired by Rear Admiral F. D. Moran, National Oceanic and Atmospheric Administration (NOAA), and the principal agencies involved in this effort are the Departments of Commerce (through NOAA), Defense, Interior and Transportation; the National Aeronautics and Space Administration (NASA); and the National Science Foundation (NSF).

Several logistics planning and coordination tasks are under consideration by the Logistics Working Group, including:

- Identifying existing and planned U. S. capabilities in facilities, aircraft and ship resources;
- Establishing mechanisms for cost-effective support of large regional coordinated projects and individual research projects; and
- Developing coordination mechanisms for scheduling Federal Arctic logistics, communications, search and rescue, remote sensing, and operational forecasting.

The initial focus is on identifying and scheduling existing and planned U.S. logistics support resources. Although mechanisms already exist to disseminate information on the schedules of research aircraft and the Federal oceanographic research fleet, the Logistics Working Group believes that more coordination of effort and scheduling is needed for Arctic operations. The product of that effort is the Federal Arctic Logistics Support Directory, a computer data base of Federal and other U. S. logistics facilities and resources. This is the first comprehensive directory of Federal Arctic logistics facilities since the former Interagency Arctic Research Coordinating Committee published the *Arctic Logistics Support Directory* in 1972.

The Federal Arctic Logistics Support Directory is currently maintained by the National Oceanic and Atmospheric Administration's Office of NOAA Corps Operations. Plans are underway to implement an electronic bulletin board to provide rapid access to the directory for the research community. The directory should be considered an evolving system. Readers are encouraged to submit additional information, specifically information on the type of support, the mission statement, the operational constraints, the scheduling requirements, the cost and the name and address of the principal contact should be sent to the Office of NOAA Corps Operations, 6010 Executive Boulevard, Rockville, Maryland 20850.

Charles E. Myers is on the Arctic Staff, National Science Foundation. CDR Richard Permenter is part of NOAA Corps Operations, National Oceanic and Atmospheric Administration.

The directory divides logistical support into five broad categories: aircraft, ships, field facilities, engineering and test facilities, and operational information. The following is a brief description of these categories.

Aircraft

Several agencies operate fleets of aircraft and coordinate aircraft support. The Department of the Interior supports an Alaska Office of Aircraft Services (OAS), which coordinates aircraft services on a reimbursable basis. The Office of Aircraft Services was established to provide aviation services safely and efficiently to all the various aircraft-using bureaus, offices and field programs within the Department. Through cooperative projects and programs, OAS has become accustomed to providing such services to other Federal and state organizations. There are 46 aircraft within the Department that are available for support, including large transport aircraft. In addition, NASA, NOAA and NSF operate research aircraft. NASA publishes the *Airborne Science Newsletter*, covering the availability and scheduling of Federal research aircraft. For information on these aircraft, contact the Airborne Science Program Office, NASA Code EE, Washington, D. C. 20546.

NSF supports the Research Aviation Facility (RAF), through the National Center for Atmospheric Research. The RAF maintains and operates three aircraft in support of atmospheric and oceanographic research. The three aircraft are the NCAR Sabreliner, a medium-range, high-altitude, pressurized twin-jet plane; the NCAR Electra, a long-range, large-payload turboprop; and the NCAR Beechcraft King Air aircraft, a low-wing, pressurized twin prop with medium range.

NOAA supports an Office of Aircraft Operations. The Navy operates NSF-owned, ski-equipped LC-130 transport planes, which are normally used in the Antarctic but may occasionally be used in the Arctic by special arrangement.

Other ski-equipped LC-130 aircraft are operated by the New York Air National Guard. The Alaskan Air National Guard operates ski-equipped Twin Otter aircraft.

Ships

The two broad categories of ships for Arctic operations are icebreakers operated by the U. S. Coast Guard and ice-capable or ice-strengthened vessels for research and survey purposes.

The two icebreakers, *Polar Star* and *Polar Sea*, are multi-mission, polar-capable icebreakers that act as platforms for scientific, strategic and economic development missions in the Arctic and Antarctic. These ships have helicopters with 24-hour operational capabilities. Up to 20 scientific personnel can be accommodated. The icebreakers are scheduled by the U. S. Coast Guard Ice Operations Office.

NSF sponsors the University–National Oceanographic Laboratory System (UNOLS). UNOLS consists of approximately 25 research vessels that support all types of oceanographic research. Most of these ships do not routinely operate in the Arctic, but several are capable of working at high latitudes during limited periods of the year.

The *Alpha Helix* is an ice-strengthened research vessel that is operated by the University of Alaska as part of the UNOLS fleet. The ship supports all types of oceanographic research and works primarily in the North Pacific, Gulf of Alaska and Bering Sea.

NOAA operates a fleet of research vessels to meet its missions in oceanographic research, nautical charting and fisheries research. Within the NOAA fleet the four Class I vessels (ranging in size from 278 to 303 feet) and three Class II vessels (231 feet) have ice-reinforced hulls. Two of the Class I ships (*Surveyor* and *Malcolm Baldridge*) are capable of carrying helicopters. NOAA policy prohibits these ships from entering areas of high ice concentration. However, several of the ships have operated in the Arctic when ice concentration was low. The ship time is allocated through the NOAA Fleet Allocation Council to directly support NOAA's missions. Piggyback projects are possible if they don't interfere with the ship's primary mission, and dedicated ship time is available on a reimbursable basis.

NOAA operates a full-time logistics and liaison office in Anchorage, Alaska, to support the NOAA ships deployed in Alaskan waters. The office also serves as a regional distribution office for nautical and aeronautical charts.

The U. S. Geological Survey operates two vessels in Alaska, the 42-foot R/V *Karluk* and the 208-foot R/V *Samuel Lee*. The *Lee* is an ice-strengthened vessel, while the *Karluk* operates in coastal waters.

Field Facilities

A diverse collection of land-based field facilities exists for supporting research in the Arctic. The NSF-funded Polar Ice Coring Office at the University of Alaska operates a base camp at Sondrestrom Air Force Base to provide logistics support for research on the Greenland Ice Cap. Also at Sondrestrom Air Force Base is the Sondrestrom Incoherent Scatter Radar Site for research on the upper atmosphere. An extensive array of optical equipment—a Fabry Perot interferometer, photometers and imagers—is located at the radar facility. For upper atmospheric research, agencies may conduct rocket launches into the polar cap from Thule and Sondrestromfjord, Greenland, subject to the approval of Danish authorities.

NOAA manages the Outer Continental Shelf Environmental Assessment Program (OCSEAP) at the Alaska Office, Ocean Assessments Division, National Ocean Service. The office and warehouse are located in Anchorage, Alaska. The OCSEAP program involves research by NOAA, other Federal agencies and academia. The office maintains an equipment pool of small boats, motors and a small amount of scientific equipment, such as microscopes, CTDs and bottom samplers. A warehouse with approximately 6000 square feet of space is managed by the office. The Alaska Office also operates facilities at Prudhoe Bay and Kasitsna Bay, and it has a 36-foot aluminum boat at Prudhoe Bay. This office is an excellent source of information about ongoing research efforts in the Arctic, and it can provide considerable expertise on Arctic logistic support.

The Alaska Science and Engineering Advisory Commission has prepared a report and map of Alaska research sites and support facilities. Numerous state facilities are identified in the report. It is available through the Office of the Governor of Alaska. In addition to State and Federal land-based capabilities in Alaska, the former Naval Arctic Research Laboratory at Point Barrow is now operated by the Ukpeagvik Inupiat Corporation.

Small seasonal camps are maintained in the Alaskan Arctic by individual agencies or groups of agencies (including NOAA, Department of Energy, Fish and Wildlife Service, National Park Service and NSF) to support field programs. Several agencies operate or provide support on sea ice camps.

U. S. investigators have access to land-based facilities in Canada and Nordic countries on a cooperative or reimbursable basis. Cooperative arrangements with the Polar Continental Shelf Project Office in Canada provide for logistics support in the Canadian High Arctic. Facilities in Svalbard are available through the Norwegian Polar Institute, Norwegian universities and other national programs (see *Arctic Research of the United States*, vol. 2, Spring 1988, p. 42).

Engineering and Test Facilities

Several agencies maintain engineering and test facilities to support and extend their capabilities in Arctic logistics. These include the Army's Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire. CRREL operates an Alaska field station for science and engineering projects. It provides laboratory space, scientific equipment, thermal sensors and testing of solid waste, sewage and water. At Hanover, CRREL maintains state-of-the-art laboratories, cold room facilities, and test basins and flumes with freeze–thaw capabilities.

The Naval Civil Engineering Laboratory at Port Hueneme, California, has the capability of maintaining snow runways, snow roads, ice wharfs, vehicles and shelters. It has two cold chambers and the facilities for developing new equipment and techniques for construction and salvage.

Other Navy laboratories have engineering research and development programs. Among these are the Naval Sea Systems Command (NAVSEA), with a research and development program in search, recovery and salvage in Arctic environments. NAVSEA coordinates the Arctic Cold Weather Surface Ship Program with the Chief of Naval Operations, Surface Ship Survivability Program Office. The Naval Oceanography Command develops short-term, mobile aerial ports and support camps on Arctic ice packs; it also develops buoys. The Naval Facilities Engineering Command supervises equipment and trains military personnel to set up and operate small Arctic camps and perform cold-weather diving operations. The Air Force operates a large refrigerated hangar at Eglin Air Force Base, Florida.

Operational Information

Several agencies have offices in Alaska or the "lower 48" involved in various programs of interest to Arctic researchers. While these offices are committed primarily to supporting parent agency programs, they represent a significant source of information and expertise on Arctic logistics and field operations. The capabilities range from program management for multiagency research efforts to additional information on points of contact and assistance in operations.

Publications

Readers may obtain further information on logistics support from the following publications:

U. S. Arctic Research Plan, Biennial Revision for 1990-1991, Interagency Arctic Research Policy Committee, 1989 (in press).

Logistics Support of Arctic Research, U. S. Arctic Research Commission, July 1988.

Alaska Research Sites and Support Facilities Inventory, Alaska Science and Engineering Advisory Commission, 1989 (in press).

Summary index of the Federal Arctic Research Logistics Directory (June 1989).

Support type	Operational area	Agency/Principal contact	Telephone
Aircraft			
Aircraft Support	Alaska	Interior/Office of Aircraft Services (OAS)	907-243-3320
Aircraft Support	Alaska and offshore	Interior/Minerals Management Service	907-261-4620
Ski-equipped C-130	Arctic; Greenland	Air National Guard/NYANG109thTAG	518-381-7422
Ski-equipped C-130	Polar regions	U.S. Navy/VXE-6	805-989-7588
Research Aircraft	Arctic	NSF/National Center for Atmospheric Research	303-497-1032
Research Aircraft	Arctic	NOAA Corps Operations	305-526-7100
Charter Aircraft	Arctic	Polar Science Center	206-543-1348
Research Aircraft	Alaska	USAF/Alaskan Air Command	907-552-1110
Aircraft Support	Arctic	NASA/Airborne Science Program Office	202-453-1720
Ships			
Icebreakers	Arctic	U.S. Coast Guard/Ice Operations	202-267-145?
Ice-strengthened Research Vessels	Arctic	NOAA Corps Operations	301-443-8101
Research Vessel (36 ft)	Prudhoe Bay, Alaska	NOAA/National Ocean Service	907-271-3033
Research Vessels	Alaska	NSF/Marine Operations	907-224-5261
Research Vessels	Alaska	NSF/UNOLS Fleet	206-543-2203
Ship Support	Arctic	Polar Science Center	206-543-1348
Research Vessels (42 ft; 208 ft)	Alaska	Interior/U.S. Geological Survey	415-459-3184
Research Vessel - Fisheries	Alaska	Interior/Fish and Wildlife Service	907-235-6546
Marine Support	Alaska	Interior/Minerals Management Service	907-261-4620
Field Facilities			
Field Camps - Parks	Alaska	Interior/National Park Service	907-257-2568
Field Camps - Public Lands	Alaska	Interior/Bureau of Land Management	907-271-5076
Field Camps - Fisheries	Alaska	Interior/Fish and Wildlife Service	907-456-0218
Field Sites and Laboratory - Forestry	Alaska	Agriculture/Forest Service	907-474-7443
Field Station (lab, equipment)	Fairbanks, Alaska	U. S. Army/Cold Regions Res. and Eng. Lab.	603-646-4100
Laboratory/Office	Alaska	NOAA/Ocean Assessment Division	907-271-3033
Upper Atmosphere Radar Facility	Sondrestrom, Greenland	NSF/SRI International	415-859-3749
Glaciology Support	Greenland; Arctic	NSF/Polar Ice Coring Office	907-474-7314
Sounding Rockets	Poker Flat, Alaska	U. S. Air Force/Geophysics Laboratory	617-377-4441
Acoustics/Ice Camps	Arctic	U. S. Navy/Navy Ocean R&D Activity	601-688-5227
Sea Ice Coring/Communications	Arctic	U. S. Navy/Navy Ocean R&D Activity	603-646-4181
Underwater Construction/Ice Camps/Diving	Arctic	U. S. Navy/Naval Facilities Engrng Command	202-325-0505
Support Camps/Buoys	Arctic	U. S. Navy/Oceanographic Office	601-688-5100
Ice Camps/Diving Support	Arctic	University of Washington/Applied Physics Lab.	206-543-1354
Ice Camp Support	Arctic	Polar Research Laboratory	805-684-0441
Ice Camps/Diving Operations	Arctic	Science Applications Intn'l Corp. (SAIC)	805-683-3881
Engineering and Test Facilities			
Engineering Support/Camps	Arctic	U. S. Army/Cold Regions Res. and Eng. Lab.	603-646-4100
Surface Ships/Air Cushion Vehicles	Arctic	U. S. Navy/David Taylor Research Center	202-227-1849
Logistics Engineering and Development	Arctic	U. S. Navy/Naval Civil Engineering Laboratory	805-982-4664
Oceanography/Remote Sensing/Acoustics	Arctic	U. S. Navy/Naval Research Laboratory	202-767-3489
Operational Information			
Ice Reconnaissance/Analysis/Forecasting	Global	U. S. Navy/Polar Oceanography Center	202-763-5972
Satellite Remote Sensing Data	Global	NASA	202-453-1725
Search and Rescue	Global	U. S. Navy/Naval Sea Systems Command	202-697-7402
Icebreakers	Global	U. S. Coast Guard	202-267-1450
International Clearances	Global	U. S. Department of State	202-647-4970
General Logistics Support	Arctic	NOAA Corps Operations	301-443-7412

Recent Reports of the Polar Research Board

Prepared by Andrea Smith, Polar Research Board, National Research Council.

Arctic Social Sciences: An Agenda for Action

In February 1989 the Committee on Arctic Social Sciences, Polar Research Board (PRB), National Research Council, published *Arctic Social Science: An Agenda for Action*. This report in the PRB's Strategy series presents a multidisciplinary research plan for Arctic social science. "The time has come for Arctic social science research to be better integrated into the mainstream of the relevant scientific disciplines," the report states. It identifies key research themes and infrastructure changes needed to support the research agenda. The committee is cochaired by Mim Dixon, Chief of the Andrew Isaac Health Center, Fairbanks, Alaska, and Oran Young, Institute of Arctic Studies, Dartmouth College. Funding for this project was provided by the State of Alaska, the National Science Foundation, the Bureau of Land Management of the Department of Interior, and the Smithsonian Institution.

Charged with developing a strategy to meet the national need for more and better social science research on northern topics, the committee identified three priority themes for research: human/environment relationships, community viability and rapid social change. The committee chose themes that are global or circumpolar in significance, address urgent topics of human survival, span the continuum between basic and applied research, transcend individual agency concerns and disciplinary boundaries, bridge the social, biological and physical sciences, and offer opportunities for international collaboration.

Key research problems are identified for each of the three main themes. Human/environment relationships focuses on problems such as allocation methods for scarce natural resources, conflict resolution in the use of natural resources, control of human activities that threaten to disrupt natural systems, human responses to habitat change, and models of the impacts of global warming on humans. For community viability the committee recommends that further research be conducted in the areas of economic diversification of Arctic communities, workforce motivation, obstacles to community survival, and the relationship between community survival and cultural survival. Rapid social change includes studies of the relationships between social change and physical and mental health, as well as the cognitive and emotional limits of people's ability to cope with rapid change.

The committee also identified several deficiencies in the infrastructure supporting U.S. Arctic social science research. The committee prepared recommendations to strengthen this infrastructure, the first of which states that the National Science Foundation should accept responsibility as the lead federal agency for Arctic social science research and should take the steps necessary to build and sustain an effective Arctic social science research community. Other recommendations concern interagency cooperation, education and training, involvement of Arctic residents, cooperative studies units, research ethics, data and information, and international cooperation.

In the course of this study the committee held two public sessions in Washington, D.C., involving 50 participants at each session. The committee held a public workshop at the AAAS Arctic Science Conference in Fairbanks, Alaska, in October 1988, to provide a forum for open discussion and a review of the committee's discussion paper. Approximately 80 individuals attended this workshop. Having developed an extensive network of interested social scientists, the committee hopes to encourage their participation in the further development of Arctic social science research and policy.

Priorities in Arctic Marine Science

The Polar Research Board's Committee on Arctic Marine Science recently completed its report *Priorities in Arctic Marine Science*. This report, also part of the Polar Research Board Strategy series, identifies priority research needs in Arctic marine science for the next decade and includes a discussion of the logistics required to support the recommended research agenda. The committee is chaired by Vera Alexander, Institute for Marine Studies, University of Alaska–Fairbanks.

Charged with reviewing long-term research directions, identifying gaps in current efforts and developing a plan for addressing priorities, the committee identifies two research areas requiring further emphasis: ecosystem dynamics of the Arctic shelf and adjacent seas, and circulation of the Arctic Ocean. The committee notes that both topics are of intrinsic importance, have global implications, and have not been adequately addressed in other documents. The committee provides a scientific framework and recommends research areas for each topic in its report.

Regarding ecosystem dynamics in Arctic shelf seas, the committee notes that there is a need for long-term basic research on marine ecology in the Arctic. The Arctic shelves are highly productive, factors affecting biological distribution and abundance are inadequately understood, and the effects of human activities on the ecosystem are increasing and may be deleterious for some species. A major priority identified for this topic is the establishment of long-term multidisciplinary ecological studies for these regions. Recommended research programs are also identified in the report.

Circulation of the Arctic Ocean merits priority attention because this ocean contains a significant thermohaline circulation with importance far beyond its borders, and knowledge of the circulation, dynamics and chemistry of the Arctic Ocean is rudimentary. Three areas identified by the committee for further study are the structure and maintenance of the interior Arctic Ocean, the interactions of the interior with bordering shelf seas, and the consequences of exchange with the seas to the south. Research programs are recommended in the report.

The committee also examined the logistics needed to support the recommended research programs. Logistical support requirements identified in the report include aircraft, ice stations, satellite remote sensing, icebreakers and ice-capable surface research vessels. The committee states, "Our capacity to learn more about the Arctic regions is severely limited by the lack of any research ships sufficiently strengthened to operate in sea ice." The committee recommends that the United States proceed with the procurement of an ice-capable polar research vessel for supporting Arctic marine research.

The committee's report includes several appendices, including a list of definitions of ships that operate in ice, a historical background of Arctic research vessel requirements, results of a survey of the Arctic marine science community on research vessel requirements, and a list of some current and proposed research in ice-covered waters.

Data Coordination and Career Stimulation in Polar Biomedical Research

The Polar Research Board's Committee on Polar Biomedical Research recently completed its final report in a series on polar biomedical research. As populations and activity in the polar regions increase, so does the awareness of polar biomedical problems and the need for polar biomedical research. The committee's 1982 report *Polar Biomedical Research: An Assessment* was prepared to develop a strategy for research in this area over the next decade in response to a request from the Department of Defense. The committee chairman is Chester M. Pierce, Harvard University.

More specific guidance was requested on ways to improve access to biomedical data and to facilitate its application, as well as to attract more people to the field; the committee recently completed the appendix *Data Coordination and Career Stimulation in Polar Biomedical Research* to provide this guidance. This report addresses lack of awareness of and access to polar biomedical research data and the interrelated problem of career opportunities and satisfaction that this field can provide.

Problems with polar biomedical data coordination include the identification of what data have been collected and where they are stored, a systematic notation of data limitations, and accessibility. The committee also noted a lack of data-processing capability and a need for greater awareness of and access to international research.

To address these concerns, the committee recommends establishing an information and research support facility. Such a center would not store data, the committee states, but would act as a network or switching station directing individuals to each other. The center could provide advice on the coordination and consolidation of research design, sources and levels of support, data collection, storage and analysis, and other kinds of data dissemination. Other functions of such a center are identified in the committee's report.

Regarding career stimulation, the committee states that "greater effort is needed to bring to the attention of students and science organizations the potential and satisfaction of total or partial careers in polar medicine." Some methods of recruiting medical students and other individuals into this field are identified in the report.

The committee's primary recommendation for stimulating interest in polar biomedical careers is to establish a circumpolar health center. This center could be concerned with dissemination of career information, curriculum development, vocational counseling, and community development. The report identifies additional functions of such a center, including sponsorship of outreach programs, information dissemination and newsletter publication, and guest lectureships and sabbaticals. The committee notes that Alaska would be a natural site for such a center.

Satellite Remote Sensing of Snow and Ice

The Polar Research Board's ad hoc Panel on Remote Sensing of Snow and Ice has recently published its report *Prospects and Concerns for Satellite Remote Sensing of Snow and Ice*. Chaired by Jeffrey Dozier of the University of California, Santa Barbara, and the Jet Propulsion Laboratory, California Institute of Technology, the panel was charged with assessing the remote sensing needs of the snow and ice community, identifying future satellite systems that may meet these needs, and examining data processing and storage issues.

The panel's report outlined the role that satellite remote sensing has played in expanding our knowledge of global snow and ice. In the past the collection of in situ measurements of snow and ice phenomena has been hampered by difficult access, polar night at high latitudes, inclement weather and mountainous terrains. During the past two decades, however, satellite remote sensing has allowed the acquisition of snow and ice data for most of the globe at regular intervals, regardless of environmental conditions. By the 1990s, because of the launch of several new satellites, much more remote sensing data relevant to glaciology will be available. The collection of these new data raise major questions regarding their processing, archiving and distribution.

The panel noted important scientific questions in the study of several snow and ice features—sea ice, snow, ice sheets and glaciers—and outlined for each feature what data are now provided by satellites and which types of remote sensing systems may provide additional data in the near future. Detailed characteristics of current and planned satellite systems are outlined in a table.

The panel concluded that it is optimistic about the future prospects for remote sensing of snow and ice but also that the glaciological community should continue to be involved with the construction and launch of new instruments and the specification of future sensor designs.

To achieve the potential benefits of the increasingly available snow and ice remote sensing data, the panel recommended a greater focus on training students in remote sensing techniques. In addition, the panel stated that the snow and ice community should agree on the definition and distribution of data products and that Federal agencies involved with remote sensing should strive to develop uniform archival standards. To this end the panel recommended that working groups be established as needed for each of the subsets of the snow and ice community to identify scientific issues, assess capabilities and make recommendations for establishing facilities for data acquisition, processing, archiving and analysis.

Additional recommendations were presented on the need for continued availability of data, the need for future sensors, the development of geophysical products from raw remote sensing data, and data distribution.

Publications Source

For copies of any of these reports, write to the Polar Research Board, National Research Council, 2101 Constitution Ave. NW, Washington, D.C. 20418.

Arctic Research Consortium of the United States

The Arctic Research Consortium of the United States (ARCUS), an association of institutions with strong interests in Arctic studies, was formed to strengthen and advance Arctic research to meet national needs. ARCUS consists of colleges and universities, as well as nonprofit institutions organized and operated for educational, professional or scientific purposes.

The consortium has been established in response to the growing and changing demands placed on organizations and individuals responsible for planning, organizing and implementing research activities in the Arctic. Its functions include

- Promoting public awareness about the Arctic;
- Improving science and education;
- Improving communication; and
- Coordinating Arctic logistics.

The consortium serves in part as an academic contributor, discussant and advocate in balance with the more policy- and agency-oriented advisory groups. Seventeen institutions have joined ARCUS as voting members since the consortium was inaugurated on October 9, 1988.

Ad hoc working groups are used to identify new initiatives and critical tasks and to assist in developing proposals on behalf of the consortium. For example, an ad hoc committee was founded in February to prepare a proposal to develop a plan for implementing the recommendations of the Arctic interactions report (see *Arctic Research of the United States,* Spring 1988, p. 59). The plan will provide Federal agencies engaged in supporting Arctic research with a framework for implementing the results of the Arctic interactions workshop.

In March, ARCUS hosted a meeting in Washington, D.C., of chairpersons of several Arctic advisory groups and other bodies concerned with Arctic research planning. The meeting, attended by representatives from eight groups, focused on the development of a national agenda for Arctic research and the opportunities that exist for initiating a synergistic plan to achieve this goal. Further discussions on these topics are planned.

In the future, ARCUS, in conjunction with the IARPC Working Group on Logistics, is organizing a special session on Arctic Operations, Communications, Technology and Research Support to be held at the AAAS meeting on September 16, 1989, in Fairbanks, Alaska. In addition, ARCUS is serving as a national sponsor and organizer for the International Conference on the Role of the Polar Regions in Global Change to be held on June 11–15, 1990, in Fairbanks, Alaska.

A two-year program operating plan for ARCUS has been prepared that identifies the goals for 1989–90 and the specific activities that will be followed for achieving these two-year goals. Copies of the plan can be obtained by writing to Chris Shepherd, Executive Director, ARCUS, c/o INSTAAR, University of Colorado, Boulder, Colorado 80309-0450.

Alaska Science and Technology Foundation

Prepared by Francis Williamson, University of Alaska–Fairbanks.

The Alaska Science and Technology Foundation (ASTF) has been in existence since the organizational meeting held on October 11, 1988, in Anchorage. (See *Arctic Research of the United States*, Spring 1988, page 3, and Fall 1988, page 92, for background on the ASTF.) The Board of Directors has held five working meetings and will hold an additional two meetings during the remainder of the first year of activity. Key accomplishments during this period have been the preparation of a document entitled *General Solicitation*, a second document entitled *Research and Development Grants Projects—General Instructions for Application*, and a third document entitled *First Request for Proposals*.

The foundation's *General Solicitation* outlines the two "windows" available to proposers for competitive funding of projects. The Alaska Research Projects window seeks to encourage precommercial projects that can reasonably be expected to result in a product, process or service that directly relates to the employment or health of Alaska residents in the development of Alaska resources. The Alaska Development Projects window is designed to encourage projects that result in new products, processes or services, employment of Alaska residents, and development of Alaska resources.

The forms distributed with the *Research and Development Grants Projects* document includes application forms for both preproposals and proposals. The foundation requires proposers to submit a preproposal application for each project. This is intended to assist the foundation in reviewing the project's program eligibility, as well as providing help while completing the longer, more-detailed proposal application forms, and in maintaining an accurate record of potential projects. To date, approximately 340 preproposals and 100 formal proposals have been submitted to the foundation. The selection of the first proposals for funding is expected to take place during the meeting of the foundation to be held July 16–18, 1989.

As reported earlier the foundation began its activities with the funding of a $6 million capital appropriation from the Alaska State Legislature. More recently, on June 2, $34 million of the $100 million authorized for deposit over the next three years was deposited in the endowment to be managed by the Alaska Permanent Fund Corporation.

The Search Committee for an Executive Director of the foundation completed its work in April, resulting in the selection of Dr. John Sibert, who began his duties on June 1, 1989. Dr. Sibert was previously employed as the Division Administrator, Division of Chemistry and Chemical Engineering, California Institute of Technology. His background includes positions as Manager of Program Research and Manager of Exploratory Research, both for the Atlantic Richfield Company, and service as an Assistant Professor of Chemistry at Yale University. He received his Ph.D. in inorganic chemistry at the University of California, San Diego, in January 1970.

Dr. Sibert has begun the process of recruiting persons for the remaining three positions approved for the foundation: Deputy Executive Director, Grants Administrator and Executive Secretary. These employees and the headquarters of the foundation will remain in Anchorage, Alaska. For more information on the foundation and its activities, contact Dr. John Sibert, Executive Director, Alaska Science and Technology Foundation, P.O. Box 230507, Anchorage, Alaska 99523.

Arctic Science Conference

Prepared by J. Morack, Department of Physics, and N. Brown, Geophysical Institute, University of Alaska–Fairbanks.

Each year the Arctic Division of the American Association for the Advancement of Science sponsors a science conference. This conference brings together scientists from Canada and its Yukon and Northwest Territories and the United States. The 1988 conference was held in Fairbanks, Alaska, on October 7–10. Since the theme of this conference was science education, it provided a unique opportunity for science teachers to interact with a diverse group of scientists who study scientific phenomena associated with the Arctic and northern latitudes.

Early in the planning stages for the conference, a staff development day for the Fairbanks North Star Borough School District was coordinated with the conference. This day (October 10) was designed so that the approximately 500 district teachers who teach science could attend the conference. The day was designated as Educator Day, and the program was designed to include a combination of science topics that would be of interest to teachers at all levels. In addition to special technical sessions designed for teachers, a group of nationally known science educators was invited to present keynote addresses.

The special technical sessions included two special symposia and several technical talks designed for the non-expert. The first symposium, titled "Science education for the public", included such talks as "Teaching about geese in the curriculum," "Environmental education and the public agencies," "The LeConte glacier study" and "Acid rain/acid snow studies."

A second symposium, titled "Programs and perspectives in Alaska Native science and education," included talks on "Intervention as a means to improve college readiness of rural Alaska Native high school students," "Observations on math readiness of rural students and attempts at improving their rate of success at UAF" and "Engineering specialty instruction as part of the rural Alaska Honors Institute." Other presentations included "Radon in Alaskan homes," "Roads and airfields on permafrost," "Advising high school students on engineering curriculum," a demonstration on computer-aided design, and a workshop entitled "Creative problem solving and toys in space," presented by Peggy Lathlean, a finalist in the Teacher in Space Program.

The keynote addresses for the conference were presented by three experts in science education. Dr. Verne Rockcastle, Professor of Education, Emeritus, Cornell University; Dr. Arnold Arons, Professor of Physics, Emeritus, University of Washington; and Dr. Robert Yager, Professor of Science Education, University of Iowa, discussed their perspectives on science education. In addition, each presented a workshop or short course. They were all involved in several lively and informal discussions with teachers during the conference. The Fairbanks teachers were also invited to present papers discussing their contributions to effective science teaching. Enough papers were submitted to run several concurrent sessions.

Other events available to teachers during the conference were tours of the Poker Flat Rocket Range, the Permafrost Tunnel, the research facilities of the Geophysical Institute, the University Musk Ox Farm and the UAF Museum, and teachers had an opportunity to attend a meeting of the Association for Women in Science. In addition to the other short courses, a conference short course was offered to those who attended the entire four-day conference. Forty-eight teachers successfully completed this course, which required attendance at the entire conference and the submission of a paper on some topic presented at the conference.

The importance and uniqueness of bringing together scientists and teachers for such a conference became obvious early in the planning stage. As registrations began to fill, it became evident that some way should be found to involve teachers from outside the Fairbanks area. As a result, a proposal was funded by the National Science Foundation to provide travel stipends for Alaskan teachers in outlying areas. Each teacher wishing to attend the conference was asked to present a poster session, a short talk or a demonstration of how they would teach a particular scientific concept in their classroom. A special session was held on October 8 for the presentation of papers by this group of teachers. (This time was selected so that there would be no conflict with the myriad of activities planned for the staff development day.)

Twenty-five teachers received travel funds to attend the conference. The grant enabled teachers from such remote villages as Barrow, Adak, Point Lay, Thorne Bay, Metlakatla, Yakutat, Petersburg, Shungnak and Sand Point to attend the entire conference. To ensure an even wider dissemination of conference information, these participants were asked to submit a plan for sharing information they received during the conference with others in their school district. It is hoped that the conference was educationally broadening for these participants. For many it was their only opportunity to interact with teachers who were not from their school and a once-in-a-lifetime opportunity to attend a scientific conference.

The full importance of this conference to those attending is only now becoming evident. The effects of the many contacts and friendships that were made, the ideas for classroom science activities, and the new and interesting things that were learned about Arctic science are now beginning to find their way into the classrooms.

Update on the Arctic Environmental Data Directory Working Group

Prepared by Mary Jones and Douglas R. Posson, Information Systems Division, U.S. Geological Survey.

As described in the Fall 1988 issue of *Arctic Research of the United States* (p. 93), the Arctic Environmental Data Directory Working Group (AEDDWG) was formed as a result of an Arctic Environmental Data Workshop convened in Boulder, Colorado, in March 1988. The Working Group agreed to do the following by March 1989:

- Establish an Arctic Environmental Data Directory (AEDD);
- Populate that directory with references to at least 12 Arctic data sets from each of the eight organizations represented in the Working Group; and
- Identify other institutions that hold Arctic data.

The original workshop determined that its activities should be coordinated with the Interagency Working Group on Data Management for Global Change (IWGDMGC), which considers the AEDD and related activities as a pilot for global change activities. The Working Group also agreed to coordinate with any similar bodies that might be created in Canada. Finally, the AEDDWG determined that a small group should be established to address technical issues such as data standards. Douglas Posson, Deputy Assistant Director for Information Systems of the U.S. Geological Survey (USGS), was selected chairman of the AEDDWG.

As reported at the March 1989 meeting of the Interagency Arctic Research Policy Committee (IARPC), the AEDDWG has met its goals. Its accomplishments include forming the AEDDWG with participation by eight organizations, reporting on the Arctic Environmental Data System and the AEDDWG in the Spring and Fall issues of *Arctic Research of the United States*, and conducting two workshops in Anchorage, Alaska, in October 1988 and March 1989. The goal of including 96 refernces to Arctic data in the AEDD had been exceeded; 208 Arctic data references were entered into the AEDD by March 1989. (At the time this report was written, the AEDD contained about 250 references.) The Earth Science Data Directory, operated by the USGS, is the vehicle for the AEDD and provides the gateway to the interagency global-change master data directory. The AEDDWG identified 46 additional organizations that manage Arctic data.

The IARPC approved the following action plan for the AEDDWG for the coming year:

- A workshop will be held at the National Snow and Ice Data Center in Boulder, Colorado, on June 13–14, 1989. The AEDDWG expects to establish Standards Working Group(s). Members of the Northern Libraries Colloquy have been invited to ensure coordination between the two groups. The second day of the workshop will focus on how to develop a useful Compact Disk Read-Only Memory (CD ROM) product. The key design feature of the CD ROM digital data journal will be to ensure that CD ROMs produced by the AEDDWG will actually be useful to Arctic and global change scientists.
- The AEDDWG will add at least 100 data references to the AEDD, resulting from contacts by AEDDWG members with the 46 potential contributing organizations and other organizations that can be identified.
- The AEDDWG will continue to coordinate closely with the Northern Libraries to develop complementary data and information dissemination mechanisms.
- AEDDWGwill be developed as a prototype digital data journal for the Arctic to distribute the AEDD, initial bibliographic information and selected Arctic data sets to Arctic scientists for use on desktop computers.
- The AEDDWG will strengthen the Arctic data outreach program by holding additional workshops, increasing publication of related activities, and seeking greater participation by the State of Alaska and Canadian Arctic data organizations. The IARPC asked that the Working Group report back next year on its progress. It urged a broad interpretation of the term "environmental" when applied to Arctic data to include references to data sets describing human interaction with the environment and recommended that the AEDDWG establish contacts and share its progress with similar data groups in other countries involved in Arctic research.

To contribute to the AEDD or become an on-line user, write to C.R. Baskin, U.S. Geological Survey, 801 National Center, Reston, Virginia 22092, or call 703-648-7112 or FTS 959-7112.

Conference of Arctic and Nordic Countries on Coordination of Research in the Arctic

Prepared by Philip Johnson, Arctic Research Commission, and Andrea Smith, Polar Research Board, National Research Council.

This scientific conference, perhaps the largest international gathering of Arctic scientists ever, was hosted by the U.S.S.R. in Leningrad from December 12 to 15, 1988, and was attended by approximately 500 participants from 15 countries. Sixty percent of the participants were from the Soviet Union, 24% were from Europe, and 11% (or 52 attendees) were from the U.S. The conference consisted of a one-day plenary session followed by two days of presentations and discussions in six disciplinary areas:

- Upper atmosphere and near-earth space;
- Arctic ecosystems;
- Air/sea heat exchange and climate;
- Pollution and environmental conservation;
- Geology, geocryology and glaciology; and
- Social sciences and polar medicine.

On the fourth day, participants in each session prepared summary recommendations. These recommendations were presented during the plenary session on the fifth day of the conference.

To learn more of the perceptions of U.S. conference participants at this event and to help communicate conference results to scientists and others unable to participate in the conference, the Polar Research Board, National Academy of Sciences, prepared and distributed a questionnaire to the U.S. participants. A report summarizing questionnaire responses was subsequently prepared.

Based on 38 responses (or 73%), the conference was judged useful and worth repeating, and various suggestions were offered to improve planning, organization, language translations and audio-visual support. Informal contacts were thought to be the most valuable outcome to the U.S. scientific research participants. Several participants noted the value of meeting scientists from outside their immediate disciplines, and others were struck by a new openness from the Soviet participants. Various follow-up research activities among individuals were initiated in hallway discussions and are listed in the PRB conference summary. The report also includes conference participant lists, tallies and lists of institutions visited and Soviet contacts made by the U.S. participants. The report is available from the Polar Research Board, National Research Council, 2101 Constitution Avenue NW, Washington, D.C., 20418.

Officials presiding over the final plenary session of the Arctic science conference in Leningrad.

The conference was an important step in improving cooperation and strengthening communications among scientists and specialists of different countries. The following list summarizes areas recommended for possible international cooperation in Arctic research. It is drawn from the General Summary issued in January 1989 by V. Kotlyakov, Secretary of the Organizing Committee. These fields of international cooperation in the Arctic were presented in more detail in recommendations worked out by the conference sections.

Upper Atmosphere and Near Space

- The influence of changes in solar activity on terrestrial processes and improving methods for forecasting these changes by means of further observations within the framework of coordinated programs;
- Methods for diagnosing space perturbations in the areas of the cusp, the auroral oval and the polar cap with the use of rocket, airborne and land observations coordinated with satellite missions; and
- Definition of the physical and chemical regime of the ionosphere and the middle atmosphere and the changes in the content of the ozone and minor constituents during the expected intense solar maximum in the early 1990s.

Arctic Ecosystems

- Adaptations of organisms to the conditions of high latitudes, as well as the structure, functioning, natural dynamics and anthropogenic transformation of terrestrial and marine ecosystems;
- The evolution of biocenoses and paleoecology and the biogeographical regionalization of the Arctic;
- Biological diversity on the population, species and ecosystem levels, the creation of cadas-

ters and of the "Red Book" of plants, animals and ecosystems of the Arctic;
- Regularities in population dynamics, changes of numbers and migrations of marine and terrestrial mammals and birds, of biological processes on the shelves of seas, and of possibilities for creating mariculture; and
- Recommendations on the rational use, renewal and protection of biological resources, as well as approaches towards optimizing the network of protected areas and principles of ecological monitoring.

Interaction Between Ocean and Atmosphere; Arctic Climate Change

- Energy and mass exchanges between the ocean and the atmosphere and their role in forming the global climate;
- Mathematical models of air–sea–ice interaction;
- The physics of climate-forming processes, applied aspects of climate, thermodynamic processes, circulation of atmosphere, ice and polar waters, water and ice exchange of the Polar Ocean with the adjacent oceans; and
- A system of monitoring of the polar atmosphere, ocean and sea ice, including observations from satellites, drifting stations, automatic drifting buoys and other platforms.

Geology, Geocryology and Glaciology

- A geodynamic scheme of the Arctic that accounts for the drift of lithospheric plates and the stratigraphy of the sedimentation mantle;
- The deep structure of the Earth's crust under the Polar Ocean;
- A model of the oceanic lithosphere's evolution;
- Natural hydrocarbon gases;
- The existence, temperature regime and fluctuations of permafrost in the Arctic;
- A reconstruction of the glacial and climatic history of the Arctic for the last glacial–interglacial cycle, including deep drilling through the inland ice sheets; and
- Coordinated observations of the mass balance and fluctuation of existing glaciers.

Environmental Conservation

- The pollution of air, water and land in the Arctic, the processes of pollutants transfer and transformation, and the creation of corresponding models;
- The ecological consequences of toxic substances and oil spills in the ocean and an estimation of the assimilation capacity of Arctic ecosystems;
- The exchange of hydrochemical elements and pollutants between the Polar Ocean and the adjacent oceans;
- Joint programs of monitoring and simulation for studying the distribution of Arctic ozone, Arctic haze, chlorinated hydrocarbons and other trace components; and
- Recommendations on minimizing anthropogenic impacts when developing natural resources and rehabilitating disturbed ecosystems of the Arctic.

Socioeconomic, Educational and Cultural Problems of the Indigenous Peoples of the North; The Problems of Polar Medicine

- The cultures of northern peoples, their history and development, especially under the present conditions of the growing interregional and international economic, educational and cultural interaction;
- Medical–demographic and genetic aspects of the health of both indigenous and nonindigenous population of the North;
- A rational combination of modern and traditional sectors of the economy;
- Socio-economic problems of nonindigenous populations of the North;
- Better methods for designing and constructing residential and industrial buildings in the North;
- The creation and introduction of machinery, materials and technologies adapted to northern conditions; and
- Long-term development of the North in an increasingly complex economic and ecological situation.

Exchanging ideas about the role of Arctic research in different global programs (the International Geosphere–Biosphere Program, UNESCO's Man and the Biosphere Program, the World Climate Program, the Solar Terrestrial Energy Program, etc.) helped reveal general approaches and create prerequisites for further joint action in different fields of international cooperation in the Arctic. The conference participants supported the idea of creating an International Arctic Science Committee, which would be active in coordinating Arctic research, organizing joint work and exchanging the results of research.

Arctic Ocean Sciences Board

Based on a report prepared by Lou Brown, AOSB Secretary, National Science Foundation.

The eighth meeting of the Arctic Ocean Sciences Board (AOSB), chaired by Gotthilf Hempel, took place February 1–3, 1989, in Washington, D.C. Representatives of Canada, Denmark, West Germany, Iceland, Norway, Sweden, the U.K. and the U.S. participated.

The two-day business meeting included a review of the Greenland Sea Project and planning for the International Arctic Polynya Project (IAPP). The Board approved the IAPP as a program for the early 1990s and established a science coordinating group and three planning groups to ensure comparability among the three proposed sites: St. Lawrence Island (Bering), Northeast Water (Greenland) and Northwater (Baffin Bay). The Board also discussed the status of the Nansen Commemoration and Arctic Ocean drilling plans. Other items included operations of research vessels in the Arctic, reports of national programs, the relation of AOSB to global programs, and a review of international Arctic activities (the recent Leningrad Conference and the status of the International Arctic Science Committee).

The third day was devoted to a visit to NASA's Goddard Space Flight Center for briefings and demonstrations on remote sensing and its applications to Arctic Ocean research.

Future meetings were proposed for January or February 1990 for the IAPP Science Coordinating Group in Denmark and for the AOSB in the U.K.

International Arctic Science Committee

A March 1988 meeting of Arctic scientists and science administrators, hosted by the Royal Swedish Academy of Sciences (see *Arctic Research of the United States*, Volume 2, Spring 1988, page 46), agreed that an International Arctic Science Committee (IASC) be established to promote international cooperation and coordination of scientific research in the Arctic. A drafting group was organized to prepare the founding articles for the IASC, which then met in Moscow in July 1988 and again in Stockholm in October 1988. This was followed by a full meeting of representatives of eight Arctic nations in Leningrad in December 1988. Discussions focused on the participation of non-Arctic countries and the structure of the IASC. Proposals were made for working groups and a periodic Arctic science conference to identify key scientific problems. A meeting was held in Helsinki in May 1989 to review the status of the founding articles of the IASC. The current version of the founding articles is being circulated in the founding countries for review. It is hoped that a concensus regarding formation of IASC will be achieved by the fall of 1989.

Working Group on Arctic International Relations

Prepared by Oran R. Young, Institute of Arctic Studies, Dartmouth College, Hanover, New Hampshire 03755.

The Working Group on Arctic International Relations held sessions in Hveragerdi, Iceland, during July 1988 and in Ilulissat and Nuuk, Greenland, during April 1989.

The Working Group was created in response to a growing realization that rapid changes are occurring in the Arctic, which, taken together, are ushering in a new era in Arctic international relations. Though many observers of Arctic affairs are aware of this development, few have been able to examine its broader implications, asking what these changes mean for the Arctic as an international region as well as for the links between the Arctic and the surrounding international system. The Working Group on Arctic International Relations takes these concerns as its principal agenda. Thus, the Working Group will meet at regular intervals over a period of years to explore the nature of rapid changes in the Arctic and the consequences of these changes for international relations. Through informal discussion the Working Group endeavors to generate intellectual capital that will prove useful in handling a range of emerging Arctic issues, thereby broadening the alternatives considered in dealing with the Arctic. More generally the Working Group seeks to develop a clear perspective of the Arctic in world affairs and, in the process, to improve the prospects for international cooperation regarding Arctic matters.

The Working Group on Arctic International Relations, supported in large part by a grant from the John D. and Catherine T. MacArthur Foundation, is a freestanding entity. Individuals participate in their private capacities. The Working Group does not take public positions on specific Arctic issues. Individual members are free to make unattributed use of information and insights gained from participation in the discussions. With the aim of facilitating international cooperation in the Arctic, the Working Group engages in activities ranging from disseminating advance warning of emerging Arctic issues through inventing policy alternatives to providing informal channels for communication among the Arctic states. The affairs of the Working Group are entrusted to the co-chairs, Franklyn Griffiths of the University of Toronto and Oran R. Young of Dartmouth College, on the understanding that they will consult extensively with other members on all aspects of the Working Group's activities.

The Iceland session was devoted to efforts to take stock of the situation in the circumpolar North, to set an agenda for subsequent work, and to get to know one another. In addition to the co-chairs, participants in the Iceland session included Melvin Conant of Conant and Associates Ltd., Pavel Dzubenko of the Soviet Foreign Ministry, Gunnar Gunarsson of the University of Iceland, Lennart Linner of the Swedish Foreign Ministry, Finn Lynge of the Danish Foreign Ministry, Kari Mottola of the Finnish Institute of International Affairs, Oyvind Nordsletten of the Norwegian Foreign Ministry, Jakov Ostrovsky of the Soviet Foreign Ministry, Fred Roots of Environment Canada, Olav Schramm Stokke of the Fridtjof Nansen Institute and Jorgen Taagholt of the Danish Commission for Scientific Research in Greenland. Marcia Levenson of the University of California at Berkeley served as rapporteur.

The second session of the Working Group took place in Ilulissat/Jakobshavn and Nuuk, Greenland, during April 1989. The theme of this session was sustainable development in the Arctic. The discussion began with the World Commission on Environment and Development's definition of sustainable development as "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs" and proceeded to a discussion of effective strategies for promoting sustainable development under the conditions in the Arctic today. In addition to the co-chairs, participants in the Greenland session included Alexander Arikaynen of the Soviet Academy of Sciences, Vernita Cassidy of RurAL CAP, Pavel Dzubenko, Thrainn Eggertsson of the University of Iceland, Marie Jacobsson of the Swedish Foreign Ministry, Finn Lynge, Kari Mottola, Oyvind Nordsletten, Willy Ostreng of the Fridtjof Nansen Institute, Jakov Ostrovsky, Fred Roots and Jorgen Taagholt.

A report on the Iceland session of the Working Group is available; a similar report on the Greenland session is in preparation. These reports, as well as other information about the activities of the Working Group, can be obtained by writing to the Group's Secretariat located at Dartmouth College. The address is Working Group on Arctic International Relations, c/o Institute of Arctic Studies, Nathan Smith Building, Dartmouth College, Hanover, New Hampshire 03755, U.S.A., Telephone: (603) 646-1277, Telefax: (603) 646-1279, Telex: 650-360-6870MCI UW.

The Norse of the North Atlantic

Prepared by Gerald Bigelow, Curator, The Peary–MacMillan Arctic Museum and Arctic Studies Center, Bowdoin College, Brunswick, Maine 04011.

Between April 17 and 21, 1988, The Peary–MacMillan Arctic Museum and Arctic Studies Center of Bowdoin College, in cooperation with the Center for Northern Studies, hosted an international gathering of 26 scholars who are investigating the medieval Scandinavian settlements of the North Atlantic. The Viking colonization of the far northern Atlantic islands probably began about 800 AD. By 1000 AD the seaborne migration had spread from the eastern islands of Orkney, Shetland and Faeroe into the subarctic regions of Iceland, West Greenland and (briefly) Newfoundland.

The rapid expansion of European people, culture and subsistence economy was followed by a period of stabilization and regional differentiation, as Norse settlers adapted to the varied island ecosystems and local resources. The later Middle Ages saw the political integration of the Norse North Atlantic settlements into the Norwegian kingdom, their cultural integration into medieval Christendom, and their increasing participation in international trade. By the sixteenth century, major demographic changes occurred as Iceland's population plummeted and the Greenland colony died out. The medieval European colonization of the high-latitude North Atlantic islands thus ended in extinction and marginalization. The processes and causes of the Norse expansion and contraction are not well understood, but they are now emerging as a focus of interdisciplinary northern research. The Norse colonists were among the very few socially complex agriculturalists to enter the circumpolar zone in premodern times, and their reaction to climatic fluctuation, their contact with hunter–gatherers, and their changing relations with larger temperate-zone societies have significant parallels in the modern north.

While traditional emphases on literary analyses and investigations of local architecture and artifacts remain important areas of scholarship in the region, several recent multidisciplinary research projects have centered on questions of human adaptation, land use and climate influence. The results of these projects are requiring considerable modification of traditional models in many areas. The Norse of the North Atlantic Conference was designed to be a forum for discussions of these new approaches and results. Participants were encouraged to present regional syntheses, theoretical models or methodological case studies. The topics included the full span of maritime settlement history to allow discussion of long-term adaptations and different cultural trajectories.

The conference sought to bring together researchers from several disciplines (archaeology, paleoecology, history, climatology, biological anthropology and ethnography) normally divided by professional and national boundaries. Generous support from the Wenner–Gren Foundation for Anthropological Research, the National Geographic Society, the American–Scandinavian Foundation, the Maine Humanities Council, the Center for Northern Studies, and The Peary–MacMillan Arctic Museum and Arctic Studies Center made such diversity possible by supporting travel and housing costs. The meeting included 27 invited paper presentations, as well as workshops, informal discussion sessions and public outreach lectures in the evenings.

The sessions started with the presentation of biological anthropological investigations by G. R. Scott, who reported on dental structure patterning in Inuit and Norse North Atlantic Scandinavian populations. Next, J. P. Hart–Hansen provided a detailed paleopathological discussion of the preserved Greenlandic mummies of Qilaqitsoq. Astrid Ogilvie reported on recent investigations of North Atlantic climate and critiqued overly simplistic models of climatic determinism by referencing Icelandic data. Kim Bartolotta described the SUNY Buffalo Archaeometry Research Group's work with metallurgical analyses of slag and smelting debris to investigate iron-working methods. The topical papers concluded with a presentation by Paul Buckland of his team's multifaceted paleoecological investigations, which combine subfossil insect investigation with palynology, sedimentology and tephra analysis in Iceland and Greenland. A series of regional settlement studies followed, moving from Arctic Norway to Orkney and Caithness, Shetland, the Faeroes, Iceland, Greenland and Vinland/Newfoundland.

Discussion sessions sparked lively but good-natured debate over apparent discrepancies between radiocarbon and artifactual dating on one hand, and tephrochronology on the other, in dating Icelandic settlements. The structure of society (isolated archaic chiefdoms vs peripheralized peasantry) in late Norse Greenland was another leading topic of debate. Other new points to emerge from the conference discussion include the apparent failure of the Norse Greenlanders to participate in later medieval fisheries, the differences between Inuit and Scandinavian sea mammal exploitation, common traits in high-altitude shielings in the pastoral economies of the Faeroes, Iceland and South Greenland, and the interplay of nutritional requirements and taxation in comestibles in shaping traditional economies in the eastern islands. On the technical side the conference inspired the production of a North Atlantic fish bone identification manual, discussion and revision of zooarchaeological and site mapping software packages, and the dissemination of a taphonomic study of fishbone attrition in canid, suid and human digestion.

The public lectures were well attended, and brochures were distributed to the audiences to broaden their understanding of the lecture topics. Scholarly and popular books on the subjects covered were also displayed and were available for purchase. In the first presentation, Thomas H. McGovern outlined the life and death of the Greenland Norse colony and discussed the influence of local ecology, climate change and ideology in molding the Norse economy. In the second lecture the distinguished Welsh historian and translator Gwyn Jones gave a tremendously moving and impressive overview of Viking history. In the final presentation Birgitta Wallace discussed new findings from ongoing studies of the Norse site at L'Anse aux Meadows, Newfoundland, which indicate the site may have served as a temporary "gateway" settlement to the Gulf of St. Lawrence region.

Plans were made for further regional and topical meetings to continue contacts made at Bowdoin. The conference also allowed several participants to plan cooperative fieldwork, and the summer of 1988 saw extensive collaborative work in Iceland and Norway. A collection of papers based on the conference proceedings, now being prepared for publication in *British Archaeological Reports*, International Series, Oxford, should be available by early 1990.

The American Quaternary Association

Prepared by Harold W. Borns, National Science Foundation.

In 1968–69 a group of North American scientists with research or other interests in Quaternary subjects, and representing both academic and applied orientations, formed the American Quaternary Association (AMQUA). Scientists concerned with the Quaternary normally function within the formal structure of many diverse disciplines (archeology, limnology, zoology, etc.) and until that time, they had no regular means of coordinating their mutual interests and providing adequate communication.

By January 1969 some 450 scientists had applied for membership. Regional organizers were appointed, and 20 regional councilors were elected. This council elected an executive committee and wrote a constitution and by-laws for the association in 1970.

AMQUA is devoted to promoting the study of the Quaternary in North America; facilitating communication between workers in different fields; encouraging participation in the worldwide effort of the International Union for Quaternary Research (INQUA); and making knowledge of the Quaternary available for purposes of management, wise use and conservation of the natural environment.

Communications are facilitated by sponsoring biennial scientific meetings modeled on the objectives of INQUA and by encouraging the publication of the results of research of all aspects of the Quaternary.

Each AMQUA biennial meeting is built around a symposium on a topic of interest to as many of the constituent groups within AMQUA as possible. It therefore draws together individuals from a variety of disciplines who have an interest in the topic or period of time. Because the record of natural and cultural events is always incomplete and because it consists of so many components, its understanding requires an uncommon appreciation of many fields of natural science. Therefore, AMQUA tries to make the program and discussions truly interdisciplinary and integrative. Field trips to nearby locales are regular parts of the meetings, taking place either before and after the meeting.

Beginning in 1976 the abstracts for the biennial meetings were distributed to all members. In addition, a newsletter is circulated periodically, containing news relating to Quaternary research.

Membership is open to all scientists engaged in Quaternary research. There are currently about 1000 members. Major disciplines represented include anthropology, archeology, botany, climatology, ecology, geomorphology, geophysics, geochemistry, limnology, oceanography, palynology, physical geography, Quaternary geology, radiometric dating, soil science and zoology. The journal *Quaternary Research*, edited by Stephen Porter, University of Washington, and published by Academic Press, is offered at a special subscription rate to members of AMQUA.

Past AMQUA meetings and themes are listed below:

- Montana State University (Bozeman), 1970: "Climatic changes from 14,000 to 9,000 years ago,"
- University of Miami, 1972: "The deep-sea record,"
- University of Wisconsin (Madison), 1974: "Quantitative methods to reconstruct past environments of the Holocene,"
- Arizona State University (Tempe), 1976: "Hot and cold deserts during the last glaciation,"
- University of Alberta (Edmonton), 1978: "The ice-free corridor and peopling the New World,"
- University of Maine (Orono), 1980: "The structure of an ice age,"
- University of Washington (Seattle), 1982: "Character and timing of rapid environmental and climatic changes,"
- University of Colorado (Boulder), 1984: "Seasonal climatic responses in the Quaternary,"
- University of Illinois (Urbana), 1986: "The environment of glacial margins."

The 10th biennial meeting of AMQUA, held June 6–8, 1988, at the University of Massachusetts in Amherst was attended by approximately 300 scientists. The program focused on "Land–sea–atmosphere interactions in the North Atlantic region between 14,000 and 2,000 years ago: A comparison between America and Europe." The theme, papers and audience represented a broad cross section of the Quaternary sciences. In addition, pre- and post-meeting field trips covering a variety of disciplines explored regional Quaternary subjects.

The Eleventh Biennial Meeting will be held in conjunction with the Canadian Quaternary Association (CANQUA) at the University of Waterloo on June 4–6, 1990.

Presidents of AMQUA

A. L. Washburn	*1968–70*
H.E. Wright, Jr.	*1970–72*
D.E. Frey	*1972–74*
D.M. Hopkins	*1974–76*
V. Haynes	*1976–78*
M.B. Davis	*1978–80*
A. Dreimanis	*1980–82*
E.B. Leopold	*1982–84*
T.L. Péwé	*1984–86*
J.T. Andrews	*1986–88*
R.A. Bryson	*1988–90*
A.V. Morgan	*1990–92*

Arctic Workshops

An Annual Forum for Arctic Researchers in the Earth and Biological Sciences

Prepared by John T. Andrews, Institute of Arctic and Alpine Research and Department of Geological Sciences, University of Colorado, Boulder, Colorado 80309.

In the spring of 1972 the first Arctic Workshop was held at the University of Colorado. The author was largely responsible for running the first meeting and several after that, but the development of the Arctic Workshop was also a measure of the shared interest in Arctic research within the Institute of Arctic and Alpine Research (INSTAAR) in 1972. Roger Barry, Jack Ives, Harvey Nichols, Nel Caine and Pat Webber all played a part in the development of the first workshop and continued their support for several subsequent meetings.

The Arctic Workshop was established to promote the sharing of ideas in an informal gathering. A significant emphasis has always been placed on encouraging the participation of graduate and undergraduate students. In addition to the normal 20- to 30-minute presentations, large segments of time were set aside for poster sessions and group discussions. Informal gatherings in the evenings at restaurants and bars were also important points of contact for individuals from different disciplines, different institutions and different countries.

The first 11 Arctic Workshops were hosted by INSTAAR, at the University of Colorado, Boulder. An abstract volume was produced for each meeting, and back issues of some of these are still available, although in limited numbers. In 1982 it was suggested that the Arctic Workshop should be hosted by other universities or institutions, and this idea was implemented in 1983 when the 12th Arctic Workshop was hosted by the University of Massachusetts at Amherst.

The meetings now alternate between an "outside" venue and the University of Colorado. Thus, since the meeting at Amherst, the 14th Arctic Workshop was hosted by Atlantic Geoscience Center/Bedford Institute of Oceanography, Canada; the 16th was sponsored by the Boreal Institute, University of Alberta; and the 18th was hosted by the University of Lethbridge, Canada. The University of Alaska may be the host institution in 1991, with the University of Colorado hosting the meeting in 1990.

A glance at the list of titles in the abstract volumes indicates that the Arctic Workshops have drawn a wide range of researchers from the earth and life sciences. At a few meetings there have been notable presentations by archeologists, social scientists and government managers. Graduates, faculty and government scientists from U.S. and Canadian institutions make up the bulk of attendees; however, a small but significant number have also attended from Europe, particularly Norway, Sweden, Denmark and Great Britain.

The Summer Institute of Circumpolar Studies

Prepared by Pauline Gunter, Assistant Professor of Library Science and Government Documents and Alaska Research Librarian at the University of Alaska–Fairbanks, Fairbanks, Alaska 99775.

The first Institute of Circumpolar Studies colloquium was held on the University of Alaska–Fairbanks campus during the first week of August 1988. Institute faculty from anthropology, geography, history and library science examined the theme "Peoples of the Circumpolar North," focusing on aspects of human adaptation and response to life in the environments of Alaska, northern Canada, Greenland, Scandinavia and Siberia.

Students participating in the institute constituted an international circumpolar group representing Canada, Great Britain and Finland, as well as Alaska and elsewhere in the United States. Their predominant academic background was anthropology, followed by education. Other students were studying or professionally employed in library science, rural development, law, nursing, political science and video production.

The Summer Institute is dedicated to increasing understanding of northern peoples through multidisciplinary study and research, and it provides an opportunity for students and scholars across the circumpolar North to participate together in a continued reexamination of northern social science knowledge. Its key objectives are to

- Generate descriptive comparisons of different cultural groups;
- Promote multidisciplinary research; and
- Teach students specific skills to conduct systematic library research.

Circumpolar northern studies involve circumstances not usually found in U.S. regional studies. These include the multidisciplinary nature of activities involving exploration, commerce, government, scientific and academic research, administrative studies and their continuing interaction with Native traditions and lifestyles. Sources are multilingual, involving European and Native languages. Documentation is widely scattered and requires specialized approaches for retrieval and evaluation.

Mastery of these research problems and awareness of the breadth of sources available for the study of northern peoples and their governments are important institute goals. Library science faculty help students direct their library research in a systematic manner and maximize use of research tools.

Thirty-two students enrolled in the institute for daily lectures and seminars on the theme "Peoples of the Circumpolar North." Participants addressed the following questions from their disciplinary perspectives:

- What are the factors in the physical environment to which adaptations must be made?
- Who are the indigenous and immigrant peoples of the North and why have the people come into the North?
- What adaptations have been made by northern peoples to their social and physical environment?
- What is the nature of the recent history of the circumpolar North?
- What is the nature and location of documentation and other research sources of the circumpolar North?

The Summer Institute offered students the option of three graduate credits if, in addition to colloquium participation, they also submitted an original research paper. The institute is now recruiting participants, especially Native students from Alaska and other northern regions, for the 1989 Summer Institute. For further information, contact Nancy Bachner, 1176 Eielson Building, University of Alaska, Fairbanks, Alaska 99775.

The Alaska Anthropological Association

Prepared by Leslie Starr Hart, Chief, Division of Cultural Resources, Alaska Regional Office, National Park Service.

The National Park Service hosted the Sixteenth Annual Meeting of the Alaska Anthropological Association on March 3–4, 1989, in Anchorage, Alaska. Over 100 papers were presented in 13 sessions. Symposia titles included "The anthropology of Bristol Bay," "Public archeology," "Medical and physical anthropology," "The Central Yup'ik Eskimos," "Ethnography and ethnohistory of the Bering Strait region," "Settlement pattern studies in archeology" and "Current developments in Arctic research," which included a summary of *Arctic Social Science: An Agenda for Action*, a report by the Polar Research Board's Committee on Arctic Social Science (see p. 36).

Technical Council on Cold Regions Engineering

Prepared by Howard P. Thomas, Director of Geotechnical Services, Harding Lawson Associates, Anchorage, Alaska, and Chairman of TCCRE.

Council Chairmen

A.J. Alter	*1979–80*
R.N. Dillon	*1980–81*
D.R. Freitag	*1981–82*
F.L. Bennett	*1982–83*
D.W. Smith	*1983–84*
C.W. Lovell	*1984–85*
T.T. McFadden	*1985–86*
W.L. Ryan	*1986–87*
R.G. Tart	*1987–88*
H.P. Thomas	*1988–89*

Founded in 1852, the American Society of Civil Engineers (ASCE) is the United States' oldest engineering society. Subdivided into technical and professional activities, ASCE's technical organization consists of 18 technical divisions and 6 technical councils. The distinction between a division and a council is the extent to which the subject area crosses disciplines within the profession.

With the increase in interest in cold regions in the 1970s, Amos J. ("Joe") Alter of Juneau spearheaded a move to establish a new ASCE council to advance the state of the art of cold regions engineering. The idea got a boost from the very successful First Cold Regions Engineering Specialty Conference held in Anchorage in 1978, and the Technical Council on Cold Regions Engineering (TCCRE) was officially formed on October 1, 1979, with Alter as its first chairman .

The stated purpose of TCCRE is to "identify, assess and report effects of cold region environment upon engineering design, construction and operations and to make recommendations for advancement of scientific knowledge and practice in engineering solution of cold region problems." TCCRE carries out its mission through five administrative committees and two technical committees, all guided by an executive committee. The purposes of the standing committees are summarized as follows:

- Awards—To recommend recipients for ASCE awards;
- Program—To plan and publicize sessions for national meetings, speciality conferences and state and regional meetings having cold regions engineering significance;
- Publications—To review manuscripts, technical notes and discussions submitted to the council for publication in the new *Journal of Cold Regions Engineering* and to be responsible for the publication of papers sponsored by the council;
- Research—To stimulate research on topics relevant to cold regions engineering and to promote the evaluation of research findings

State-of-the-Practice Monographs

Design for Ice Forces (1983)

Cold Regions Construction (1983)

Frost Action and Its Control (1984)

Thermal Design Considerations in Frozen Ground Engineering (1985)

Freezing and Thawing of Soil–Water Systems (1988)

Arctic Coastal Processes and Slope Protection Design (1988)

Embankment Design in Cold Regions (1988)

with respect to their utility in engineering practice;

- Education—To promote attention to cold regions concerns in engineering, education and training and to act as a source of referral for educational material with a cold regions emphasis;
- Design and Construction—To identify, assess and report influences and effects on engineering concepts, methods and facilities in environments where below-freezing temperatures occur for a significant period of time; and
- Frost Action—To encourage the development of new scientific and engineering knowledge of freezing and thawing of soil–water systems and to foster dissemination of this knowledge.

In addition to the standing committees, task committees are formed from time to time for specific purposes, such as organizing a particular publication. Committees typically convene at specialty conferences or national meetings once or twice a year. TCCRE has also established a formal connection with the U.S. Arctic Research Commission; this is accomplished via a Commission member who attends all TCCRE executive committee meetings. Membership in TCCRE and its committees is open to all ASCE members. TCCRE has about 4300 members, including some 50 committee members.

Major activities of TCCRE include planning and sponsoring specialty conferences (often in cooperation with Canadian Society of Civil Engineers), publishing a series of monographs on the state of the practice, publishing a quarterly refereed journal (*Cold Regions Engineering*), supporting the International Permafrost Association and its periodic International Permafrost Conferences, and most recently, establishing a national award named after the late Harold R. Peyton. Specialty conferences have been held in Anchorage (1978), Seattle (1981), Edmonton (1984), Anchorage (1986) and St. Paul (1989). Papers presented at each of these conferences have been published in preprint proceedings, a copy of which is provided to each conference attendee.

Readers interested in additional information or membership applications can write to ASCE at 345 East 47th Street, New York, New York 10017-2398 or telephone (800) 548-ASCE or (800) 628-0041 in New York state.

Port and Ocean Engineering under Arctic Conditions

Prepared by William M. Sackinger, University of Alaska–Fairbanks, Fairbanks, Alaska 99775.

Conferences on Port and Ocean Engineering under Arctic Conditions (POAC) are held every two years; the series is organized by national POAC committees under the long-term policy direction of the POAC International Committee. POAC conferences have been held in Norway (2), Canada (2), Iceland, Finland, Greenland and Alaska. The ninth conference in the POAC series (POAC '87) was held at the University of Alaska, Fairbanks, Alaska, between August 17 and 21, 1987.

A total of 224 people registered for POAC '87, and 122 papers were presented during 14 sessions. The sessions were: Arctic Database; Ice Properties; Icebreaking Vessels; Ice Modeling; Arctic Port Design; Geotechnical; Ice–structure Interaction; Ice Morphology; Ice Dynamics; Ice, Climate and Forecasting; Spray Ice; Remote Sensing; and two special symposia on Noise and Marine Mammals, and Steel/Concrete Composite Structural Systems.

Highlights of the conference sessions included presentations on the following:

- The icebreaking performance of the West German polar research ship R.V. *Polarstern;*
- The icebreaking trials of the modified Soviet icebreaker *Mudyug;*
- Recently released results of the 1980 and 1981 Hans Island experiments;
- An experiment to measure Arctic pack ice driving forces;
- A number of papers highlighting the increased concern over icing of structures and vessels at high latitudes;
- The establishment of the Alaskan SAR Facility at the University of Alaska–Fairbanks and the potential application of satellite radar imaging to studies relating to Port and Ocean Engineering under Arctic Conditions.

In addition to the scientific and technical sessions, the conference delegates enjoyed a number of evening social events, including the concluding conference banquet followed by a speech by Ken Croasdale of Esso Resources Canada on his view of progress in ice engineering. Also, a number of conference delegates took advantage of two field trips to Prudhoe Bay to visit the oilfield installations and facilities as guests of Standard Oil and ARCO. Most people flew to and from Prudhoe Bay, but several chose to drive the Dalton Highway both ways.

All papers submitted for POAC '87 were reviewed and edited prior to publication. The papers have been refereed by two or more reviewers, edited to ensure a consistent and high standard of style and format, and prepared for publication in

Port and Ocean Engineering under Arctic Conditions edited by W.M. Sackinger and M.O. Jeffrie. This will appear in three hard-bound volumes, published by the Geophysical Institute, University of Alaska, Fairbanks. Copies will be available for purchase from the Geophysical Institute.

POAC '89 was held in Lulea, Sweden, on 12–16 June 1989.

International Offshore Mechanics and Arctic Engineering Conference

Prepared by Jin S. Chung, Conference Chairman, Colorado School of Mines, Golden, Colorado 8040. Telephone: (303) 273-3673; Fax: (303) 273-3278; Telex: 910-934-0190 CSM GLDN.

The 1989 International Offshore Mechanics and Arctic Engineering Conference was attended by 650 participants from more than 40 countries, led by the British, Dutch, U.S., Norwegian and Japanese delegates. The conference was held in The Hague, The Netherlands, March 19–23. The opening speech was delivered by Rudolf de Korte, the Deputy Prime Minister of The Netherlands. There were 11 polar technology topic sessions among the 71 sessions and 440 presentations.

The conference has been playing a major role in international technology transfer and in bridging the communication gap between researchers and designers. The conference program included about 60 papers each from the U.K., U.S. and Canada; 50 papers each from Japan and Norway; 20 papers each from China, West Germany and The Netherlands; and 10 papers each from India, Finland, France, Denmark and Korea.

The majority of the polar technology papers were presented by authors from North American and Scandinavian countries. The presentations described Arctic and Antarctic technology research programs by various countries, technologies needed in the petroleum development in the Norwegian Barents Sea, spray ice technology, Canadian developments of codes for Arctic structures, pipelines and ice research. The Barents Sea papers were presented by seven speakers from Norway, France and the U.S. Arctic pipeline technologies were presented by the U.S.S.R., Canada and the U.S. and included a review of the U.S.S.R. pipelines and research, particularly on materials and welding.

The sessions of the Polar Technology Working Group (PTWG) included presentations on the U.S. polar research program by the National Science Foundation; ESARC (Esso/Sintef) ice research programs by Norway; the Adelie land airport (Antarctica) by France; scientific drilling in the Arctic in 1990; Arctic (Greenland) resources and technology for mining, hydropower and transportation by Denmark; and icebreaking technology by Finland and Sweden.

The conference was founded in 1980 by Jin S. Chung, Colorado School of Mines, with the help from Joseph Galate, then of Exxon. The first annual conference was held in New Orleans in 1982, and the conference has been international since 1983. It has gained worldwide recognition for dealing with high-level technology with broad support at an international level. Since 1986 the conference has been among the world's leading conferences of refereed papers.

International Symposia on Ground Freezing

Prepared by Hans L. Jessberger, Professor of Civil Engineering, University of Bochum, Germany, and Chairman of the International Organizing Committee for the ISGF.

The first International Symposium on Ground Freezing (ISGF) was held in 1978 in Bochum, Germany. It was intended to provide a forum for exchanging knowledge and to bring together scientists and engineers working in the field of ground freezing, especially artificial ground freezing. Since then there have been four other symposia on this subject, in Trondheim (1980), Hanover, N.H. (1982), Sapporo (1985) and Nottingham (1988). The Sixth International Symposium on Ground Freezing will be held in Beijing, People's Republic of China, in 1991, and the Seventh International Symposium on Ground Freezing will be held in France in 1994.

Until now the symposia have consisted of four sessions:

- Thermal properties and processes of freezing and frozen soil;
- Heat and mass transfer, phase transitions and frost action;
- Mechanical properties of frozen soil; and
- Engineering design and case histories of frozen soil structures.

The accepted papers of each symposium are published in proceedings, which together contain more than 400 papers. The proceedings are available as follows:

- *1st ISGF, 1978, Bochum, West Germany.* The original proceedings was in two volumes and is now out of print. However, all the papers were reprinted by Elsevier as both *Engineering Geology*, vol. 13 and *Developments in Geotechnical Engineering*, no. 26 (H.L. Jessberger, Ed.).

- *2nd ISGF, 1980, Trondheim, Norway.* The proceedings was originally published in two volumes by the Norwegian Institute of Technology, Trondheim. Some of the papers were reprinted by Elsevier as both *Engineering Geology*, vol. 18 and *Developments in Geotechnical Engineering*, no. 28 (P.E. Frivik, N. Janbu, R. Saetersdal and L.I. Finborud, Ed.).
- *3rd ISGF, 1982, Hanover, N.H., USA.* The proceedings were published by USA CRREL as Special Report 82-16.
- *4th ISGF, 1985, Sapporo, Japan.* Most of the papers appeared in *Ground Freezing*, published by A.A. Balkema, Rotterdam. Five papers and all the posters were published as *Ground Freezing*, 1985, vol. 2 by Hokkaido University Press, Sapporo, Japan (S. Kinosita and M. Fukuda, Ed.).
- *5th ISGF, 1988, Nottingham, England.* Most of the papers appeared in *Ground Freezing, 1988*, vol. 1, published by A.A. Balkema, Rotterdam. Volume 2 contains late papers and poster summaries.

Each International Symposium on Ground Freezing is organized by a local organizing committee. In 1982 an International Organizing Committee was established to provide continuity. The present members of the International Organizing Committee are H.L. Jessberger (Chairman), R.H. Jones (Secretary), E.J. Chamberlain (Treasurer), M. Fremond, S. Kinosita, B. Ladanyi, A.V. Sadovsky, J.A. Shuster and Yu Xiang.

There are two ISGF working groups active. The Working Group on Testing Methods for Frozen Soils consists of 14 members. The present chairman/convenor is Frank Sayles, recently retired from CRREL, Hanover, N.H., USA. In 1986 the working group published "Classification and laboratory testing of artificially frozen ground" in *ASCE, Journal of Cold Regions Engineering*. The following priorities for future work were decided: sample preparation, field tests (cone penetration) and data compilation (creep data).

The Working Group on Mechanical and Thermal Design of Frozen Soil Structures consists of 15 members. Hans L. Jessberger is the chairman. The working group will discuss preinvestigations, site conditions, thermal analysis, stability and deformation analysis, and field monitoring.

The International Organizing Committee of the ISGF keeps in close contact with scientific groups in fields related to frozen ground, such as permafrost (International Permafrost Association), frost action (ISSMFE—TC8) and cold region engineering. The International Organizing Committee initiated the ISSMFE technical committee (TC 23) on frozen ground. This committee is organizing a speciality session of the International Conference on Soil Mechanics and Foundation Engineering in Rio de Janeiro in 1989.

International Symposium on Frost in Geotechnical Engineering

Prepared by Virgil Lunardini, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755-1290.

The Finnish Geotechnical Society sponsored the International Symposium on Frost in Geotechnical Engineering on March 13–15, 1989, in Saariselka, Finland. Approximately 150 researchers from around the world attended. Three sessions were held, including special lectures on the mechanics of freezing and thawing by B. Ladanyi, the frost heave properties of soils by D.M. Anderson, and frost protection in design and construction by R. Nordal.

Other keynote lectures were as follows:

- Simulation of freezing and thawing of soil materials, by E. A. Bondarev;
- Frost problems in road construction, by H. Brandl;
- Modeling of thermal soil behavior, by M. Fremond;
- Determination of frost susceptibility of soils, by H. Jessberger;
- Frost protection of design and construction in Japan, by F. Kohno;
- Preventative measures against frost action in soils, by S. Kinosita;
- Freezing and thawing in cylindrical coordinates, by V. J. Lunardini;
- Preventative measures against frost action in soils, by A. Phukan;
- Evaluation of frost heave properties of soils, by S. Saarelainen;
- Adfreeze strength of soils, by A.V. Sadovsky; and
- Physical changes in clay due to frost action and their effects on engineering structures, by E. Chamberlain.

After the keynote lectures, 52 related papers by other authors were presented and discussed. All of the papers and talks have been published in two volumes, which are available from Technical Research Center of Finland.

Following the symposium was a two-day field trip to observe roads and road-construction techniques in Lapland. Methods of dealing with road icings, cracking and snow drifting were examined in detail.

The next symposium is scheduled for Anchorage, Alaska, in 1993.

Colloquy on Arctic Technology and Economy

An international colloquy called "Arctic technology and economy—Present situations and problems, future issues," was held in Paris, France, February 15–17, 1989. The topics discussed included physical and life sciences, shipbuilding and aeronautics, civil engineering, social sciences and economy, and transfer of technology to Native populations.

Workshop on Cold Regions Engineering Research

Prepared by Charles Myers, National Science Foundation.

A workshop on Cold Regions Engineering Research, sponsored by NSF's Engineering Directorate and the Division of Polar Programs, was held on November 30 to December 2, 1988, in Hanover, New Hampshire. Over 40 engineers and scientists identified 14 research programs in 4 broad groups: offshore technology; watersheds, rivers and coastal zones; facilities infrastructure technology; and transportation infrastructure technology.

The offshore technology group, led by S. Shyan Sunder of MIT, considered programs in ice technology, offshore geotechnology, materials science and pollution control. The group emphasized the unique and challenging environment of the cold regions offshore areas and how safe and economical designs must be developed to conduct resource development activities.

The watersheds, rivers and coastal zones group, led by Robert Ettema of the University of Iowa, considered topics of cold regions watersheds and rivers, nearshore and coastal processes, and nearshore engineered structures.

Virgil Lunardini of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) led the group on facilities infrastructure technology, which addressed the special problems in designing buildings, utilities and other public and private facilities in cold regions. The research areas addressed by this group included coping with the natural environment, improving the built environment, and designing environmental protection facilities. A special problem is that of safe operations at low temperatures. The group focused on fire protection at low temperatures and minimization of damage from freezing.

The transportation infrastructure technology group, led by Ted Vinson of Oregon State University, considered the problems of transporting goods and personnel in support of resource development activities in cold regions. The group selected as its first priority the impact of global climatic change on the cold-regions transportation infrastructure. This issue, with its importance for pipelines, buildings and coastal areas, may dominate cold-regions designs for many years. The group also focused on protection and restoration of the environment, materials science problems and geophysical methods of site investigation.

The workshop report will be published by the University of Alaska–Fairbanks (UAF) by the fall of 1989 and will be available through the School of Engineering at UAF and the Division of Polar Programs at NSF. The editors of the report are Robert F. Carlson and John Zarling of the University of Alaska–Fairbanks and Ed Link, Technical Director of CRREL.

The Lanzhou Institute of Glaciology and Geocryology

30th Anniversary Celebration

Prepared by Lonnie Thompson, Byrd Polar Research Center, The Ohio State University, Columbus, Ohio 43210.

The Lanzhou Institute of Glaciology and Geocryology (LIGG) celebrated its 30th anniversary and hosted the Fourth Conference on Glaciology and Geocryology from October 5–9, 1988, in Lanzhou. A total of 142 scientists from seven nations participated. The conference was held to celebrate the 30th anniversary of the founding of LIGG, to introduce foreign guests to the history of

LIGG and the main research accomplishments over the last 30 years, to present recent results from the study of glaciology and geocryology in China, and to isolate and better define areas for future research. The author's invitation to join the conference resulted from the longstanding cooperative glaciological and climatological program between LIGG and the Byrd Polar Research Center (BPRC) to study the Dunde ice cap in the Qilian Shan.

The conference was broken into concurrent sessions on glaciology and permafrost. The topics discussed under glaciology included snowfall, glaciology, geomorphology, surging glaciers and hydrology (particularly related to the glaciers of western China). The permafrost sessions dealt with periglacial landforms and processes, recharge of groundwater in permafrost regions, hydroengineering construction and the ecological environment in permafrost regions. Most papers dealt with studies in China, but papers reporting permafrost studies in the Soviet Union and Canada, as well as glaciological studies in the Alps, also were presented.

Several key questions were discussed. One dealt with evidence for and against extensive glaciation of the Qinghai-Xizeng (Tibetan) Plateau during the last glacial stage. The current estimates range from a 10% increase in ice cover to complete coverage of the plateau by an extensive ice sheet. Prof. Li Jijun from the Department of Geography of the Lanzhou University argued, based on geomorphic information, that the ice cover during the last glacial stage was about 10% greater than present. Another key issue is whether the plateau was cold and dry or cold and wet during the last glacial stage. The latter condition would allow for greater growth of glaciers. The clear message from these discussions is the need for more research with better time control.

The author presented the first results from the completed analysis of one of the three ice cores recovered from the summit of the Dunde ice cap in 1987. These three cores drilled to bedrock were 136.6, 138.4 and 139.8 m long and are expected to provide the first ice core record covering at least 100,000 years from the subtropics. The conference provided the opportunity to compare the results from the ice core research laboratory at BPRC with the first results from the LIGG laboratory.

The director of LIGG, Prof. Xie Zichu, in his closing remarks presented an excellent summary of the conference. He emphasized that the future of scientific development at LIGG will rest with young people, such as Dr. Yao Tandong, who has recently completed a year of study at the Laboratorie de Glaciologie in Grenoble, France, and an eight-month study with BPRC. These young people will lead the future development of both laboratory and field research programs at LIGG.

LIGG presented a fine banquet in the traditional Chinese custom for all participants in the conference. A film strip that was made by Prof. Shi Yafeng during the 1957–58 Chinese–Soviet expedition to the Qilian Shan was shown. It was this expedition that led to the founding of LIGG. In addition, several field trips were provided in the Lanzhou area. Of particular note was the loess and terrace field trip led by Prof. Li Jijun. The Lanzhou area boasts some of the world's best exposed loess deposits and terrace sequences, which date back at least 1.5 million years.

U.S.–Canada Review of Hydrocarbon Developments in the Beaufort Sea

Prepared by Harlan Cohen, Department of State.

The 1989 U.S.–Canada Review of Hydrocarbon Developments in the Beaufort Sea was held at the NOAA Western Regional Center in Seattle, April 25–26, 1989. The U.S. delegation, led by Raymond Arnaudo of the Department of State, included representatives from the Departments of State, Interior and Commerce, the Environmental Protection Agency, the U.S. Coast Guard, the National Science Foundation and the North Slope Borough in Alaska. The Canadian side was led by Brian Buckley, Director of the U.S. Transboundary Division, Department of External Affairs, and included representatives from the Departments of External Affairs; Environment; Energy, Mines and Resources; Indian and Northern Affairs (DIAND); Fisheries and Oceans (DFO); and the Canadian Oil and Gas Lands Administration (COGLA). These annual meetings are held primarily to exchange information.

Rodney Smith of the Minerals Management Service (MMS) provided an overview of offshore hydrocarbon developments in the Beaufort and Chukchi seas since November 1987. A total of 21 wells have been drilled in the U.S. Beaufort Sea. The Department of the Interior held two Outer Continental Shelf (OCS) lease sales in the Arctic. There has been drilling at three locations in the Beaufort since November 1987. The Endicott field is the only producing offshore field in the U.S. Beaufort. MMS published its Consolidated Offshore Operating Regulations for oil, gas and sulfur operations in the OCS on April 1, 1988, with an effective date of May 31, 1988.

COGLA spokesman Graham Campbell presented an overview of Canadian activities in the Beaufort Sea and the Mackenzie Delta. Of the 239 exploratory and delineation wells that have been drilled, 49 have yielded significant oil and gas discoveries. Discovered resources are estimated (with a 50% level of probability) to be 1.7 billion barrels of oil and 11.7 trillion cubic feet of natural gas. Current activities include a plan by Esso and Shell to produce gas onshore and export it via pipeline to the United States, probably connecting to the existing pipeline at Norman Wells, NWT. Campbell described the legislative and regulatory framework for oil and gas management in Canada, specifically the Canada Oil and Gas Act of 1987 and the Oil and Gas Production and Conservation Act of 1970 as amended. Under the Northern Accord, signed in September 1988, the federal government agreed to a phased transfer to the governments of the Yukon and the Northwest Territories of administrative and legislative powers to manage oil and gas in northern onshore areas. It was also agreed to negotiate a joint management regime for the offshore areas following some offshore development. Revenues from both onshore and offshore development will go to the territorial governments.

Tom Albert, from the North Slope Borough, Alaska, spoke about the possible environmental dangers of hydrocarbon developments in the area. The Borough is concerned that the environmental hazards of hydrocarbon developments may not be adequately recognized. Albert believes that neither industry nor the government could cope with a significant oil spill in the Beaufort or Chukchi seas. The Borough is worried about the effects of noise and possible oil spills on bowhead whales, as well as the effect of man-made causeways on fish migration. Albert stressed the need for quality in environmental impact statements.

David Stone reported on the Canadian Northern Oil and Gas Action Program (NOGAP). This program was introduced in 1984 and was to be reviewed after seven years. Its purpose is to advance federal and territorial preparedness for hydrocarbon developments in the North.

Graham Campbell reported on the Environmental Studies Research Fund (ESRF), which is administered by COGLA to finance environmental and social studies. It is funded by levies on holders of exploration rights for hydrocarbons and is controlled jointly by industry and the government. Ninety reports have been published, including studies on bottom sediments, sea bottom scour and oil spill research. Of these, 37 are directly related to the Beaufort Sea.

Wayne Richardson of Environment Canada reported on the Program for Energy Research and Development (PERD). PERD supports science and technology research for a diversified, economically and environmentally sound, sustainable energy program. Costs are shared by the government, the private sector and universities. PERD funded over half of the Baffin Island Oil Spill Program.

Lt. Tom Sullivan of the U.S. Coast Guard, in an overview of U.S. Coast Guard Marine Environmental Response activities, noted that the U.S.–Canada Joint Response Plan on oil spills has five annexes for specific areas, including one on the Beaufort Sea. Neal Thayer of the U.S. Coast Guard described plans for a future third U.S. polar icebreaker to be in operation during the mid-1990s.

Paul O'Brien of the Environmental Protection Agency described the Exxon Valdez spill. The ship had 53 million gallons of oil on board; 10–11 million gallons had spilled.

Bob Wolotira presented NOAA's new *Bering, Chukchi and Beaufort Seas Data Atlas,* published in November 1988. The majority of the plates show information on marine living resources.

Charles Smith of MMS discussed technology for working in ice and permafrost, as well as the effects of extreme cold weather on materials and pipelines. MMS is working with industry on such problems as pipelines in pack ice, ice keel gouging and seabed permafrost. MMS plans to do research on open ocean oil spill response.

Pierre Lapointe of Energy, Mines and Resources reported on Canadian Arctic Science research projects supported by the Polar Continental Shelf Program. PCSP provides logistical support for research in the High Arctic from Resolute, Tuktoyaktuk and an ice island. New storage and laboratory facilities have been added at Resolute and Tuktoyaktuk, and new housing has been added at Resolute. The ice island, which is 8.7 km long, 5.7 km wide and 50 m thick, calved from the north of Ellesmere Island. It has a life expectancy of 20–40 years and has 20 buildings that can house 40 people. The major subjects of study on the ice island are geophysical topics and ice dynamics and movement.

Graham Campbell described the Marine Engineering Studies for offshore structures. Research is underway on design criteria, structural engineering, ice–structure interaction and personnel safety. Steve Blasco gave an overview of cooperative programs between the Geological Survey of Canada and the U.S. Geological Survey.

Alan Heginbottom of the Geological Survey of Canada discussed geophysical, geothermal and geotechnical activities regarding hydrocarbon development and transportation. Researchers are monitoring the environmental effects of the pipeline from Norman Wells, NWT, to Zama, Alberta.

Steve Blasco described sea floor research in the Beaufort Sea, which is driven by exploration and construction problems and includes ice scour, subsea permafrost, potential hazards of hydrates, sources of aggregates (sand and gravel), coastal stability, pingo-like features on the seabed, and geological history. Pressure ridges in the Beaufort can build up to 12 m high with a keel of up to 47 m. Surveys are done of the ocean floor to map ice scour and note its characteristics. There are very high rates of recurrence of sea floor scouring; 90% of the sea floor has been rescoured in the last 40 years. Offshore permafrost, which is discontinuous both vertically and laterally, could be up to 700 m thick and in the Mackenzie Delta area is multilayered due to sea level regression and growth. Since oil at production has a temperature of 80–100°C, the subsea permafrost around a production well or pipeline would thaw unless protected.

Blasco described engineering problems associated with structures on artificial islands and berms. One quarter of the artificial islands in the Beaufort Sea have experienced some failure, including slope failure, gravitational failure or erosion.

Bob Wilson of DFO presented a talk on oceanographic and hydrocarbon studies, including work on ice motion to improve short- and medium-term ice forecasting.

Jerry Imm of MMS reported on a series of studies of bowhead whales. MMS began these studies in 1978. Between 1980 and 1985 most of the work was done in the Canadian Beaufort. MMS is now concentrating on long-term monitoring of bowhead whales in the Beaufort and Chukchi seas. An isotope analysis project is currently underway to study bowhead feeding. David Withrow of NOAA discussed the National Marine Laboratory work to estimate the number of bowhead whales, particularly in the Barrow area. Paul Sutherland of DFO reported on bowhead whales in Canada. In the western Arctic, Canada relies on U.S. data. The Inualivit are pressing to be allowed to hunt whales again. David Stone of DIAND indicated that studies are underway on the effects of the hydrocarbon industry on bowhead whales. The whales may get 20% of their annual energy intake during the six weeks that they spend in the Canadian Beaufort Sea. Ron Morris of NOAA described the rescue of the two grey whales who were stranded near Barrow during October 1988.

Randy Bailey of the Fish and Wildlife Service discussed the Arctic cisco, a fish whose only known spawning area is in the Mackenzie Delta. The cisco migrate westward along the shore to an area west of Prudhoe Bay. There is some concern that man-made causeways could interfere with this migration. Both countries are involved in studying the movement patterns of the cisco and Arctic char.

David Stone of DIAND gave an update on the report "Canada and polar science" produced in 1987. A subsequent report suggested that the Polar Science Commission be established to promote natural and social sciences and studies on heritage and culture.

Jerry Brown of the National Science Foundation gave an overview of recent activities of the Interagency Arctic Research Policy Committee. The 1989 biennial revision of the U.S. Arctic Research Plan is scheduled be published in the Fall 1989 issue of *Arctic Research of the United States*. Current U.S. Federal spending on Arctic research is approximately $95 million.

At the conclusion of the meeting, it was agreed that a great deal of information had been exchanged and contacts between officials had been promoted. The Canadians offered to host the next meeting. Following these sessions a group of U.S. and Canadian researchers and participants reconvened at the NOAA Pacific Marine Environmental Laboratory. Information on current and proposed research activities was exchanged. It was agreed that cooperative projects should be planned in spite of uncertainties in funding.

U.S.–Canada Arctic Fisheries and Marine Mammals Coordination Workshop

Prepared by Richard Marshall, Fisheries Management Services, U.S. Fish and Wildlife Service, Anchorage, Alaska 99503.

Representatives from U.S. and Canadian resource agencies have met five times since 1975 to discuss matters of mutual concern in the Arctic, examine the state of the information base, and develop a framework of cooperative and complementary programs for managing shared resources. The first three meetings (1975 in Winnipeg, 1978 in Whitehorse, and 1982 in Anchorage) covered a wide range of Arctic environmental issues. The fourth meeting (1986 in Banff) was devoted entirely to North Slope and Beaufort Sea fisheries and marine mammals issues. At this meeting, which opened up a new level of dialogue and information exchange between scientists from the two countries, it was decided that the next meeting should be held in two years to build on the momentum that the group had developed, and that the focus should again be on fisheries and marine mammals. The U.S. Fish and Wildlife Service agreed to host that meeting.

The meeting, the U.S.–Canada Arctic Fisheries and Marine Mammals Coordination Workshop, was held at Chena Hot Springs, Alaska, during January 9–12, 1989. Twenty-five individuals from Canada attended, representing five offices of the Department of Fisheries and Oceans (Winnipeg, Yellowknife, Inuvik, Sidney and Ottawa), the Canada Oil and Gas Administration, the Department of Indian and Northern Affairs, Environment Canada: Parks, Environment Canada: Environmental Protection, the Fisheries Joint Management Committee and the Inuvialut Game Council. Thirty-six individuals from the United States attended, representing the U.S. Fish and Wildlife Service, the Minerals Management Service, the National Park Service, the Outer Continental Shelf Environmental Assessment Program, the Environmental Protection Agency, the U.S. Army Corps of Engineers, the Alaska Department of Fish and Game, the University of Alaska, the Arctic Environmental Information and Data Center and the North Slope Borough.

The first day's discussions focused on the Arctic roles, responsibilities and current activities of the participating agencies and organization. During most of the remaining two and a half days, the attendees broke up into three concurrent working groups: Fisheries/Oceanography, Marine Mammals and Administration. A similar format had been followed at the Banff workshop in 1986, so each working group had something on which to build.

In the Fisheries/Oceanography working group, participants reviewed and updated a list of research and management needs and concerns that had been developed during the 1986 workshop. They also reviewed several research proposals that had been prepared as a result of that meeting and agreed to implement one, a joint assessment of char on the Firth River in 1989, using a field crew of biologists from both nations. The working group also confirmed that the major species of transboundary importance is the Arctic cisco. Since most scientists feel that all Arctic cisco populations found in Alaska originate in Canada's Mackenzie River, development activities in Alaska that might place those populations at risk have international implications. Although some progress was noted in implementing proposed research (notably char river-of-origin studies using starch-gel electrophoresis), the working group agreed that further committment was necessary on the part of the agencies if we are to understand the Arctic aquatic ecosystems adequately.

The Marine Mammals working group reviewed ongoing programs and recent achievements, discussed major information needs relating to conservation and management, and identified areas for cooperative or coordinated programs. They focused primarily on bowhead and beluga whales and on ringed and bearded seals. Subsistence, disease and contaminant studies were reviewed.

The Administration working group discussed information exchange, points of contact, a clearinghouse for tagging and marking efforts, and streamlining procedures for transborder shipment of specimens and tissues. They also discussed increasing the level of coordination by scheduling more frequent meetings of agency administrators at the policy level.

All participants placed a high level of value on these workshops and felt that the resources they are dedicated to conserving will be well served by continuing them.

U.S./Canada Joint Ice Working Group

Prepared by Richard Hayes, Office of the Oceanographer of the Navy, Washington, D.C. 20390-1800.

The third meeting of the U.S./Canada Joint Ice Working Group was held in Montebello, Quebec, from May 1–4, 1989. The JIWG is co-chaired by John J. Carey, Deputy Assistant Administrator, National Ocean Service, NOAA, and Gordon M. Shimizu, Director General, Central Services Directorate, Atmospheric Environment Services.

The JIWG provides an informal exchange of ideas and ice-related information between representatives of the governments of both countries. The group's emphasis is on operational services and supporting research. There are seven standing committees and three ad hoc working groups dealing with such diverse issues as terminology, training, archiving and communications. Previous meetings of the JIWG were held in Ottawa in October 1986 and the Washington, D.C., vicinity in October 1987.

Alaska Arctic Offshore Oil-Spill-Response Technology Workshop

Prepared by John B. Gregory, Minerals Management Service, Reston, Virginia 22091.

The Minerals Management Service (MMS) is responsible for leasing and managing oil, gas and other mineral exploration and development on the Outer Continental Shelf/Exclusive Economic Zone. MMS has been actively involved in sponsoring research efforts to evaluate and improve oil-spill-response capabilities for offshore Arctic areas. This program has been administered by the Technology Assessment and Research (TA&R) Program within MMS.

In 1988 it became apparent to the MMS that an assessment of Arctic oil-spill-response technology and research needs would be beneficial. Consequently, a workshop was designed to bring together experts in the areas of oil-spill containment, recovery and cleanup from around the world to assess the state of the art and to identify future research needs and priorities.

On November 30, 1988, the National Institute of Standards and Technology conducted a three-day workshop for the MMS entitled "Alaska Arctic Offshore Oil-Spill-Response Technology Workshop." Attendees came from the U.S., Canada, Norway and Finland. During the first portion of the workshop, keynote speakers gave presentations pertaining to the state of the art for Arctic oil-spill response and the status of ongoing research efforts. The second portion of the workshop was divided into five panels: mechanical containment, mechanical recovery, chemical treatment, in situ burning and readiness. Each panel was asked to address and set priorities for research needs in their area of expertise. In addition, the panels discussing mechanical recovery and chemical treatment addressed remote sensing as it related to these areas.

The panel on mechanical containment examined the use of boats, booms, ice and other equipment and materials, in various forms and configurations, to contain oil on the water surface in open water, broken ice and solid ice. They also addressed radio tracking buoys in and under solid ice. They indicated that bubble barriers, the use of air bubbles as a containment boom, warranted no future research.

Mechanical recovery refers to the use of equipment such as skimmers and sorbent mops to recover spilled oil from the shoreline and the water surface in open water, broken ice and solid ice. The panel discussed specific items such as cleaning oiled ice, the use of controlled lightning as an ice-breaking mechanism, and the use of peat as a collecting agent for shoreline cleaning.

Chemical treatment refers to the use of chemical treating agents to disperse oil to keep it as a single mass, to gel oil for easier recovery, to herd oil to keep it as a single mass, to biodegrade oil, to break emulsions, to increase ignition capabilities and to wash oil from the shoreline. Each of these categories was discussed for use, where applicable, on shorelines, in open water, in broken ice and on solid ice. The panel also discussed the approval process for using chemical treating agents, as well as each category of chemical treating agents (dispersants, gelling agents, surface washing agents, biodegradation and recovery agents) and determined the research needs in each area.

In situ burning refers to the burning of spilled oil in place: on the shoreline, in open water, in broken ice or on solid ice. The panel focused on research needs for field testing, laboratory work and studies. Among the issues addressed were tests relating burn rates to burn efficiencies and emissions, experiments for determining the thermal requirements to break down various water-in-oil emulsions, and development of mechanisms to enhance in situ burning such as air or water injection.

Readiness refers to planning for oil-spill response: planning for contingencies, describing response times, and describing "windows of opportunity" for using specific pieces of equipment and methods for the containing and recovering oil. The panel discussed refining windows of opportunity, improving acceptable performance criteria, refining disposal options, improving transportation and logistics programs, and reviewing the utility of small-scale and large-scale experimental burns.

Two panels discussed the topic of remote sensing: chemical treatment and mechanical containment. Remote sensing can be used to detect oil and describe its movement and characteristics on the water surface. The two panels developed research priorities for open water, broken ice, solid ice and shorelines.

The workshop proceedings, *Alaska Arctic Offshore Oil Spill Response Technology*, November 29–December 1, 1988, National Institute of Standards and Technology, NIST SP 762, may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Copies may also be obtained from the Minerals Management Service Public Library, 249 E. 36th Ave., Room 502, Anchorage, Alaska 99508-4302.

Arctic Fisheries Coordinating Committee

Prepared by Richard Marshall, Fisheries Management Services, U.S. Fish and Wildlife Service, Anchorage, Alaska 99503.

The intensity of fisheries investigations on Alaska's North Slope and the Beaufort Sea has been increasing steadily as a result of current and proposed oil and gas development. Recognizing this, agencies and organizations involved in those investigations formed the Arctic Fisheries Coordinating Committee in early 1988 to implement their programs more effectively. The committee, comprising government and industry representatives, meets in Anchorage on a regular basis to discuss objectives, methods and results of their investigations and to explore the potential for sharing logistical assets.

In 1989, for example, industry is funding two causeway monitoring programs (one under a Corps of Engineers permit and one under a North Slope Borough permit), the U.S. Fish and Wildlife Service is conducting a near-shore and inland investigation on the Arctic National Wildlife Refuge, the Alaska Department of Fish and Game is evaluating the modification of flooded gravel borrow pits for enhancing fish habitat, the North Slope Borough is continuing fisheries investigations in Dease Inlet near Barrow, and Canada's Department of Fisheries and Oceans is conducting fisheries investigations in the Mackenzie River Delta.

All committee members are benefiting from coordinating their efforts before planning and implementing their programs and from timely review of data following the field season.

NASA Global Tropospheric Experiment

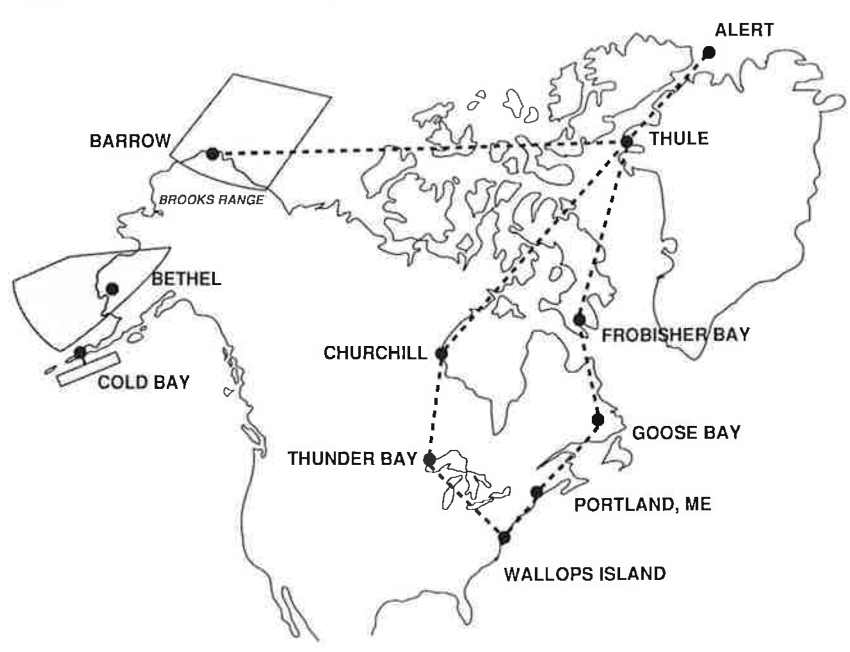
Scientists from three NASA research laboratories, nine universities, two private research companies and the Brazilian Space Research Institute spent most of the summer of 1988 camped in tents on the Alaskan tundra and flying in a NASA research aircraft equipped with state-of-the-art laser sensors over the tundra, ice and oceans from Thule, Greenland, to Cold Bay, Alaska (see *Arctic Research of the United States,* Fall 1988, p. 65–66).

Computer models of the greenhouse effect (a warming of the Earth's atmosphere due to the accumulation of carbon dioxide, methane and other gases released by human activities) predict that climate warming will be most pronounced in the northern high-latitude continental regions. The NASA Global Tropospheric Experiment (GTE) Arctic Boundary Layer Expedition (ABLE-3A) is the first coordinated, multidisciplinary study of how northern tundra ecosystems and Arctic air quality will respond to any future climate change.

Two results of the ABLE-3A study were the discovery that the release of methane to the atmosphere from Alaskan tundra is very sensitive to soil moisture levels and that the summer Arctic atmosphere has higher levels of air pollution than previously detected.

Methane, the most rapidly increasing greenhouse gas, is emitted to the atmosphere by a variety of human activities and from natural swamps, bogs and tundra. The discovery that even slight changes in soil moisture increase or reduce methane emissions from tundra by a factor of 100 introduces an important new component into forecasting future climate change. Present computer models do not include this potentially critical biological response.

ABLE-3A research areas.



The NASA aircraft probed the Arctic atmosphere from altitudes of 500–20,000 feet above the Arctic Ocean and tundra at over 100 locations during a 43-day period in July and August. Operating primarily from Barrow and Bethel, Alaska, scientists on the aircraft measured highly variable concentrations of more than 20 atmospheric gases in air that had originated in North America, the Soviet Union and Europe. Carbon monoxide, a sensitive tracer of air pollution from coal and oil combustion or forest fires, was found to be enhanced from clean air concentrations of 70 parts per billion (ppb) to concentrations of 130–140 ppb at many altitudes over remote regions of the Arctic Ocean and tundra. Previously, such high levels of atmospheric pollution in the Arctic had only been observed during the spring months. Because the oxidizing capacity of the Arctic atmosphere is relatively low, these pollutants can accumulate to higher levels.

In the Arctic, pristine air with extremely low concentrations of critical photochemically active gases were also the focus of the ABLE-3A study. Studies of these pristine baseline regions provided the first verification of theoretical models of controls on tropospheric ozone production and destruction processes. It is now possible to better define both the levels and effects of human activities in North America on regional and global air quality. Nitrogen oxide gases (NO and NO_2) are typically below the critical level of 15 parts per trillion (ppt) necessary for ozone formation in all clean regions of the Arctic atmosphere.

Detailed results of the ABLE-3A study were presented at the annual spring meeting of the American Geophysical Union, May 8–9, 1989, in Baltimore, Maryland. Thirty-three papers were presented in the two-day special session.

Further information is available from Dr. Robert J. McNeal, Program Manager, NASA GTE/ABLE, NASA Headquarters (202-453-1479); James M. Hoell, Jr. (project manager), NASA Langley Research Center (804-864-5826); or Dr. Robert C. Harriss (mission scientist), University of New Hampshire (603-862-3875).

Airborne Arctic Stratospheric Expedition

The 1985 discovery of large, rapid decreases in atmospheric ozone each spring in the Antarctic has led to major changes in theories of stratospheric chemistry and dynamics in polar regions. It is now thought that polar stratospheric clouds, which form at low temperatures, are the sites of a series of chemical reactions that accelerate the catalytic destruction of ozone by chlorine. Studies have suggested that the chemical composition of the lower stratosphere becomes perturbed when chemically inactive chlorine compounds become converted to photochemically active compounds on the surfaces of these clouds. There has been speculation that similar phenomena might be occurring to a lesser, but important, extent at northern high latitudes, since winter ozone levels have been known to decrease in the Arctic since 1970.

The Airborne Arctic Stratospheric Expedition was organized to determine whether the processes that contribute to Antarctic ozone depletion also occur in the Arctic. Between January 1 and February 15, 1989, two aircraft, a high-altitude ER-2 and a modified DC-8, flew 14 flights each from Sola Airfield near Stavanger, Norway. The aircraft were equipped with state-of-the-art instrumentation for determining the chemical composition and physical state of the atmosphere. The DC-8 flew as far north as the North Pole and as far west as the western coast of Greenland; the ER-2 ranged as far as 82°N and the center of Greenland. Satellite and ground-based measurements were also used in the campaign.

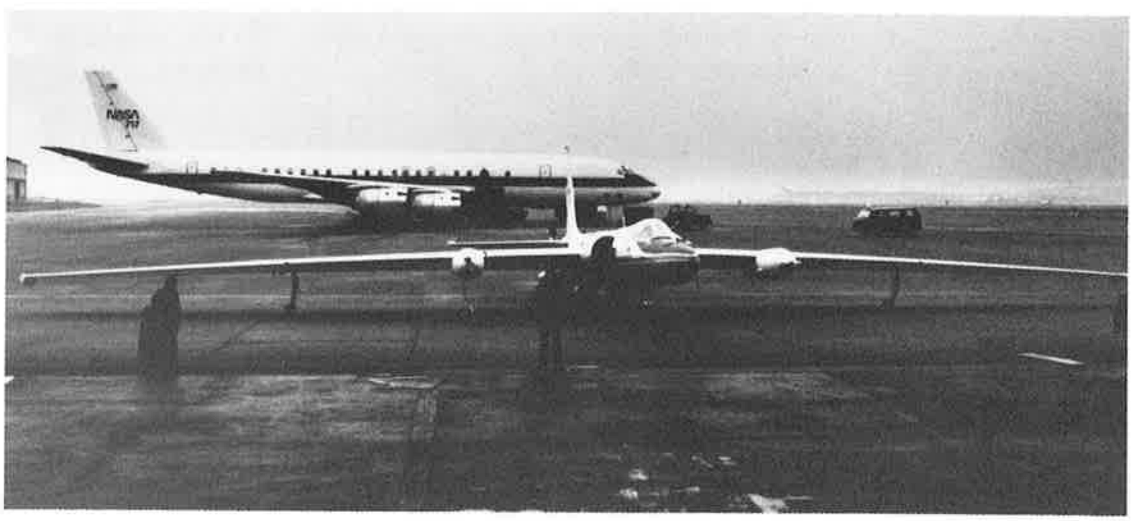
The National Aeronautics and Space Administration coordinated the campaign, which was cosponsored by the National Oceanic and Atmospheric Administration, the National Science Foundation and the Chemical Manufacturers Association with support from the governments of Great Britain, Norway and Denmark. Participating scientists and engineers were from universities and government laboratories in the U.S., Great Britain, West Germany, Norway and Denmark.

Because the issue of global ozone depletion due to human activities is of concern to policymakers and the public, preliminary results of the campaign were released soon after it was completed. A more thorough assessment by the international scientific community is scheduled for completion by August 1989, and the results will serve as input to the 1990 policy review of the Montreal Protocol on Substances that Deplete the Ozone Layer. Comprehensive data analysis will continue for at least another year.

The preliminary results of the expedition suggest that the chemical composition of the Arctic polar stratosphere was highly perturbed and that chemical reactions were occurring on polar stratospheric clouds. Chemically active chlorine compounds were as much as 50 times more abundant than would be expected if chemical reactions were not occurring on polar stratospheric clouds. Since the relevant meteorological conditions for the formation of polar stratospheric clouds were not unusual this year, the observed phenomena are expected to occur in most years. A direct cause-and-effect relationship between the decrease in high-latitude winter ozone levels and the chemical perturbations has not yet been established.

Further information is available from Dr. Robert Watson, Branch Chief, NASA Headquarters, Code EEU, Washington, D.C. 20546; or Dr. Adrian Tuck (project scientist), NOAA Aeronomy Laboratory, 325 Broadway, Boulder, Colorado 80303.

The NASA ER-2 and DC-8 at Sola Military Air Station, Stavanger, Norway.



National Science Foundation's Polar Ice Coring Office

PICO Bulletin, an occasional publication describing PICO activities, can be obtained from the Director, PICO, University of Alaska–Fairbanks, Alaska 99775.

The Polar Ice Coring Office (PICO) provides administrative support, manages field operations and coordinates logistical requirements for a variety of NSF-sponsored projects. PICO primarily supports NSF's Division of Polar Programs (DPP) glaciology projects and secondarily supports other DPP projects and those sponsored by other divisions within NSF. PICO's ice-drilling operation consists of designing, building and operating ice-drilling equipment in support of NSF-sponsored projects. PICO has provided drilling support in Antarctica, Greenland, Peru and China.

PICO began as part of the Ross Ice Shelf Project (RISP), which had its management office at the University of Nebraska–Lincoln (UNL) from 1971 to 1979. In 1974 NSF shifted responsibility for shallow ice drilling and logistics of NSF projects in Greenland from the Army's Cold Regions Research and Engineering Laboratory to RISP. To accomplish these tasks PICO was formed. In 1979 PICO became a separate contract at UNL, and it progressed through two five-year contracts.

In 1988 NSF requested proposals from other institutions interested in managing the PICO contract. As a result of this process the University of Alaska–Fairbanks was awarded the contract and assumed responsibility on November 1, 1988. The new director is John Kelley.

The Greenland logistics operation, based at the Sondrestrom Air Force Base on Greenland's west coast, provides support for up to 25 NSF-sponsored projects each summer. Between 1979 and 1981 logistical support was provided for the Greenland Ice Sheet Program (GISP), which retrieved a core from the bottom of the ice sheet at the DEW line station DYE-3 in central Greenland. The 1989 GISP II drilling program will produce several hundred meters of ice core. It will also initiate the first U.S. attempt to drill through a major ice sheet since 1968.

PICO provides arrangements for transportation of personnel and equipment between the U.S. and Greenland, including military clearances for personnel, access to air base facilities in Greenland, and on-site coordination of field activities originating at Sondrestrom Air Force Base. The PICO field office controls and maintains an inventory of field equipment that includes oversnow vehicles, shelter and tents, radios, generators and various types of fuels, and it also provides liaison between NSF, scientists and support subcontractors. PICO also provides ice-core and hot-water drilling services, the loan of some drilling equipment to scientific parties, and borehole logging services for NSF–DPP glaciological and geophysical projects.

The PICO operation in Greenland is possible only through the support of many organizations. The U.S. Air Force Space Command allows PICO access to the air bases in Greenland. Support at Sondrestrom AFB is provided by the 4700th Operations Support Squadron and the 1015th Air Base Squadron. The 1012th Air Base Group provides support at Thule AFB. The 109th Tactical Airlift Group of Schenectady, New York, provides flight support between the U.S. and Greenland and on the ice cap. GreenlandAir also provides air support between communities in Greenland and to the ice cap. Felec Services, Inc., Greenland Contractors, Danish Arctic Contractors, The Royal Greenland Trade Department, Statoil, The Danish Meteorological Service, Gronlandsbanken and Scandinavian Airlines all provide valuable services in support of PICO in Greenland. Activities in Greenland are reviewed and approved by the Danish Commission for Scientific Research in Greenland.

The Alaska Air Command at Eielson AFB and the U.S. Army at Ft. Wainwright supply support in Fairbanks.

The Resource Apprenticeship Program for Students

Prepared by Robert Jones, RAPS Program Coordinator for BLM, Anchorage, Alaska. The program was develop in 1987 by Tom Dean, Arctic District Manager.

Alaskan Natives are among the largest private land owners in the world. The passage of the Alaska Native Claims Settlement Act (ANCSA) in 1971 provided Alaskan Natives with a land settlement of 44 million acres. As a result, they have found themselves managing a diverse ecosystem.

Young Alaskan Natives, as with any people trying to enter the job market for the first time, are always faced with the problem of competing against experienced workers for entry-level positions. In rural Alaska this problem is particularly acute since there are few jobs to begin with. One of every four Natives dropped out of high school in 1980, and only 3.5% have completed college. Suicides and alcoholism problems among youth in rural communities have been well documented and are attracting public attention.

In the summer of 1987 the Bureau of Land

Management's (BLM) Arctic District piloted a "hosted workers" program by hiring a high school junior from Barrow and another from Point Hope. The costs were paid by BLM and the Bureau of Indian Affairs. BLM expanded the program in 1988 to include ten students placed in three BLM Districts plus two students in the National Park Service (NPS) and two in the Fish and Wildlife Service (FWS). Students helped archeologists excavate historic sites, worked with recreation specialists on river patrols, and helped biologists conduct various wildlife studies.

This "hosted student" approach by BLM was renamed Resource Apprenticeship Program for Students (RAPS) and is now beginning its third year. It combines the efforts of Federal and state land-managing agencies, the Alaska school system (both secondary and university), and private industry to provide worthwhile employment and educational opportunities for rural Alaskan students seeking careers in natural resource management.

RAPS links a potential labor pool with a demonstrated employment need. By participating in the program, students get on-the-job training in natural resource management. They can also qualify for tuition waivers in natural resource management programs at the University of Alaska–Fairbanks to continue their education after high school. They also learn to live away from home, and they are exposed to cultural differences in larger cities. Students live with host families near their summer jobs. These families receive a small reimbursement for food and transportation costs and are an extremely important part of the program.

At the end of the summer, students are required to write a paper on their experiences. Follow-up with the student's parents and school continues in the fall and winter. Students are encouraged to return to the agency for additional experience through their college years. Every effort is made to place them in a job following graduation, either in a sponsoring state or Federal agency, or in a private agency or Native corporation.

The program has been widely publicized and well accepted. More students apply than can be accommodated, and additional agencies want to join the program. The RAPS program operates under the philosophy that it is better to offer a quality experience to a small number of students than to offer "make-work" projects to a larger number of students. In 1988 the USDA Forest Service and the Alaska State Department of Natural Resources cooperated with BLM, NPS and FWS to sponsor 28–30 students. BLM will continue to serve as the lead coordinating agency. Other state agencies and the North Slope Borough have expressed interest in joining the program in the future. This program has been endorsed by the Alaska Department of Education and the Alaska Association of School Administrators.

RAPS participant working on an archeological excavation.

Heap Leaching and its Applicability to Alaska

Prepared by Denise Herzog, Mining Engineer, Alaska Field Operations Center, Bureau of Mines, Anchorage, Alaska.

Heap leaching, a method of using sodium cyanide solutions to dissolve precious metals from low-grade ore deposits, is widespread throughout the western United States. U.S. mines using this technology produced 998,603 ounces of gold and 3,641,741 ounces of silver in 1986. This amounts to a 20-fold increase in leached gold and a 125-fold increase in leached silver over the production figures of 1979.

In heap leaching, ore is placed on impermeable pads. A sodium cyanide solution is added to the heaped ore via a sprinkler or drip line. The solution permeates the ore, dissolving the gold and silver. The solution then flows into a collection pond, where it is pumped to the processing plant. The gold and silver are recovered either by carbon absorption or zinc precipitation.

A heap leach operation was initiated near Fairbanks, Alaska, in 1985. Following tests the project went into production in 1987, with 70,000 tons of ore leached.

Alaska faces problems with the use of heap leaching because of its cold climate and sensitive environment. The main deterrent to leaching is the short operating season (from mid-May to the beginning of October). During the severe Alaskan winters, the leaching solutions freeze, plugging the lines and sprinklers. The cyanidization process also slows to 30% of its normal reaction time. Solutions can be heated to prolong the operating season, but high power costs may make this uneconomic. The limited season results in short leaching periods, limited cash flow, and shutdown and start-up expenses.

The cold climate also creates problems with frozen ground. When liner pads are placed on frozen ground with a high moisture content, melting and refreezing causes frost heaving, which can tear the liners. The result can be leakage of the cyanide and the solution with dissolved precious metals.

Development costs in Alaska are greater than those in the conterminous states, so higher-grade deposits are necessary to make a profit. For example, many deposits in lower latitudes can successfully leach ore grading 0.05 ounces of gold per ton and less. The Ryan Lode, Alaska's only operating heap leach project, processes ore grading 0.3 ounces of gold per ton.

The Alaska Department of Environmental Conservation (DEC) has initiated a regulation requiring no more than 0.02 ppm of cyanide in wastewaters. The heaps must be double-lined and equipped with devices for groundwater monitoring, vadose zone monitoring and thermal monitoring. Sealing requirements are difficult to meet. The heap must be completely capped and recontoured. This cap must prevent percolation to the leached ore and must be able to withstand damaging freeze–thaw cycles. The operator must maintain the cap and monitor the systems for five years (or longer if determined by the DEC).

Such strict regulations may not be necessary because cyanide quickly detoxifies by volatilization, bacterial oxidation, complexation with metals (forming very stable compounds), plant metabolization and ultraviolet photolysis. Also, cyanide wastes may be artificially detoxified by using hydrogen peroxide, chlorine, or SO_2 and air. Furthermore, since leakage of cyanide solution also represents a loss of dissolved gold and silver, the operators of heap leaching projects are very unlikely to allow accidents to happen during production, when solutions are at their maximum cyanide content.

When heap leaching properties are selected carefully, this mining procedure can be used safely and effectively to recover metals from deposits that are considered uneconomic using conventional mining methods. Research by the Bureau of Mines is resulting in new technologies to extend the mining season in cold climates.

Interagency Arctic Research Policy Committee

Fifth Meeting: March 27, 1989

Prepared by Charles E. Myers, National Science Foundation.

Chairman Erich Bloch convened the meeting. He noted that under the terms of the executive order establishing the Committee, the Chairman may invite the representative of any executive agency to join the Committee. Chairman Bloch then stated that in response to the Department of Agriculture request for membership, he had invited the Department to become a member agency of the Committee.

Jerry Brown of the National Science Foundation presented a summary of the biennial revision to the U.S. Arctic Research Plan. He noted the revision's emphasis on coordinated activities. Agency representatives then presented short discussions of the major components of the biennial revision: Joseph Fletcher, NOAA, presented the coordinated ocean/atmosphere program; Douglas Posson of the U.S. Geological Survey discussed the coordinated Arctic data program and the establishment of the Arctic Environmental Data Directory Working Group; and Robert Hoffmann of the Smithsonian presented the social and health sciences program. Dr. Hoffmann noted that the Polar Research Board had recommended in its report *Arctic Social Science: An Agenda for Action* that the Interagency Committee establish a task force of social scientists. Mr. Bloch proposed that the Social Science Working Group be upgraded to a task force. This recommendation was accepted by the Committee. Mr. Bloch also asked each agency to provide comments within 30 days on the Arctic social science report. The Department of Education, although not a member of IARPC, was invited to comment on the report.

Committee Members or Agency Representatives Present: *Erich Bloch, National Science Foundation; Stanley Krugman, Department of Agriculture; Joseph O. Fletcher, Department of Commerce; Ted Cress, Department of Defense; David Nelson, Department of Energy; Jay Moskowitz, Department of Health and Human Services; Doyle Frederick, Department of the Interior; Frederick M. Bernthal, Department of State; George Martin, Department of Transportation; Courtney Riordan, Environmental Protection Agency; Shelby Tilford, National Aeronautics and Space Administration; Jack Fellows, Office of Management and Budget; Robert S. Hoffmann, Smithsonian Institution.*

Jay Moskowitz of the Department of Health and Human Services then discussed the broad goals of Arctic health research. Juan Roederer, Chairman of the Arctic Research Commission, presented the Commission's formal comments on the biennial revision to the Plan. Chairman Bloch then asked for the Committee's agreement that the biennial revision be prepared for transmittal to the President and the Congress by July 31, 1989, subject to editing and final approvals. There being no objection, Mr. Bloch directed the staff representatives to complete the biennial revision.

Robert Corell, Assistant Director for Geosciences, NSF, reviewed recent international developments, including the International Arctic Science Conference in Leningrad in December 1988 and planning activities for an International Arctic Science Committee (IASC). The IASC is intended to be a nongovernmental scientific organization.

Chairman Bloch noted that the Committee's journal, *Arctic Research of the United States,* has now been through three issues. He noted the proposal to establish an editorial advisory group. The Committee accepted this proposal with the provision that the membership of the editorial group be on a rotational basis. With this, Mr. Bloch adjourned the open session of the Committee meeting.

The Committee reconvened in closed session to discuss coordination and budgetary constraints. Mel Peterson of NOAA presented the rationale for the proposed ocean/atmosphere coordinated program. After discussing this proposal in some detail, the Committee agreed to prepare an interagency document for the coordinated ocean/atmosphere program to include FY 89 and 90 expenditures. This will be updated for FY 91 and made available once the budget is submitted to the Congress in early 1990. Jack Fellows of OMB agreed to provide OMB's assistance in the crosscutting budget analysis. (At this point, Mr. Bloch asked Robert Corell to assume the Chair.) The agency representatives agreed to develop the coordinated program using the Committee on Earth Sciences' global change report as a guide for the crosscutting analysis. The Committee agreed to review progress on this pilot exercise at a meeting to be held in approximately two months.

Sixth Meeting: June 1, 1989

The meeting was convened by Chairman Erich Bloch, at which time he requested that the staff develop an annual calendar for Committee meetings. Mr. Bloch noted that at its March 27 meeting, the Committee had designated the Social Science Working Group as a task force. He reminded the agencies that he had requested their review of the Polar Research Board's report on Arctic social science. Mr. Bloch called on William Fitzhugh, chairman of the task force, to report on that review. Dr. Fitzhugh summarized the agencies' responses and the task force recommendations. Mr.

Bloch announced that NSF accepts the task force recommendation to establish an Arctic social science program in NSF. Mr. Bloch also asked for the Committee's approval to insert the task force conclusions and recommendations into the draft biennial revision to the U.S. Arctic Research Plan. There being no objection, the Plan was amended as proposed.

Mr. Bloch then noted that the draft biennial revision to the U.S. Arctic Research Plan was ready to send to the Office of Management and Budget for review. There being no further comments on the Plan, Mr. Bloch reminded the agency representatives that their final approvals of the Plan were due. (All agency approvals were received by June 7, 1989.)

Mr. Bloch then turned to a number of informational items. Robert Corell of the National Science Foundation presented a progress report on the pilot Arctic Oceans research cross-cut planning activity. He noted that approximately $36 million was expended in this area during FY 89. The Oceans Working Group will continue its efforts over the summer, with the goal of completing the oceans cross-cut analysis by the fall of 1989. Dr. Corell also noted that this effort would serve as a model for the balance of the U.S. Arctic Research Plan, especially in the areas of land–atmosphere and people.

Dr. Corell then reported on the planning for the International Arctic Science Committee (IASC). The IASC planning group had recently met in Helsinki to further refine the founding articles for the IASC. Further review is planned for the summer. Chairman Bloch then called for brief reports on a number of Arctic environmental issues. Mike Kurylo of NASA reported on the Arctic stratospheric ozone expedition (see p. 61). This was followed by several reports on agency responses to the March 1989 Valdez oil spill and plans for future research presented by Charles Ehler of NASA's Office of Oceanography and Marine Assessment; Vern Wiggins, Interior's Deputy Under Secretary for Alaska; Paul Dunn of the Department of Agriculture; and Jay Benforado of the Environmental Protection Agency.

The open session of the meeting concluded with brief remarks by David Garman, representing Senator Frank Murkowski of Alaska. Mr. Garman thanked the Committee and the Arctic Research Commission for their excellent work in implementing the Arctic Research and Policy Act.

In closed session the Committee discussed the oceans cross-cut planning exercise and the proposed amendments to the Arctic Research and Policy Act. The Committee and staff will review the proposed amendments and develop a consensus position with the Commission.

United States Arctic Research Commission

Sixteenth Meeting: January 20–21, 1989

The Arctic Research Commission held its sixteenth meeting in conjunction with the American Association for the Advancement of Science in San Francisco, California, on January 20–21, 1989. Chairman Roederer opened the meeting, introduced Advisors and guests, and noted the successful all-day symposium "The Arctic: A New Key to World Climate and Resources," jointly sponsored by the Commission and the Polar Research Board on January 19th. The Chairman commented that the recent report *Statement of Goals and Objectives to Guide United States Arctic Research: Findings and Recommendations* (December 1988) was the most important document yet published by the Commission.

Alaska Science and Technology Foundation (ASTF)

Dr. Francis Williamson, a member of the Board of Directors of the Foundation, reported that ASTF, since it began in the fall of 1988, had focused on two subjects:

- Developing mechanisms for soliciting and evaluating proposals, awarding grants and contracts, and monitoring progress and expenditures; and
- Hiring an executive director.

The proposal process will accommodate both solicited and unsolicited proposals. Research priorities of the Alaska Science and Engineering Advisory Commission will be used to establish technical areas of emphasis.

Interagency Arctic Research Policy Committee

Jerry Brown summarized activities of IARPC. The logistics working group completed an initial draft identifying Federal agency logistic assets. The Commission's proposal to examine the Bering Sea as a system was assigned to the oceans/atmosphere working group for consideration in the revised Arctic Research Plan.

The first biennial revision of the U.S. Arctic Research Plan is in draft form and has been circulated for review. Reviews have been scheduled in Alaska. The intent of the revision is to provide a brief update focused on the next two years. Various recommendations forwarded by the Commission are being considered for incorporation. The body of the report consists of two parts. The first part describes proposed interagency programs in ocean–atmosphere interactions, biosphere–atmosphere interactions, and Arctic data and information. The second part describes the research components of Federal agencies, organized in six areas: Arctic ocean and marginal seas, atmosphere and climate, land and offshore resources, land and atmosphere interactions, engineering technology, and people and health.

The Commission has asked for a review of the draft revision by the Commissioners and Advisors. The Chairman will collate the responses and correspond with IARPC.

International Scientific Cooperation

The Chairman reported on the "Conference of Arctic and Nordic countries on coordination of research in the Arctic" held in Leningrad, December 12–15, 1988. Many useful discussions, both formal and informal, occurred among the some 500 scientists. Some papers reported on recent research or summarized programs, but much of the discussion was focused on the state of Arctic science (including physical and biological disciplines) and possible areas of cooperation. An assessment of the results, however, must await publication of the conference summary and proceedings.

Progress in defining an International Arctic Science Committee (IASC) over the past ten months has occurred primarily through the hard work of a drafting committee assigned as a result of the Stockholm conference in March 1988 (see *Arctic Research of the United States*, Spring 1988). A draft of proposed Founding Articles has been circulated for review to the eight proposed founding nations. The intent is to solicit comments to be incorporated into a revised statement so that IASC could be formally inaugurated later in 1989. Some concern remains as to whether the board of IASC should be restricted to members from the eight founding Arctic countries. The consistent U.S. position remains that as a nongovernmental organization, IASC should be open to institutions and scientists from all qualified nations. The Commission concluded that review comments of the Advisors and the Commissioners would be forwarded, as requested, to the Interagency Arctic

Commission Members Present: *Juan G. Roederer, Chairman; Ben C. Gerwick; Elmer E. Rasmuson; John H. Steele; Peter Wilkniss, representing Erich Bloch.* Staff: *Philip L. Johnson, Executive Director; Lyle D. Perrigo, Staff Officer.* Commission Advisory Group Members: *Arthur Grantz, USGS; John P. Middaugh, Alaska Department of Health and Social Services; Wilford Weeks, University of Alaska–Fairbanks.* Visitors: *E.N. Bernard, NOAA; Jerry Brown, NSF; William E. Davis, Cultural Dynamics, Ltd.; Luis Proenza, University of Alaska; Gunter Weller, Chairman, Polar Research Board, NRC; Francis S. Williamson, Alaska Science and Technology Foundation.*

Policy Group chaired by the Department of State and that the Commission would propose the establishment of a U.S. National Committee as a means for U.S. participation when IASC is officially inaugurated.

Assessment of Commission Initiatives

In addition to the recommendations of the Commission to IARPC on logistics and research priorities for inclusion in the revised Arctic Research Plan, the Commission received reports on the status of its recommendations on Arctic health, social science, and the Bering Sea. Dr. John Middaugh, Alaska State Epidemiologist, reported on the recent interest at the National Institutes of Health, particularly the intent to fund a five-year study by Louisiana State University and the Alaska Division of Public Health on atherosclerosis in Eskimos. Dr. Middaugh also described a concept for linking the polar scientific community and the Federal health agencies through a new role for the Polar Research Board. If approved and funded, an appropriate staff person would assess and help coordinate opportunities for needed health research in the Arctic. The Commission agreed to endorse this concept.

Dr. Gunter Weller, Chairman of the Polar Research Board, reported on a publication, *Arctic Social Science: An Agenda for Action,* just issued by the Polar Research Board (see p. 36). The Commission will follow with interest the responses to this report.

Dr. Eddie Bernard, Director of the Pacific Marine Environmental Laboratory, NOAA, reported that the agency's proposal for ice-edge research, an integral part of a multiagency effort and a proposal advocated by the Commission, had been approved within NOAA but not in the final FY 89 budget review. This illustrates a problem in recommending coordinated multiagency programs. If some components are not funded, the overall program may not be viable. This concern is shared by the Commission and IARPC.

Other efforts to organize research on the Bering Sea are underway. Mayor Paul Fuhs, Unalaska, is exploring state and private funding to establish the Bering Sea Research Institute as a basis for logistic support. Private fishing boats may also be able to help investigators.

The Commission discussed its concern with the scientific quality of information used in environmental assessments and impact statements. The Chairman agreed to develop a discussion paper for the next meeting and to explore options for constructive recommendations to improve the scientific quality and timeliness of the impact statement process.

Other Business

The Commission reviewed a draft of its annual report, decided to publish a brochure about Arctic science and Commission activities, discussed the need for a policy on joint sponsorship of events such as scientific conferences, and decided to meet in Anchorage and Dillingham, Alaska, and to plan a field trip to review Arctic research in Greenland.

In executive session the Commission reviewed an advisory opinion on administrative law issues as they affect the Commission's operations and decided to establish an ethics policy for the Commission. Proposed amendments to the Arctic Research and Policy Act of 1984 were reviewed and endorsed.

Seventeenth Meeting: March 28–29, 1989

The Arctic Research Commission held its seventeenth meeting in Washington, D.C., on March 28–29, 1989. Chairman Roederer noted that since the last meeting the Commission had published its annual report for the period October 1987 through September 1988, which included a summary of activities since the Commission's inception in 1985. The Commission has also undertaken a review of opportunitites to improve the environmental impact assessment process, followed up on international Arctic initiatives, continued to examine the initiative for a study of the Bering Sea as a system, urged coordination of logistic support, and reviewed the draft revision of the U.S. Arctic Research Plan.

Interagency Arctic Research Policy Committee

Erich Bloch, Chairman of IARPC, noted that the revision of the Arctic Research Plan was on schedule for delivery to the President in July 1989 and will incorporate comments from many sectors of the Arctic community. He indicated that many of the Commission recommendations had been included in the revised plan and noted the budget uncertainty for realizing these plans. He briefly reviewed the IARPC meeting on March 27, particularly the proposed interagency initiatives. Currently Federal research funding for the Arctic totals about $96 million and appears to be about level, although the National Science Foundation is experiencing modest increases.

Comments from Congress

David Garman, representing the Alaska Congressional delegation, reported the recent introduction of S. 677, a bill to amend the Arctic Research and Policy Act of 1984 (Public Law 98-373) to clarify and improve some of its provisions. The changes include the addition of two Commissioners for a total of seven and the requirement that Federal agencies respond to Commission recommendations.

Arctic Research Consortium of the United States (ARCUS)

Dr. Luis Proenza, President of ARCUS, explained that the goals of ARCUS, established in 1988, were to

- Increase public awareness of the Arctic,
- Increase educational opportunites,
- Enhance access to Arctic data and information, and
- Enhance the ability to support research by means such as establishing a logistics clearinghouse.

One hundred universities and research institutions have been invited to join the consortium.

Federal Environmental Impact Procedures

Dinah Bear, General Counsel, Council on Environmental Quality (CEQ), summarized the National Environmental Protection Act (NEPA) and the role of CEQ in publishing regulations binding on all Federal agencies. She summarized the preparation procedures, including the scoping phase, leading to an environmental impact statement (EIS). The issue of incomplete or insufficient information has been considered in the revised regulations. Public comment is required in both the scoping phase and on the draft EIS. Litigation by both individuals and groups over the past 20 years has refined and reinforced the process.

A discussion paper prepared by the Chairman was the basis of a discussion that focused on what questions are to be answered, how data are evaluated, and how impacts are predicted. There seems to be considerable variation among agencies preparing EISs as to the quality of science included. The Commission was encouraged by scientists and government officials to explore ways to improve the process, such as by using scientific peer review, particularly of study plans before work is contracted.

Federal Budget Process for Funding Research

Jack Fellows, Budget Examiner, Office of Management and Budget, summarized the Federal agency budgetary process. Interagency issues such as Arctic research are dealt with across many OMB offices. He discussed the budget environment, showing an increase in outlays and a decrease in budget authority on discretionary spending, which determines a majority of science funding. Mr. Fellows noted that three budgets are simultaneously in different stages: agencies are managing the 1989 budgeted expenditures, Congress is working on 1990 budget legislation, and agencies are formulating 1991 budget requests. He encouraged coordinated multiagency budget submissions, as exemplified by the global change initiative, as an effective and innovative mechanism for managing Arctic research.

Review of Selected Agency Research Activities

Presentations of Arctic activities were made by representatives of the Departments of Interior (Bureau of Land Management, Bureau of Mines, Fish and Wildlife Service, Minerals Management Service, National Park Service and Geological Survey) and Commerce, and the National Science Foundation. The organization, funding programs, and selected accomplishments were summarized. Much of this information has been covered in previous issues of *Arctic Research*.

Arctic Engineering

Dr. Robert Carlson, University of Alaska, presented the outline of a strategic plan for cold regions engineering research that was developed from a workshop in Hanover, N.H. (see p. 53). The workshop was conducted for the National Science Foundation to help guide their engineering programs. The topics were discussed in four groups: offshore technology; watersheds, rivers and coastal zones; facilities infrastructure; and transportation infrastructure.

Arctic Vessels

After reviewing the classes of vessels suitable for northern operations and current Federal plans for new ships, the Commission adopted a resolution supporting the President's budget for a third icebreaker now before the Congress and recommending that the United States charter with an option to purchase an ice-capable research vessel for the academic fleet in 1991.

Other Business

In executive session the Commission discussed and adopted a policy governing meeting procedures, and duties and responsibilities of officers and staff. An ethics policy for the Commission was adopted. A budget request for operating the Commission in FY 91 was adopted.

Commission Members Present: *Juan G. Roederer, Chairman; John H. Steele, Vice Chairman; Elmer E. Rasmuson; Oliver Leavitt; Erich Bloch, ex-officio member.*

Staff: *Philip L. Johnson, Executive Director; Lyle D. Perrigo, Staff Officer; Jennifer Loporcaro, Administrative Assistant.*

Commission Advisory Group Members: *Tom Albert, North Slope Borough; William Fitzhugh, Smithsonian Institution.*

Visitors: *Shere Abbot, Marine Mammal Commission; Dinah Bear, Council on Environmental Quality; Joe Bishop, Gabrielle Kordon, Marcia Lagerloef, Tom Murray and Alan Thomas, NOAA; Jerry Brown, Ted De Luca, Charles Myers, Jack Talmadge, Patrick Webber and Peter Wilkniss, NSF; Robert Carlson, Luis Proenza and John Zarling, University of Alaska; Larry Cosgriff, Gibbs & Cosgriff, Inc.; Harlan Cohen, State Department; Tom Curtin and G.L. Johnson, ONR; John Dennis, National Park Service; Nancy Gale and Capt. Julian Wright, U.S. Navy; David Garman and Gregg Renkes, Senator Murkowski's office; Ozzie Girard, Department of the Interior; Wendy Graham, House Subcommittee on International Scientific Cooperation; John Haugh, Bureau of Land Management; Richard Hayes, Office of the Oceanographer of the Navy; Jorma Heinonen, Embassy of Finland; Robert Hoffmann, Smithsonian Institution; Capt. George Martin, U.S. Coast Guard; Bruce Molnia, USGS; Andrea Smith, Polar Research Board; Marnie Sweet; John Topping, Climate Institute; Bill Westermeyer, OTA; Priscilla Young, Bureau of Mines.*

Forthcoming Meetings

Listed here is a compilation of forthcoming meetings, workshops and conferences on Arctic or northern topics and activities. Readers are invited to submit information on upcoming meetings, as well as reports on national or international meetings attended, to J. Brown, Arctic Research, National Science Foundation, Room 620, 1800 G St., NW, Washington, D.C. 20550.

Eastern Snow Conference
8–9 June 1989, Chateau Frontenac, Quebec City, Quebec, Canada
Contact: Gerald Jones, INRS-Eau, C.P. 7500
2700 rue Einstein, Sainte-Foy, Quebec, Canada
GIV 4C7
Phone: (418) 654-2533

Tenth International Conference on Port and Ocean Engineering Under Arctic Conditions (POAC 89)
12–16 June 1989, Lulea, Sweden
Contact: Lena Karbin, S-951 87 Lulea, Sweden
Phone: +46 920 917 75
Telex: 80207 Centek S
Fax: 2 + 16 920 997 26

American Society of Limnology and Oceanography
18–23 June 1989, Fairbanks, Alaska
Contact: John Goering, Institute of Marine Sciences, University of Alaska, Fairbanks, Alaska 99775-1080
Phone: (907) 474-7895, 7797

28th International Geological Congress
9–19 July 1989, Washington, D.C.
Workshop on Arctic Geological Processes and Global Change
Contact: Bruce Molnia, U.S. Geological Survey, 917 National Center, Reston, Virginia 22092
Phone: (703) 648-4120
Telex: 248 418 GEOINT UR
Fax: (703) 648-4227

International Symposium on Mining in the Arctic
17–19 July 1989, Fairbanks, Alaska
Contact: Dr. Sukumar Bandopadhyay, 108 Brooks Building, University of Alaska, Fairbanks, Alaska 99775-1190
Phone: (907) 474-6876

Inuit Circumpolar Conference
24–28 July 1989, Sisiniut, Greenland
U.S. Contact: Dalee Sambo, ICC, 429 D Street, Suite 211, Anchorage, Alaska 99501
Phone: (907) 258-6917

International Association of Meteorology and Atmospheric Physics—Symposium on the Influence of Polar Regions on Global Climate
31 July–12 August 1989
Contact: Ross Reynolds, IAMAP 89, University of Reading, Reading RG6 2AU, United Kingdom
Phone: (0734) 318956
Telex: 847813
Fax: (0734) 314404

Institute of Circumpolar Studies
31 July–18 August 1989, Fairbanks, Alaska
Contact: Nancy Bachner, Conferences and Institutes, 1176 Eielson Building, University of Alaska, Fairbanks, Alaska 99775
Phone: (907) 474-7800

International Symposium on Geocryology
1–10 August 1989, Tyumen, Siberia, U.S.S.R.
Contact: V.P. Melnikov, Institute of Problems of Northern Development, Academy of Sciences, 625003, Tyumen (P.O. Box 2774), U.S.S.R.
Phone: +13441

Circum-Pacific Prehistory Conference
2–6 August 1989, Seattle, Washington
Contact: Dale R. Crowes, The Seattle Center, 1001 4th Avenue Plaza, Seattle, Washington 98154-1101
Phone: (206) 464-6580
Telex: 6838153 BSC SEA
Fax: (206) 382-9648

International Conference on the Role of the Polar Regions in Global Change

June 11–15, 1990, Fairbanks, Alaska

An international conference on the role of the polar regions in climate and global change will take place at the University of Alaska in Fairbanks on June 11–15, 1990. The conference is co-sponsored by the Arctic Research Consortium of the United States, the American Meteorological Society, the Scientific Committee on Antarctic Research, and the Arctic Division of AAAS.

The polar regions of the earth have become the focus of considerable attention in recent years in connection with atmospheric pollution and global climate concerns. For example, there is growing evidence that the polar regions play a key role in the physical processes responsible for global climatic fluctuations. In many instances the polar regions may be the prime source of such fluctuations. Polar regions are now widely recognized as important repositories of information on past climates and the causes of past climatic fluctuations. There is mounting concern that systematic warming in polar regions will alter the equilibrium of the polar ice masses and in this way affect the global sea level. Induced changes in the chemistry of high-latitude air are also viewed with increasing apprehension, based on dramatic trends in ozone depletion and the occurrence of Arctic haze.

The conference will include sessions on detection of climate change in the polar regions, polar regions processes, interactions between the middle and high latitudes, paleoclimatic data, and the impacts and consequences of global change. Both disciplinary papers and interdisciplinary ones linking atmospheric to oceanographic, cryospheric and biological processes will be accepted.

A call for abstracts will be issued in mid-1989. For further information, contact Dr. Gunter Weller, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800, USA, Telephone: (907) 474-7371, Telex: 35414.

IUTAM/IAHR Symposium on Ice–Structure Interaction
14–17 August 1989, Newfoundland, Canada
Contact: Ian Jordann, Faculty of Engineering and Applied Sciences, Memorial University, St. John's, Newfoundland, Canada A1B 3X5

Symposium on Ice and Climate
21–25 August 1989, Seattle, Washington
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +233 355974
Fax: +223 336543
U.S. Contact: Charles Raymond, University of Washington, AK-50, Seattle, Washington 98195
Phone: (206) 543-8020

Public Access to Resource Data
28–29 August 1989, Juneau, Alaska
Contact: Council on Northern Resources Information Management, Ron Longley, Office of Information and Technology, University of Alaska–Anchorage, 3211 Providence Drive, Anchorage, Alaska 99775-0800

American Fisheries Society, 119th Annual Meeting
4–8 September 1989, Anchorage, Alaska
Contact: Randy Bailey/Richard Marshall, U.S. Fish and Wildlife Service, 1011 E. Tudor Rd., Anchorage, Alaska 99503
Phone: (907) 786-3423

Arctic Science Conference, AAAS Global Change
14–16 September 1989, Fairbanks, Alaska
Logistics Workshop, September 16
Contact: Frank Williamson, Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska 99775-0800
Phone: (907) 474-7648

Global Significance of the Transport and Accumulation of Polychlorinated Hydrocarbons in the Arctic
18–22 September 1989, Oslo, Norway
Contact: Norwegian Institute of Air Research (NILU) P.O. Box 64, N-2001, Lillestrom, Norway

Symposium on the Arctic and Global Change
25–27 October 1989, Ottawa, Ontario, Canada
Contact: Climate Institute, Suite 403,
316 Pennsylvania Ave., SE, Washington, D.C. 20003

The Role of Circumpolar Universities in Northern Development
24–26 November 1989, Thunder Bay, Ontario, Canada
Contact: Dr. Paul Watts, Director, Centre for Northern Studies, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1
Phone: 807-343-8360
Fax: 807-343-8023

AGU, Snow, Ice and Permafrost Sessions:
5–9 December 1989, San Francisco, California
Contact: American Geophysical Union, 2000 Florida Avenue, NW, Washington, D.C. 20081

Circumpolar Ecosystems in Winter: First International Symposium and Workshop
16–23 February 1990, Churchill, Manitoba, Canada
Contact: Dennis Macknak, Churchill Northern Studies Center, P.O. Box 610, Churchill, Manitoba, Canada R0B 0E0

PRO MARE, Symposium on Polar Marine Ecology
12–16 May 1990, Trondheim, Norway
Contact: Egil Sakskaug, Trondheim Biological Station, Bynesveren 46, N-7018 Trondheim, Norway
Phone: +47-7-513260
Fax: +47-7-509034

International Congress on Circumpolar Health: Community Health—Problems and Solutions in the North
20–25 May 1990, Whitehorse, Yukon Territory, Canada
Contact: 8th International Congress on Circumpolar Health, 801-750 Jewis Street, Vancouver, British Columbia, Canada V6E 2A9
Telex: 04-352848 VCR

CANQUA/AMQUA—Rapid Change in the Quaternary Record
4–6 June 1990, Waterloo, Ontario, Canada
Contact: Alan V. Morgan, WATERLOO 1990, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
Phone: (519) 885-1211 (x3231)
Fax: (519) 746-2543, (519) 888-4521

Fifth Canadian Permafrost Conference
6–8 June 1990, Quebec City, Quebec, Canada
Contact: Mike Boroczki, Fifth Canadian Permafrost Conference, National Research Council of Canada, Ottawa, Ontario, Canada KIA OR6
Phone: (613) 993-9009
Telex: 053-3145
Fax: (613) 952-7928

13th Polar Libraries Colloquy
10–14 June 1990, Rovaniemi, Finland
Contact: Liisa Kurppa, Arctic Center, University of Lapland, P.O. Box 122, 96101 Rovaniemi, Finland
Phone: +358-60 324-275
Telex: 19205519
Fax: +350-60 324-270

International Conference on the Role of the Polar Regions in Global Change
11–15 June 1990, Fairbanks, Alaska
Contact: Gunter Weller, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775
Phone: (907) 474-7371
Telex: 35414
Fax: (907) 474-7290

Polar Tech '90
14–16 August 1990, Copenhagen, Denmark
Contact: Conference Secretariat, Danish Hydraulic Institute, Agern Alle 5, DK-2970 Horsholm, Denmark
Phone: +45 42 86 80 33
Telex: 37402 DHICPH DK
Fax: +45 42 86 79 51

Arctic Geology and Petroleum Potential
15–17 August 1990, Tromso, Norway
Contact: Norwegian Petroleum Society, Box 1897, Vika, 0124 Oslo 1, Norway
Phone: 47 2207025
Telex: 77 322 NOPETN
Fax: 47 2830547

Seventh Inuit Studies Conference
19–23 August 1990, Fairbanks, Alaska
Contact: Dr. Lydia Black, Department of Anthropology, University of Alaska, Fairbanks, Alaska 99775.
Phone: 907-474-6760 or 474-7288
Fax: 907-474-7720
BITNET: FFLTB @ALASKA

10th IAHR Symposium on Ice
20–23 August 1990, Helsinki, Finland
Contact: Mauri Maattanen, Helsinki University of Technology, Otakaari I, Sf02150, Espoo, Finland

Symposium on Ice–Ocean Dynamics and Mechanics
27–31 August 1990, Hanover, New Hampshire
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +233 355974
Fax: +223 336543

Second International Conference on Ice Technology
18–20 September 1990, Cambridge, United Kingdom
Contact: C.A. Brebbia, Computational Mechanics Institute, Ashurst Lodge, Ashurst, Southampton SO4 2AA, United Kingdom
Phone: 0 42129 3223
Telex: 47388 ATTN COMPMECH
Fax: 042129 2853

XIII INQUA Congress
2–9 August 1991, Beijing, China
Contact: Secretariat, XIII INQUA Congress, Chinese Academy of Sciences, 52 Sanlike, Beijing 100864, China
Phone: 863062, 868361-336,568
Cable: Beijing SINICADEMY
Telex: 22474 ASCHICN
Fax: 8011095

Mountain Glaciology—Relation to Human Activities
26–30 August 1991, Lanzhou, China
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +233 355974
Fax: +223 336543

Symposium on the Physics and Chemistry of Ice
1–6 September 1991, Sapporo, Japan
Contact: Norikazu Maeno, Institute of Low Temperature Science, Hokkaido University, Sapporo, 060, Japan

6th International Symposium on Ground Freezing
September 1991, Beijing, China
Contact: Hans Jessberger, Ruhr-University Bochum, P.O. Box 102148, D4630 Bochum 1, Federal Republic of Germany
Phone: 02 341700-6135
Telex: 0 825 860 UNIBO D

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Back Cover

The extensive facilities for auroral and upper atmospheric research in the near eastern Arctic. The important network of ground observatories, which is constrained by the relatively small land area, is located in Greenland, northern Scandinavia, the Kola Peninsula and the Svalbard and Franz Josef Land archipelagoes. These stations have a long tradition of auroral and upper atmospheric research, including optical observations of the dayside aurora, which are not possible elsewhere in the Northern Hemisphere. The sites form a multinational array of riometers, magnetometers, all-sky imagers and meridian-scanning photometers. Rocket sounding is carried out from Andoya in Norway and Esrange in Sweden; satellite downlink facilities and real-time communication from key ground observatories are planned to aid in real-time rocket and satellite experiments. There are extensive radar and radio facilities in northern Scandinavia, including EISCAT and STARE. An important air sampling station is on Spitsbergen, and there are plans for a new incoherent scatter radar there. These Arctic facilities and platforms provide the observational and experimental bases for planned NSF initiatives such as CEDAR and GEM.

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