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The evolution of knowledge about the Arctic
and its climate

Overview

The land of the midnight sun has enchanted humankind for centuries. Rarely does a visitor to this unique and storied region leave without impressions that last a lifetime. Whether it is images of immense glaciers, the shifting pack ice under steel grey skies, or bountiful wildlife grazing treeless, windswept tundra, the Arctic, even today, evokes images of a largely wild and untamed place. For many, the Arctic is as much a feeling as it is a region. Those with even a passing knowledge of the Arctic are familiar with the spirit of adventure – humans against nature – that drove some of the early exploration of the region. But the history of Arctic exploration and discovery is much more than Peary’s glorified, albeit doubtful conquest of the pole. The expeditions of Bering, Franklin, Frobisher, Hudson, Nansen, Nares, Sverdrup, Wegener and others variously reflected nationalism, the shifting economic significance of the region, and scientific inquiry. Many of the geographic place names in the Arctic honor these explorers (Figure 1.1). To appreciate our present understanding of the Arctic, we need to step back and review some of this rich history over the past four or five centuries, recognizing, of course, that there have been indigenous populations in the Arctic for many thousands of years.

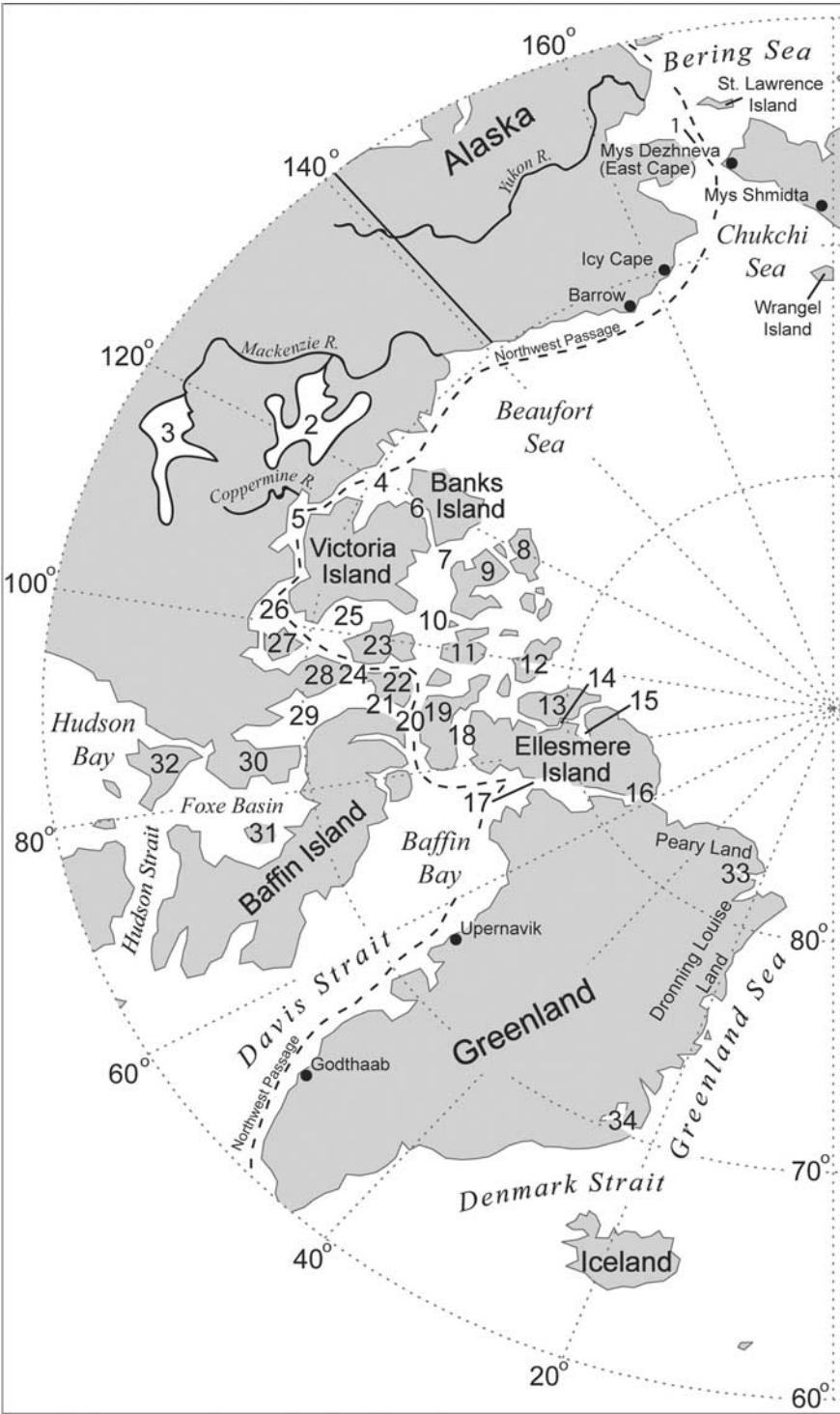
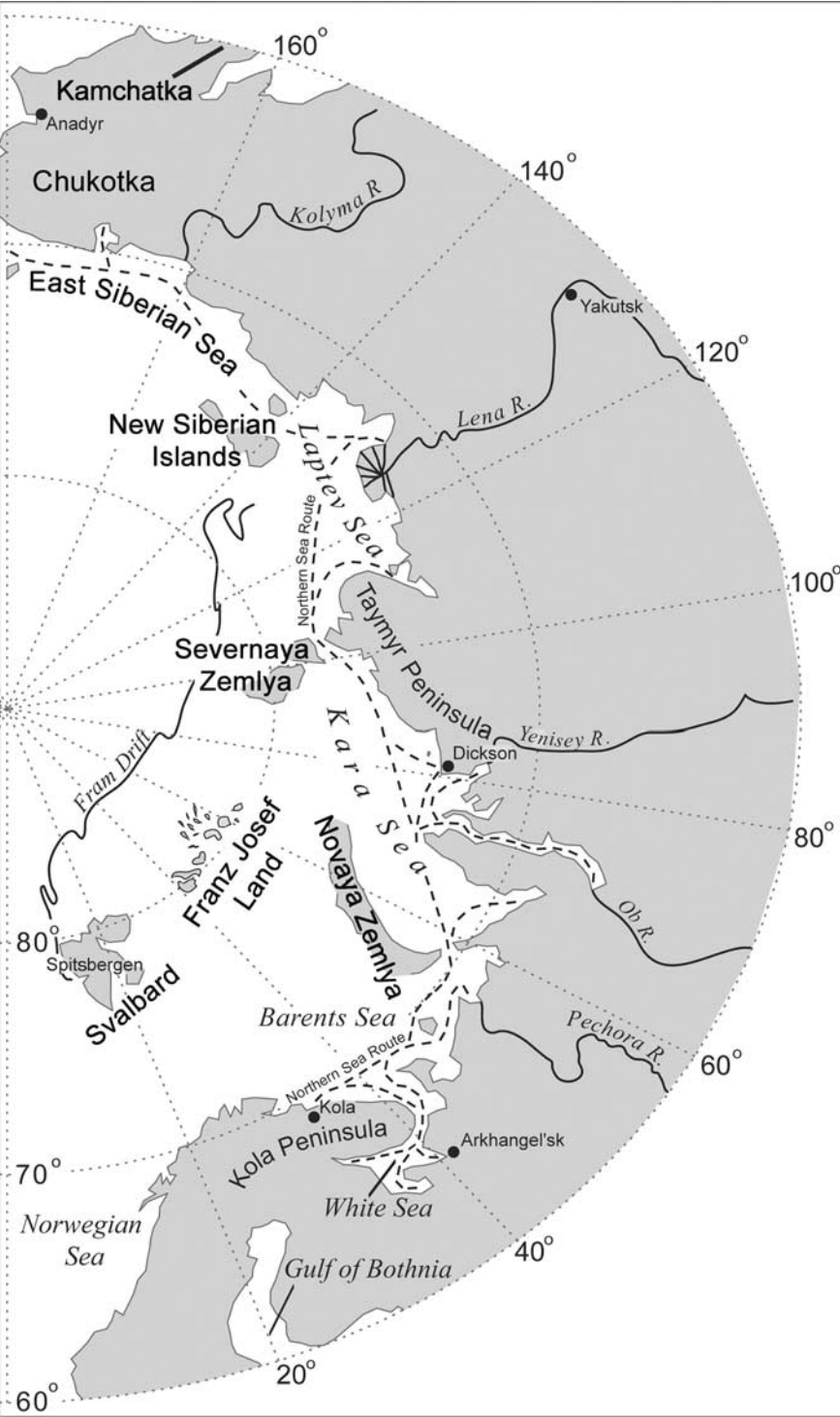


Figure 1.1 Geographic place names of the Arctic with special reference to early exploration of the region. 1. Bering Strait, 2. Great Bear Lake, 3. Great Slave Lake, 4. Amundsen Gulf, 5. Coronation Gulf, 6. Prince of Wales Strait, 7. M'Clure Strait, 8. Prince Patrick Island, 9. Melville Island, 10. Melville Sound, 11. Bathurst Island, 12. Ellef and Amund Ringnes Islands 13. Axel Heiburg Island, 14. Eureka Sound, 15. Greeley Fiord, 16. Lady Franklin

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Bay, 17. Smith Sound, 18. Jones Sound, 19. Devon Island, 20. Lancaster Sound, 21. Prince Regent's Inlet, 22. Somerset Island, 23. Prince of Wales Island, 24. Bellot Strait, 25. M'Clintock Channel, 26. Queen Maud Gulf, 27. King William Island, 28. Boothia Peninsula, 29. Gulf of Boothia, 30. Melville Peninsula, 31. Prince Charles Island, 32. Southampton Island, 33. Independence Fiord, 34. Scoresby Sound (courtesy of M. Lavrakas, NSIDC, Boulder, CO).

1.1 **Historical exploration**

In the sixteenth century, the Arctic came to be seen by the nations of northern Europe as a potential route to China. Three possible routes were considered – directly across the Arctic Ocean, the Northwest Passage (from Davis Strait, through the channels of the Canadian Arctic Archipelago, and then along the coast of Alaska) and the Northeast Passage (along the Eurasian coast, also known as the Northern Sea Route) (Figure 1.1). Although the motives of the explorers and their backers were sometimes complex, the promise of a shortcut to the mythical riches of the Orient deluded European traders and financiers for almost three centuries (Saladin d’Anglure, 1984). Arctic geography, as represented by early cartographers, was a mixture of myth and hypothesis. Most charts identified the northern ocean as the *Mare Glaciale*, or *Congelatum* (frozen ocean). Prevailing views ingrained from maps like those of Nicolo Zeno (1558) and Gerhard Mercator (1569 and 1595), arguably hindered the incorporation of observations from early explorers such as Martin Frobisher (1576–8) and John Davis (1585–7) (Wallis, 1984).

Knowledge gained from subsequent expeditions complemented reports from fishermen, whale and walrus hunters, traders of the Hudson’s Bay and English Muscovy companies, as well as Dutch and Russian merchants in the Northeast Passage (Mirny, 1934; Kirwan, 1962; Armstrong, 1984). According to Barr (1991), Russia had a trade route from the White Sea to western Europe by AD 1500. In the 1550s to 1580s, the English Company of Merchant Adventures mounted expeditions in search of a Northeast Passage (Mansir, 1989). After Richard Chancellor reached the White Sea in 1553, trading through the Muscovy Company soon followed (Okhuizen, 1995). Europeans soon “discovered” Novaya Zemlya and an open passage to the Kara Sea. The name Novaya Zemlya (“new land”) was already in established use by the local coastal inhabitants (*pomor’ye*), although it then referred only to the southern island. Its origin is uncertain according to Bulatov and Popov (1996).

Between 1565 and 1584, the Dutch White Sea Trading Company under Oliver Brunei established a station on the Kola Peninsula. Traveling overland, Brunei then reached the Ob River. Already by this time Russian fishing vessels were sailing east of the Pechora River into the Kara Sea. During subsequent Dutch expeditions, ships, led by Willem Barents, sailed into an ice-free Kara Sea in 1594. In 1596, they discovered Spitsbergen and sailed along its west coast beyond 80° N. Unfortunately, their ship was beset by ice off Novaya Zemlya and they were obliged to over-winter on the northeast coast at Ice Haven. A group of hardy survivors reached Kola in small boats in the summer of 1597 (DeVeer, 1876). The remnants of their hut and possessions were found in 1781.

Henry Hudson also sailed northward to the west of Spitsbergen in 1607, reaching 80.38° N, a latitude not exceeded until 1773. In 1609–10 he discovered and explored Hudson Bay until the crew mutinied and he and a number of others were cast adrift. Despite this setback, the discoveries made by Hudson and his successors led to the establishment of the Hudson’s Bay Company in London in 1670. In 1616, William

Baffin followed the west coast of Greenland and worked through pack ice to Melville Bay and the entrance to Smith Sound. On his southward voyage, he sighted both Jones Sound and Lancaster Sound opening westward. Regrettably, Baffin's map and tables were discarded by Samuel Purchas, a successor to the Elizabethan naval chronicler Richard Hakluyt, so that even Baffin Bay did not appear on many English maps of the early nineteenth century.

On the Asian side of the Arctic, Russian traders had explored the Laptev Sea coast by the mid seventeenth century (Barr, 1991) and reached the Sea of Okhotsk by traveling overland. A Cossack group traveled to the Kolyma River in 1644 and then sailed down it. In 1648 their boats rounded the East Cape (referred to as Mys Dezhneva on Russian charts, after Semyon Dezhnev, a leader of the expedition) reaching the Anadyr River, but these accomplishments were unknown until an account was located in Yakutsk by G. Mueller, during Bering's overland journey to Kamchatka in 1725 (Fisher, 1984). A map of Siberia by the Dutch cartographer N. Witsen (dated 1687), drew on many Russian sources and provided a wealth of detail on western Siberia (Okhuizen, 1995). However, his account of the eastern limit of the Asian coast indicates uncertainty and lack of knowledge of the Cossack expedition. A chart included by Witsen depicted a sea ice limit at about 75° N in the Barents Sea in the year 1676, apparently based on a voyage by an English expedition under John Wood.

Russian exploration of the Arctic began to be nationally organized under Peter the Great. In 1725, Vitus Bering was appointed to find a Northeast Passage to the Pacific Ocean. G. F. Mueller was a German working in the new Russian Academy of Sciences established by Peter the Great. In reporting on Dezhnev's explorations in northeast Siberia, Mueller recognized that climatic and ice conditions rendered the Northeast Passage impractical as a trade route. Bering's expedition traveled overland from Yakutsk to the Sea of Okhotsk. Subsequently, he circumnavigated Kamchatka, reaching the Gulf of Anadyr, St. Lawrence Island and the fog-shrouded Bering Strait (the narrow channel separating Asia and Alaska). He sailed through the Bering Strait without sighting Alaska, but in 1732 one of his vessels sailed off the coast of Alaska near Nome (Barr, 1991). Between 1733 and 1743, nearly 1000 men participated in the Great Northern Expedition to explore the possibility of a Northern Sea Route. Their goal was to chart the north coast of Siberia in five sectors: from Archangelsk to the Ob River, and then east to the Yenisey River, the Taymyr Peninsula, the Lena River, and the Anadyr River. Members of Bering's team included S. Chelyuskin (who reached Asia's most northerly point) Kh. P. Laptev and D. Y. Laptev. Occasionally, as in 1737, the explorations were favored by mild summer weather, but commonly sea ice and fogs hampered them. Indeed, the severe ice conditions led to the abandonment of interest in the sea route.

Russian mapping of the Asian Arctic coast was well advanced by the mid eighteenth century. However, for Europeans and North Americans, the fact that Asia and North America are separated by the Bering Strait was only established later by James Cook. In 1778, Cook sailed into the Chukchi Sea reaching Mys Shmidta. This encouraged the Russians to explore Chukotka (eastern Siberia) with land parties in the late eighteenth

century. During 1820–3, surveys were made by F. Anzhu of the New Siberian Islands and by F. Wrangel of the north coast of Chukotka. The latter also tried unsuccessfully to reach the land offshore (Wrangel Island) that is now named after him.

Knowledge of the North American Arctic lagged far behind that of northern Eurasia. In northwestern Canada, the combined interests of commercial and mining opportunities, as well as company sovereignty, led to land expeditions mounted by the Hudson's Bay Company northwestward from Churchill. Samuel Hearne crossed overland to the Arctic coast at the mouth of the Coppermine River on his third attempt in 1771–2. The Royal Society aided in scientific investigations and Dymond and Wales (1770) published meteorological observations made at Prince Wales's Port (Churchill), on the coast of Hudson Bay in 1768. Trading posts also kept records of the freeze-up of the ice (Catchpole and Faure, 1983). In 1789, Alexander Mackenzie, a fur trader, reached the delta of the river named after him, but the rest of the North American Arctic coast remained largely unknown until the 1850s.

In the late eighteenth century, recurring notions of an open polar sea led to several attempts to sail northward to find it (Wright, 1953). A Swiss geographer, Samuel Engel, had advanced this view in 1765. In 1764–5, M. V. Lomonosov sailed north from Svalbard (Spitsbergen) with little success, and in 1773, C. Phipps made a similar unsuccessful attempt in the same area, using two British Royal Navy ships equipped with ice-strengthened bows and bottoms. Phipps' chart shows the location and nature of the marginal ice zone north of Svalbard during July–August 1773 (Savours, 1984). In 1818, John Barrow prepared a chronology of early voyages of discovery. It includes many reports of ships encountering sea ice and icebergs. Barrow (1818) also observed that conditions were generally colder on the eastern as opposed to the western coasts of continents and islands. He accepted the views of Martin Frobisher, John Davis and others that the central Arctic Ocean, which was assumed to be deep, should hence be ice-free. William Scoresby Jr., a British whaling captain, made regular visits to northern waters in the early nineteenth century. Encouraged by contacts with scientists of the day, he made observations of ocean temperature, meteorological phenomena, atmospheric refraction, ice conditions and snow crystals (Scoresby, 1820; McConnell, 1986). In one paper he rejected the notion of an open polar sea (Scoresby, 1811–16). But after encountering much less ice than usual off the east coast of Greenland between 74° N and 80° N in 1817, he suggested that ice-free conditions might recur once every ten or twenty years (Martin, 1988).

Concern over the explorations of Otto von Kotzebue in Russian Alaska (1815–18), and the imperial *ukase* (decree) of 1821 (claiming the western North American Arctic as Russian) led to objections by the British and US governments. This in turn prompted new explorations of northwest Canada by the British Royal Navy. John Franklin, accompanied by several scientifically trained explorers, made overland journeys from Hudson Bay to the Arctic in 1819–22 and 1825–7. The discovery of coal formations and fossiliferous limestone along the Mackenzie River, indicative of warmer past climates, added to nineteenth-century controversy over climatic change. John Richardson reported the existence of permanently frozen ground (permafrost) and encouraged the Hudson's Bay Company to begin making ground temperature

measurements. The first results, available in 1841, and similar observations made by Baer (1838) in Siberia, led to acceptance of the reality of such frozen ground. The Franklin expeditions made meteorological observations at Fort Franklin on Great Bear Lake in 1825–7 (Franklin, 1828). George Back and Richard King kept records at Fort Reliance on Great Slave Lake during 1833–5. A compilation of the meteorological observations that were made on 36 Arctic expeditions undertaken between 1819 and 1858 are listed in a special report (Meteorological Council, 1885). The British Admiralty and Royal Society ensured that John Ross' 1818 expedition to search for the Northwest Passage also carried out geomagnetic, meteorological and oceanographic observations (Levere, 1993). The first deliberate over-wintering in the Arctic took place at Winter Harbour, Melville Island, during William Parry's first expedition in 1819–20. Again, observations of magnetic and meteorological conditions were recorded, as well as of wildlife (Parry, 1821). The expedition reached longitude 113.80° W, before being stopped by ice at the entrance to M'Clure Strait. A decade later John Ross and his nephew James were forced to overwinter at Felix Harbour on Boothia Peninsula, where they collected meteorological and magnetic data (Ross, 1835).

Russian interest in its Alaskan Territory waned in the 1860s. This was due to its remoteness, the small number of settlers, and the control Russia had gained in 1860 of areas on the Pacific coast of northeast Asia, including the site of Vladivostok (Vaughan, 1999). Financial problems finally resulted in its sale to the USA in 1867. The purchase price of \$7.2 million, while a considerable sum at the time, must be considered a bargain. Although American whalers were already operating in Alaskan waters and there was some inland exploration, there was little serious scientific interest in Alaska until well into the twentieth century, apart from the International Polar Year station set up at Barrow (Ray, 1885).

Scientific measurements made by the British navy received careful attention following the publication of an Admiralty Manual (Herschel, 1851). It outlined requirements for observations in the physical and natural sciences, including meteorology and hydrography, to be made at least four times daily, and every two hours during voyages of discovery. Regular meteorological observations and weather reports began in many countries in the 1850s.

In 1848, the first searches began for Sir John Franklin's ships *Erebus* and *Terror* that had set out in 1845 to conquer the Northwest Passage but failed to emerge in the Pacific. The hydrographer to the British Admiralty, Francis Beaufort (best known for his wind scale), was a staunch supporter of the search, both for the Northwest Passage and later for the missing Franklin expedition (Friendly, 1977). In all, some twelve naval and four land expeditions to Arctic Canada and Greenland sought answers to the fate of Franklin and his men – answers that were finally provided by the discoveries of remains by John Rae (1853–4) and Francis McClintock (1857–69). These search expeditions ranged far and wide throughout the Canadian Arctic Archipelago.

During 1850–5, R. Collinson and R. M'Clure searched Amundsen Gulf, Coronation Gulf, Victoria Island and Banks Island, confirming the existence of a Northwest Passage via Melville Sound, reached 30 years earlier by Parry. These expeditions also made numerous scientific observations (Meteorological Council, 1879–88; Levere, 1993).

C. Schott, for example, analyzed the records of McClintock (1862) in Baffin Bay and Prince Regent's Inlet. An American expedition led by Elisha Kane searched the west coast of Greenland northward to Smith Sound during 1853–5. Weather records were maintained at 78.62° N, 70.67° W from September 1853 through April 1855 (Kane, 1856). The book also includes monthly mean isotherm charts for Baffin Bay prepared by C. Schott using Kane's observations and earlier charts of H. Dove. Kane also espoused the recurring notion of an open polar sea, perhaps based on his observations of the North Water polynya in Smith Sound (Dunbar and Dunbar, 1972).

In 1822, William Scoresby Jr. followed the east coast of Greenland from 72° N, southward to 69° N, while his father explored the extensive sound named after him. In 1820–30, W. Graah of the Royal Danish Navy traveled northward along the east coast to 65° N using native boats (umiaks). However, he was stopped by heavy ice. East Greenland was then neglected until 1869 when Karl Koldewey in the *Germania* over-wintered at Pendulum Island (74.5° N). The next spring they reached 77° N on a sledging trip. Between 1879 and 1900, Danish Navy expeditions completed mapping of the east coast of Greenland and studied the ice conditions (Ryder, 1896).

The margins of the Greenland Ice Sheet were visited once or twice in the eighteenth century, but no serious attempt to visit the interior was made until Nordenskiöld traveled inland near Godthaab in 1870. Soon afterwards, Norwegian and Danish geologists observed high rates of glacier motion compared with glaciers in the Alps, arousing scientific interest. Nordenskiöld made another unsuccessful attempt to cross Greenland in 1883. Finally, in 1888, Nansen, Sverdrup and four companions skied and sledged westward across the ice at about latitude 64° N, eventually reaching Godthaab. In 1892, Robert Peary traveled northeastward from Smith Sound crossing the northern part of the ice sheet finding ice-free Peary Land. He also reached the head of Independence Fiord and wrongly concluded that he was at the shore of the East Greenland Sea. This incorrect conclusion had tragic consequences for members of a subsequent Danish expedition in 1906.

In the 1860s and 1870s, Arctic exploration was dominated by attempts to reach the Pole. Among notable expeditions are those of Charles Hall who explored Baffin Island and Melville Peninsula. In 1871 he took the steamer *Polaris* up Smith Sound to 82.18° N and explored ice-free north Greenland. Hall's work in Ellesmere Island was followed by the British Arctic Expedition of 1875–6 under George Nares. In the vessel *Alert* he rounded the north tip of Ellesmere Island, halting at Floeberg Beach (82.27° N) as the sea began to freeze. The name floeberg refers to ice blocks rafted up onto the beach by onshore winds (Gadbois and Laverdiere, 1954). Sledging trips conducted in spring over the hummocked and ridged sea ice demonstrated the fallacy of the open polar sea. Indeed, the expedition coined the phrase "paleocrystic sea" (Levere, 1993). Robert Peary's claim to have attained the Pole across this irregular and chaotic surface with Matthew Henson in April 1909 remains in doubt.

During 1898–1902, Otto Sverdrup in the *Fram*, accompanied by cartographer Lt. Isachsen, made discoveries of new land in the northwestern part of the Canadian Arctic Archipelago by sailing along Jones Sound and then traveling overland. Axel Heiberg

Island, Ellef Ringnes and Amund Ringnes islands, Eureka Sound and Greely Fiord were all added to the map. Mohn (1907) summarized the meteorological observations from the expedition. In 1903, Roald Amundsen sailed the *Gjoa* from Norway into Lancaster Sound. After spending two winters near King William Island, he reached the Mackenzie Delta in August 1905, finally achieving the Northwest Passage. Remaining blank spaces on the maps of the Canadian Arctic Archipelago were now being filled in. In 1914, the American “Crocker Land” Expedition led by Donald MacMillan, showed that Peary’s “Crocker Land” northwest of Ellesmere Island was an illusion. Apparently, Peary was confused by the towering effect of a superior mirage (*fata morgana*). Vilhjalmar Stefansson’s Canadian Arctic Expedition of 1913–18 focused on the Beaufort Sea, Banks Island, Prince Patrick, Borden and Meighen islands in the northwest of the Archipelago. This added considerably to the known extent of Canadian territory. The mapping of northeast Greenland was completed by the Danmark Expedition, 1906–8, with surveyor J. P. Koch and Alfred Wegener, and by the Thule Expeditions led by K. Rasmussen in 1912 and 1916–17. A notable discovery was the mountainous ice-free (nunatak) region of Dronning Louise Land (*c.* 76.0–77.3° N, 23–26° W) inland from the coast near modern Danmarkshavn. In 1913, J. P. Koch and Alfred Wegener set out from there to cross the widest part of the ice sheet, barely making it to Upernavik on the west coast.

A new scientific direction in the exploration of the Arctic Ocean began with the voyages of the *Tegethoff* in the Eurasian Arctic in 1871 and 1872–4. Pursuing a suggestion of the German geographer August Petermann, that the northeastward flow of warm Atlantic water might reduce the ice cover in the eastern Arctic, two Austrian scientists, Lt. Karl Weyprecht and Lt. J. Payer found little ice off Novaya Zemlya in 1871. The following year, they were less fortunate and the ship drifted northwestward in the ice. In August 1873 they discovered Franz Josef Land and were obliged to over-winter. The ship was abandoned and they were rescued in a small boat off Novaya Zemlya in August 1874. They advanced a new hypothesis that Franz Josef Land pointed to a landmass over the North Pole. This same idea led Lt. George De Long to explore the East Siberian Sea in the vicinity of Wrangel Island. However, his ship, the *Jeanette*, became trapped in the ice in September 1879 and drifted northwestward before being crushed north of the New Siberian Islands in June 1881. Only three members of the crew survived. Three years later a remarkable find was made of some wreckage from the *Jeanette* on the southwest coast of Greenland. Professor Heddrik Mohn proposed that the sea ice, drifting under the influence of winds and ocean currents, must have transported them. Nils Nordenskiöld finally conquered the Northeast Passage in 1878–9. The steam-powered *Vega* became beset in late September off the North Cape and could not proceed into the Bering Strait until July 20, 1879. Nevertheless, the feasibility of the Northern Sea Route had been established.

The first polar icebreaker, the *Yermak*, was built for the Russian Navy in Newcastle, England in 1898. However, after sustaining some damage in heavy ice off Svalbard in 1899, it was operated mainly in the Baltic Sea (Barr, 1991). Two small icebreakers were built to facilitate the survey of the Siberian coast by the Russian Arctic Ocean

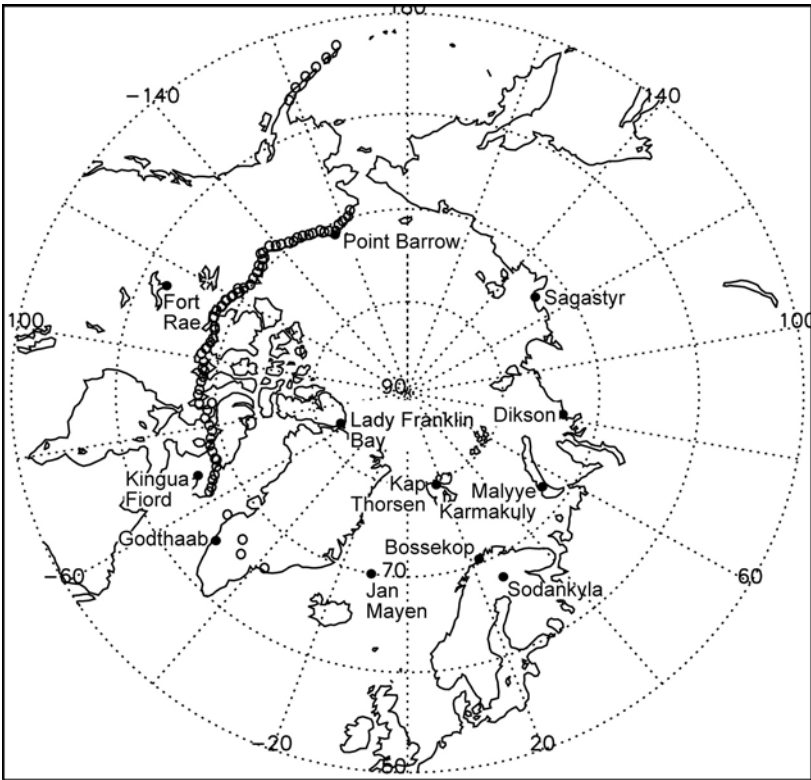


Figure 1.2 Distribution of the 12 principal stations established during the first International Polar Year (IPY) (solid circles) and the Defense Early Warning Line (DEWLINE) stations (open circles). The DEWLINE network was installed during 1957–9. Weather records were collected for over 30 years (courtesy of M. Lavrakas, NSIDC, Boulder, CO).

Hydrographic Expedition during 1910–15. In 1913, the surprising discovery was made of the Severnaya Zemlya archipelago, which was not mapped until 1930–2 by G. A. Ushakov (Vaughan, 1999). In the 1920s, following the Russian Bolshevik Revolution, the Kara Sea began to be exploited by cargo ships supported by icebreakers. This accelerated in 1932 after the formation of the Northern Sea Route Directorate, which also took over administration of the Russian Arctic islands and the Asiatic part of the Soviet Union north of 62° N (Gakkel and Chernenko, 1959; Belov, 1969; Armstrong, 1952, 1995).

1.2 **The beginning of systematic observations**

The modern basis of Arctic science, and meteorology in particular, was the outcome of Karl Weyprich’s suggestion for an International Polar Expedition. Planning began at a conference in Hamburg in 1879, with 11 nations pledging support. Weyprecht died in 1881, but the first International Polar Year (IPY) was mounted in 1882–3. Barr (1985) provides a detailed account of the various national expeditions. Figure 1.2 shows