Ilulissat

The Arctic

GREENLAND TOURISM/LARS MJAALAND

Seqinersuup alakkaqqilerpai
qaqqavut kusanartorsuit
qamani neriuutit ikippai
*maqaasiuartakkavut**

(The sun has begun to appear again
Our beautiful mountains
have ignited hopes within us
that we have missed all this time)

In mid-January every year, people in Greenland gather to greet the returning light. In Ilulissat, they sing this greeting, waiting for the sun to peek above the horizon. Its first rays manage only a brief glimmer, but the promise they bring is strong, the hope of summer:

Seqinersuup qimaatilereerpaa
ukiorsuup kaperlassua

(The sun has put to flight
winter's long gloom)

Dark winters followed by long summer days are one of the most profound features of the Arctic, and are responsible for the ubiquitous snow and ice. The spring and summer sun brings enough energy to sustain life, but not enough to melt all the frozen water or the frozen ground. Ice and snow have therefore shaped and are still shaping the northern landscape.

The Arctic is not a uniform environment. Different geological histories, warm and cold ocean currents, and varying weather patterns bring diversity to the scene. A circumpolar voyager will meet everything from the permanent ice cover of the High Arctic to the boreal forest of the subarctic, with the wide expanse of tundra in between.

This chapter describes the land, the seas, and the climate of the AMAP region, setting the stage for the rest of the report.

*Greenlandic text: Samuel Knudsen, Kangersuatssaat

ANNIKA NILSSON

The Arctic Circle marked in the terrain next to the railroad in Sweden.

What is the Arctic?

Arctos is Greek for bear, and the Arctic region derives its name from the stellar constellation of *Ursa major*, the Great Bear. A common geographical definition of the Arctic is the area north of the Arctic Circle (66°32'N), which encircles the area of the midnight sun.

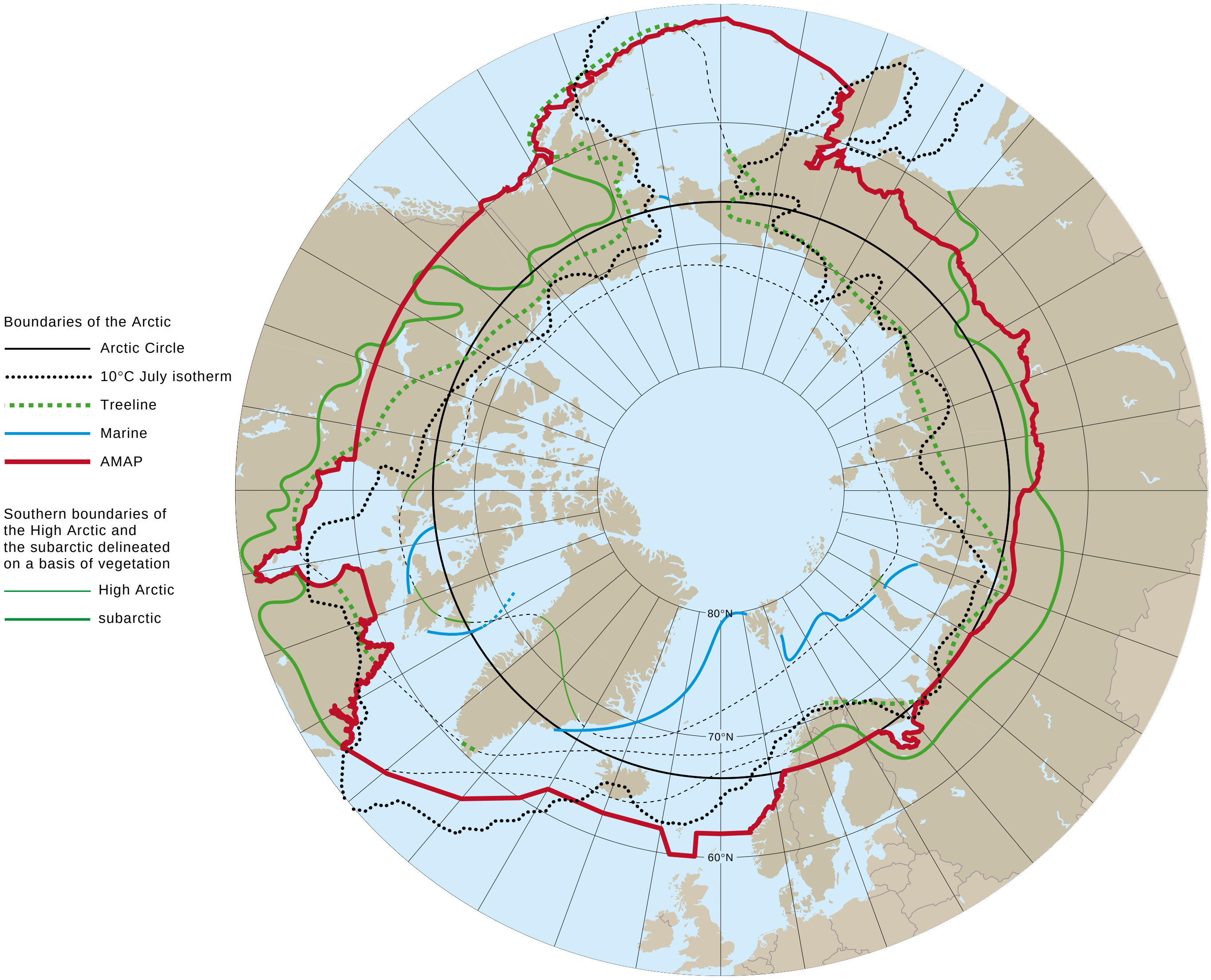
July temperatures create a climatic definition

From an environmental point of view, defining the Arctic solely on the basis of the Arctic Circle makes little sense. Vegetation types follow climate more than solar radiation. Climatically, the Arctic is often defined as the area north of the 10°C July isotherm, i.e. north of the line or region which has a mean July temperature of 10°C.

The climate is highly influenced by regional weather patterns and ocean currents. In the Atlantic Ocean west of Norway, the warming effect of the North Atlantic Current (an extension of the Gulf Stream) pushes this 10°C isotherm north of the Arctic Circle, so that only the northernmost parts of Scandinavia are included in this definition. In North America and northeast Asia, the isotherm is pushed south by cold water and cold air moving down from the Arctic Basin. Here the Arctic would include northeastern Labrador, northern Quebec, Hudson Bay, central Kamchatka, and the Bering Sea. Greenland and most of Iceland also fall north of this isotherm.

A treeline boundary would move Arctic limits further south

A third definition of the Arctic region uses the treeline as the boundary. Simply put, the treeline is the border between southern forests and northern tundra. It is a transition zone where continuous forest gives way to tundra with



sporadic stands of trees and finally to treeless tundra. In North America, the tundra-forest boundary is a narrow band, but in Eurasia it is up to 300 kilometers wide. The treeline corresponds with a climate zone where the cold Arctic air meets warmer airmasses from farther south.

In some places, the treeline roughly coincides with the 10°C July isotherm, but across much of mainland Eurasia and North America the treeline is 100 to 200 kilometers south of the isotherm. By the treeline definition, the Arctic also includes western Alaska and the western Aleutians.

The subarctic lies between the treeline to the north and the region to the south where the forest becomes dense enough to have a closed canopy. The subarctic is also called the taiga or forest tundra. Permafrost (permanently frozen ground) is only present in patches, and in summer the unfrozen layer is generally thick. The presence of discontinuous permafrost is sometimes used to define the subarctic, in contrast to the Arctic where permafrost is continuous.

Meeting of cold and warm water forms the marine boundary

The marine boundary of the Arctic is formed when the water of the Arctic Ocean, cool and dilute from melting ice, meets warmer, saltier water from the southern oceans. In the Canadian Arctic Archipelago, this belt is at approximately 63°N and swings north between Baffin Island and the coast of west Greenland. Off the east coast of Greenland, the marine boundary lies at approximately 65°N. In the European Arctic, the marine boundary is much farther north, pushed to about 80°N to the west of Svalbard by the warming effect of the North Atlantic Current. At the other entrance into the Arctic, warm Pacific water flows through the Bering Strait to meet Arctic Ocean water at about 72°N, forming a boundary that stretches from Wrangel Island in the west to Amundsen Gulf in the east.

AMAP's boundaries

Because of the difficulty of defining the Arctic in a way that is relevant for all areas of science, AMAP does not define the Arctic but gives a guideline about the core area to be covered by the AMAP assessment. The boundary should lie between 60°N and the Arctic Circle, with the following modifications:

- In the North Atlantic, the southern boundary follows 62°N, and includes the Faroe Islands, as described in 'The Joint Assessment and Monitoring Programme' of the Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention). To the west, the Labrador and Greenland Seas are included in the AMAP area.
- In the Bering Sea area, the southern boundary is the Aleutian chain.
- Hudson Bay and the White Sea are considered part of the Arctic for the purposes of the assessment.
- In the terrestrial environment, the southern boundary in each country is determined by that country, but lies between the Arctic Circle and 60°N.

The map on the opposite page shows the area covered in this report.

Eight countries have land within the area of AMAP's responsibility: Canada, Denmark (Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden, and the United States (Alaska).

The land

About 13.4 million square kilometers, 40 percent, of the AMAP area is covered by land. The map below shows the major physical-geographical regions. Old crystalline shields underlie most of eastern Canada, Greenland, and Fennoscandia. Younger sedimentary rock, eroded into plains, covers large parts of Russia and the Mackenzie River valley in Canada. In the Ural Mountains, in the northeastern corner of Russia, in Alaska, and in the Yukon Territories of Canada the sedimentary rock has folded into mountain ranges. Similar folded sedimentary rock forms the mountain ranges of the northern Canadian Arctic islands. Iceland and the Aleutian islands are of volcanic origin.

Major physical-geographical regions of the Arctic. Colors indicate similar landscape features.

Glacier Bay, Alaska.

Ice has shaped the landscape

On a shorter time scale, ice has put its signature on most of the terrestrial landscape. Some of the land is covered by glaciers, which are large masses of snow and ice that flow under their own weight. Glaciers form where the mean winter snowfall exceeds mean summer melting. Melting, refreezing, and pressure gradually transform the snow to ice.

Many areas have been shaped by repeated glaciations. In the North American and western Eurasian Arctic, ice sheets have scoured the landscape like giant bulldozers, tearing away topsoil and broken rock. In areas with hard crystalline granite bedrock, the glaciers left the land dotted with depressions that filled with water and became lakes. Glaciers that eroded the bedrock below sea level at the coast created deep, winding fjords. In other areas, the glaciers piled extensive moraines and sedimentary deposits on top of the bedrock.

Some of the land is still rebounding after being pressed down by the weight of the ice sheets during the latest glaciation. Along the coasts, the land is still emerging from the sea. Around Hudson Bay, for example, the land rises at a rate of one meter per century.

Permafrost creates patterned ground and governs water movement

Much of the ground is frozen by permafrost, and only a thin top layer, called the active layer, thaws each summer. Permafrost is defined as ground that remains frozen for at least two summers in a row. The frozen layer can reach depths of 1500 meters in the coldest areas of the Arctic. The active layer ranges between a few centimeters in the northernmost wet meadows to a few meters in warmer, drier areas with coarse-grained soils. Perennially frozen ground occurs throughout the Arctic and extends into the forested regions to the south. Along the northern coasts, frozen grounds meet the sea, and the permafrost extends under some shelf seas.

The constant freezing and thawing in permafrost areas makes the ground move. In the process, debris is sorted and rocks are forced to the surface. In some areas this sorting has created extensive polygonal patterns; see figures on the opposite page. Another physical feature is the pingo, a mound of earth thrust up by a core of ice. Pingos can be as high as 40 meters. Occasionally, changes in local climate or physical disturbance of the ground can

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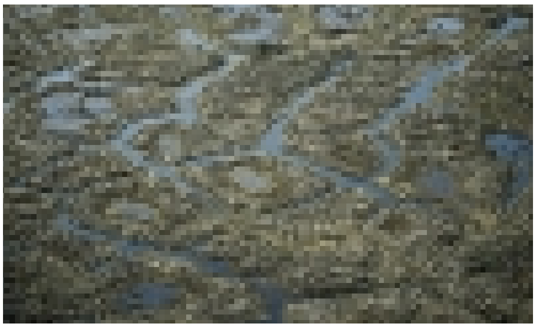

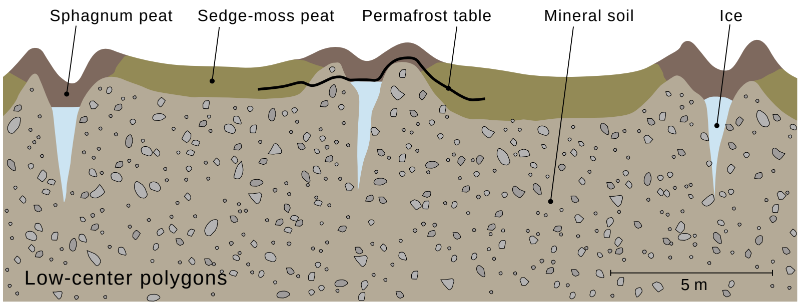

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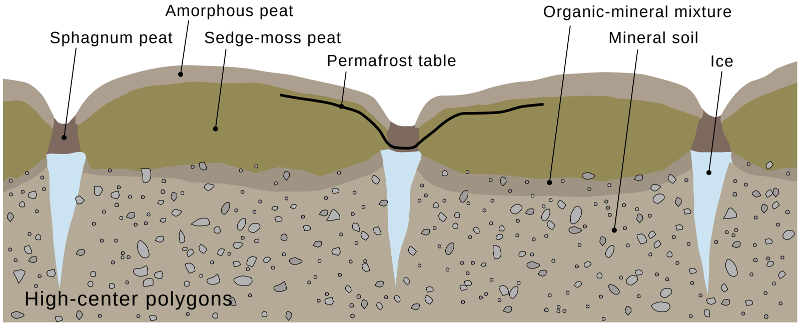

Cross-sections of low- and high-centered polygons found in Arctic wetlands. The low-centered polygons gradually evolve into high-centered polygons with the accumulation of biomass.

cause the permafrost to melt. In some cases, this causes the ground to sink, and the depression fills up with water, creating so-called thermokarst lakes, which are unique to the Arctic.

Permafrost governs the fate of water in the Arctic landscape. For example, groundwater formation is much slower in frozen ground than in unfrozen ground. The groundwater can be on top of, in cracks within, or underneath the permafrost layer.

In spring, permafrost contributes to flooding. Eighty to ninety percent of the freshwater input to the land occurs during the two to three weeks of snowmelt in spring. Instead of seeping into the ground, the meltwater flows over the frozen surface and into streams, rivers, lakes, and various wetlands, which cover vast areas on the flat plains.

The lack of oxygen in the waterlogged soil of wetlands delays the decomposition of plant matter and results in a build-up of organic materials, such as peat and humic substances. In drier areas where the water can escape, such as steep slopes and high narrow ridges, increased bacterial activity in the soil leads to a lower content of organic matter. These areas often

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Tundra, Kolyma, Russia.

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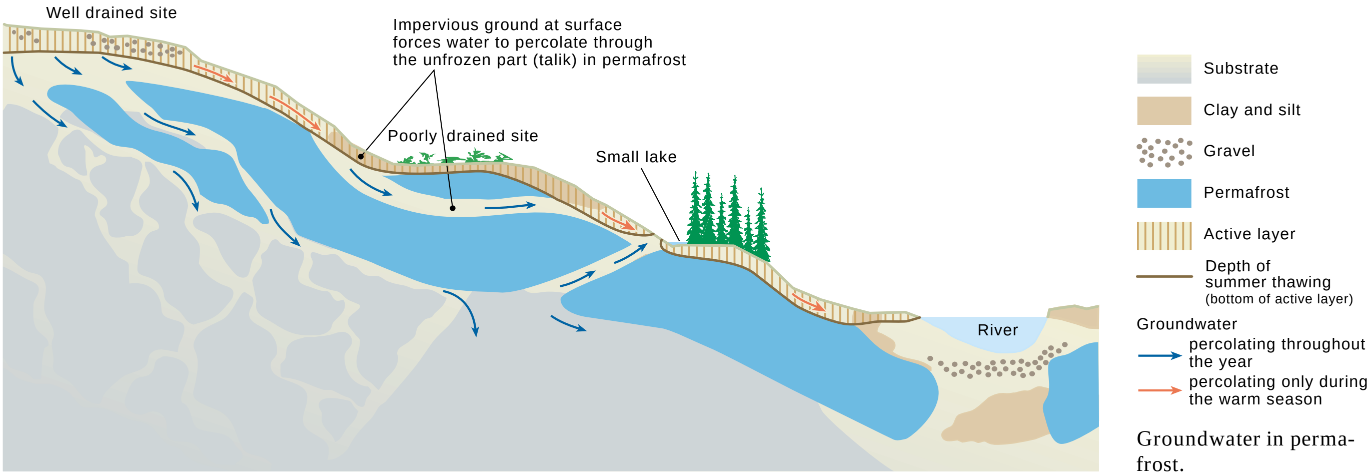
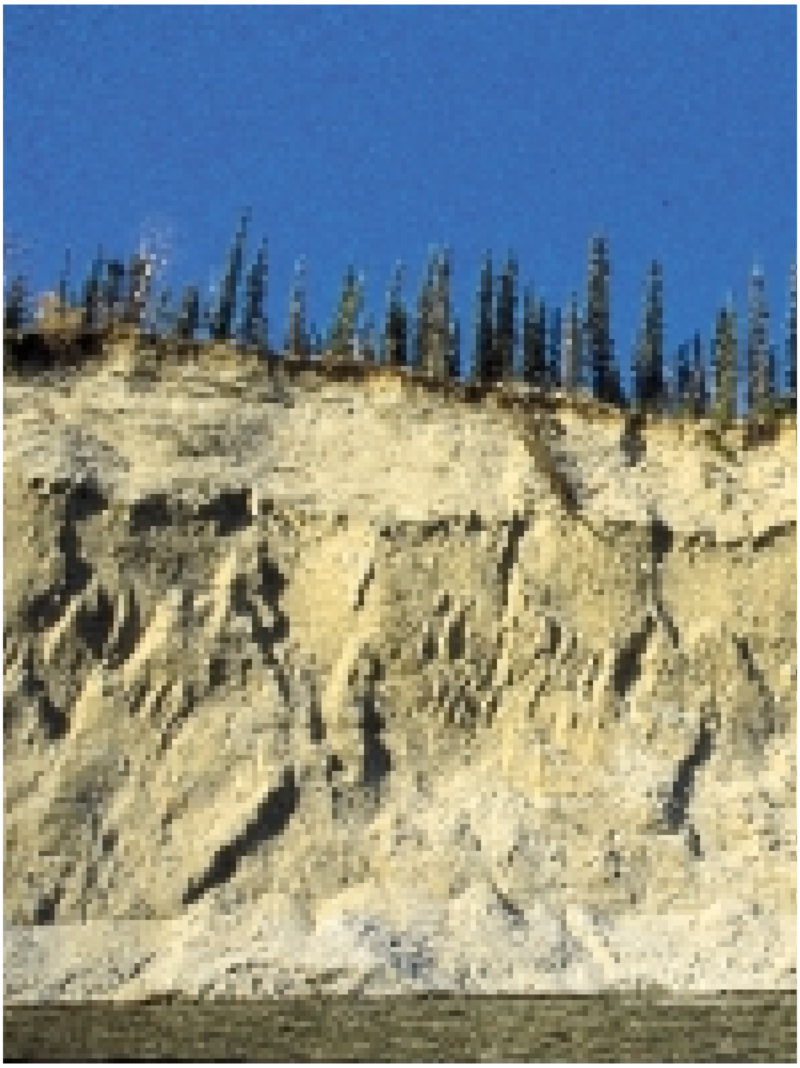
Driftwood and pingo, Tuktuyaktuk, Yukon, Alaska



Groundwater in permafrost.



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Erosion, Kobuk River, Alaska.

have a characteristic soil profile caused by the redistribution of soil particles and chemicals.

Arctic rivers also owe much of their character to the permafrost. Because the ground has such a limited ability to store water, the spring flood can be violent, undercutting the river bank and causing extensive erosion along its path. Ice jams add to the uneven flow and erosion. The rivers thus carry huge amounts of sediments that are deposited along their course and in wide deltas.

Natural resources are abundant

The circumpolar region has numerous large deposits of fossil fuels and minerals. Examples include nickel in the vicinity of Norilsk in Russia, the recently discovered diamond deposits in the Northwest Territories in Canada, coal in Svalbard, and oil and gas fields at Prudhoe Bay in Alaska and in many other areas that are described in the chapter *Petroleum Hydrocarbons*.

The AMAP region also contains many renewable resources. Forests supply fuel for energy and material for pulp and paper production. Both marine and freshwater ecosystems are important for commercial fishing. Powerful rivers provide hydroelectric power, while geothermal energy is used for heating in some areas.

The seas

The marine areas within AMAP's boundaries cover approximately 20 million square kilometers. These include the Arctic Ocean, the adjacent shelf seas (Beaufort, Chukchi, East Siberian, Laptev, Kara, and Barents Seas), the White Sea, the Nordic Seas (Greenland, Norwegian, and Iceland Seas), the Labrador Sea, Baffin Bay, Hudson Bay, the Canadian Arctic Archipelago, and the Bering Sea. The narrow Bering Strait connects the Arctic Ocean and the Bering Sea (and the Pacific Ocean), while the main connection between the Arctic Ocean and the northeast Atlantic Ocean (Nordic Seas) is via the deep Fram Strait and the Barents Sea. There are two major basins in the Arctic Ocean, the Canadian Basin and the Eurasian Basin, separated by the transpolar Lomonosov Ridge.

The Arctic Ocean has a vast continental shelf, extending from northern Scandinavia eastward to Alaska. All the Eurasian marginal seas are located over this shelf, which has a width of up to 900 kilometers off the coast of Siberia. Off North America, the shelf extends only 50 to 100 kilometers from the coast.

Most of the water in the Arctic Ocean comes from the Atlantic Ocean via Fram Strait and the Barents Sea, with some additional inflow from the Bering Strait. Rivers account for about two percent of the input, a high proportion compared with other oceans. The main outflow from the Arctic Ocean is via the East Greenland Current, with a minor portion flowing out via straits in the Canadian Archipelago. The water flow is further described in the figure on page 31. A prominent feature in the surface water is the oceanic polar front, which separates the cold, less saline surface water of the Arctic Ocean from saltier, warmer water originating in the oceans farther south. The position of the front is relatively stable in most areas, moving little from year to year.

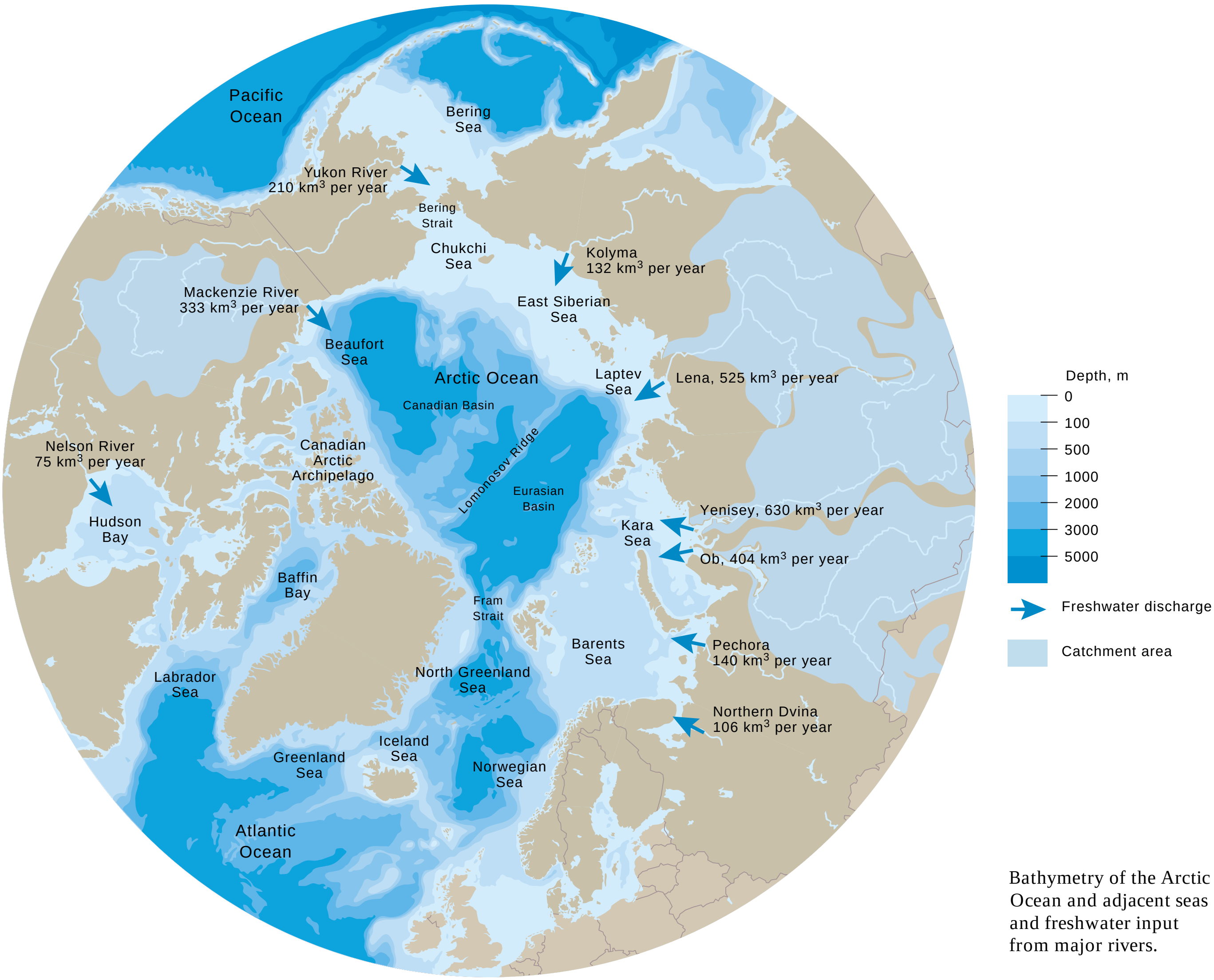
Surface water temperatures vary both seasonally and geographically. In the Arctic Ocean, the surface water temperature is close to freezing point year-round because of the ice. In the shelf areas, the sun can warm the water from freezing point in winter to 4-5°C during summer. In areas influenced by Atlantic and Pacific water, there may be greater seasonal variability, and the temperature remains higher than 0°C throughout the year.

Salinity varies with depth and with the water's source. Arctic surface water is less salty than the deep ocean water and than the surface waters of other oceans because of meltwater from ice as well as large inputs of freshwater from north-flowing rivers. The highest salinity

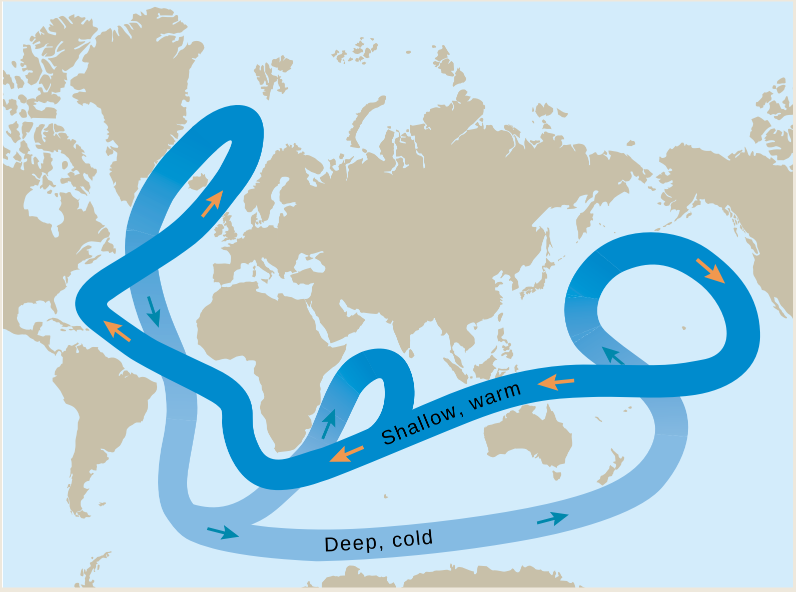
HEIDI KASSENS

The central Arctic Ocean.

is in water of Atlantic or Pacific origin. The fresher water floats on top of more saline water, and the water mass is best described as having distinct layers with different temperatures and salinities. This is further discussed on page 31. The halocline that separates the fresher from the saltier water creates a lid that keeps deeper, warm water from reaching the surface.



Bathymetry of the Arctic Ocean and adjacent seas and freshwater input from major rivers.



The polar front influences global ocean currents

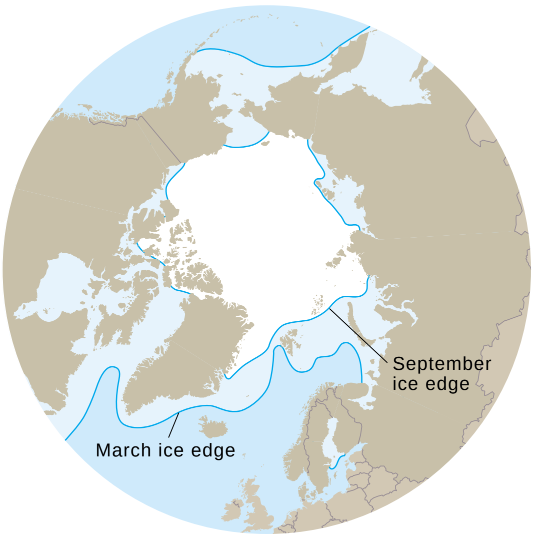
The Arctic plays a fundamental role in the circulation of water in the oceans of the world. When warm, salty North Atlantic water reaches the cold Arctic around Greenland and Iceland and in the Labrador Sea, it becomes denser as it cools, and therefore sinks to deeper layers of the ocean. This process of forming deep water is slow, but takes place over a huge area. Every winter, several million cubic kilometers of water sink to deeper layers, which move water slowly south along the bottom of the Atlantic Ocean.

Many coasts feature semi-enclosed bodies of water

Semi-enclosed water bodies in the Arctic Basin include fjords, bays, straits, and channels between islands. Many of these estuarine environments are important links between the terrestrial environment and the ocean because they act as sediment traps.

Each of the semi-enclosed bodies of water is unique, and its environment is governed by ice cover and tides. In Frobisher Bay, Baffin Island, for example, the tides are extreme. In Lancaster Sound, Baffin Bay, an area of open water within sea ice, called the North Water Polynya, forms every year. Fjords in some regions, such as Norway, are ice-free year-round, due to the warming effect of the North Atlantic Current.

Maximum and minimum sea-ice extent.



Hudson Bay in Arctic Canada is considered part of the AMAP area even though it extends as far south as 51°N. The bay is ice-covered in the winter, and gets much of its water from rivers draining central and northeast North America. A similar semi-enclosed body of water in the Eurasian Arctic, also heavily influenced by freshwater runoff, is the White Sea.

Sea ice dominates the Arctic Ocean

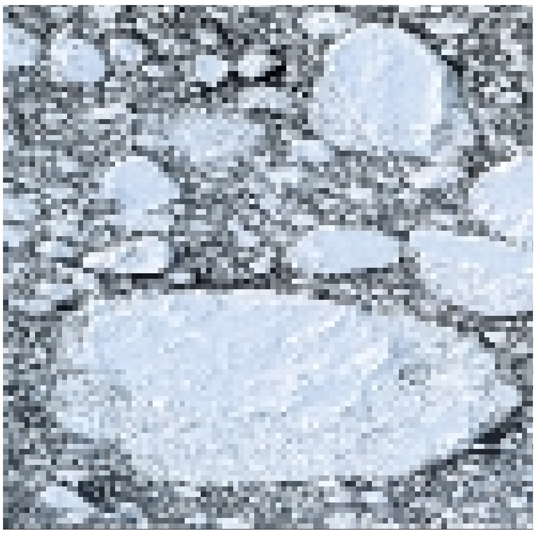
Ice is the most striking feature in the Arctic Ocean. The perennial pack ice covers about 8 million square kilometers. The total area covered by sea ice changes with season, reaching its peak in March to May, at about 15 million square kilometers; see figure below left.

The ice is in constant motion, following the major currents and growing in thickness as it moves along. The trip from one end of the Arctic Basin to the other can take up to six years, allowing the ice to grow as thick as three meters or more; see the map on page 32.

Forces from winds, upwelling water, and water currents create strains and stresses on the moving ice, which lead to patches of open water even in the depths of winter. In some areas, these leads and polynyas are formed every year and serve as important gathering grounds for marine wildlife and as hunting grounds for Inuit. They also represent areas of high energy exchange between the ocean and the atmosphere. During summer, about 10 percent of the pack ice area is actually open water.

In other areas, the ice is pushed into huge hummocks and pressure ridges. The height of hummocks is typically 4 to 5 meters, but they sometimes reach heights of 12 to 15 meters. An underwater ice ridge can extend 30 to 40 meters below the surface.

Shelf seas mainly have first-year ice, which builds from the coast and the ice edge during winter. Offshore winds often separate the pack ice from the landfast ice.



STAFFAN WIDSTRAND

Pancake ice.

HEIDI KASSENS

Nilas ice, Laptev Sea.

FRIDTJOF NANSEN AND HJALMAR JOHANSEN, SUMMER 1896

The icescape from near and far

About a century ago, the Norwegian Arctic explorer Fridtjof Nansen traveled over the drifting ice pack in his quest for the North Pole. Some days the ice was smooth enough to allow the sleds an easy passage, but oftentimes open water came in the way or huge hummocks turned his travel into arduous work. His description from early August 1895 gives a sense of the Arctic icescape:

'It was as if a giant had thrown the worst iceblocks helter-skelter, strewn deep, wet snow between them and water underneath, so that we sank all the way up to our thighs . . . It was like struggling over mountains and valleys, up and down over block after block, and ridge after ridge with deep crevices between, not an even surface large enough to put a tent on.'
Fridtjof Nansen: Fram over Polarhavet, 1897.

Today's Arctic travelers can get a bird eye's view of this icescape:

'Flying over the ice is an easy way to appreciate its tectonic activity on a larger scale, to better understand it as the never-quite-settled surface of the Arctic Ocean. From above, the finger-rafting of huge, transparent sheets of nilas seems like a delicate and regular joinery of panes of glass . . . Dark ice cakes below prove to be ones covered with epontic algae and flipped over by animals, or places where walrus have hauled out, rested and defecated. Long streaks on gray-white ice cutting across a broad, snow-covered expanse show where leads have recently frozen over. A low pressure ridge may lead to a dark hole and a patch of reddish snow, a polar bear kill. Streamers of grease ice in patches of open water line up with the wind. In winter the leads steam with frost smoke where the (relatively) warm water meets the frigid air.'
Barry Lopez: Arctic Dreams, 1986

HEIDI KASSENS

Black nilas ice,
Laptev Sea

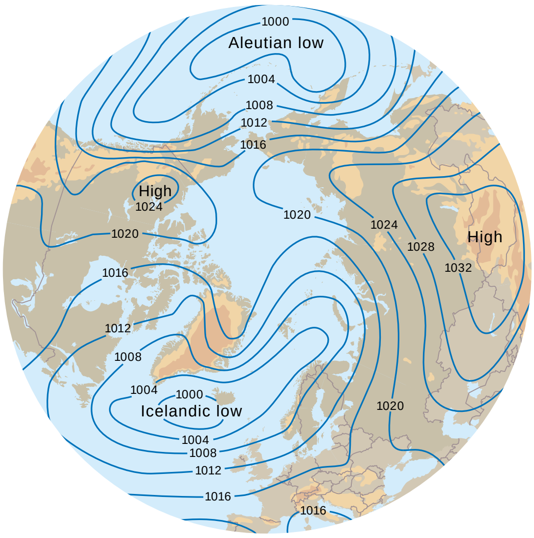
Climate

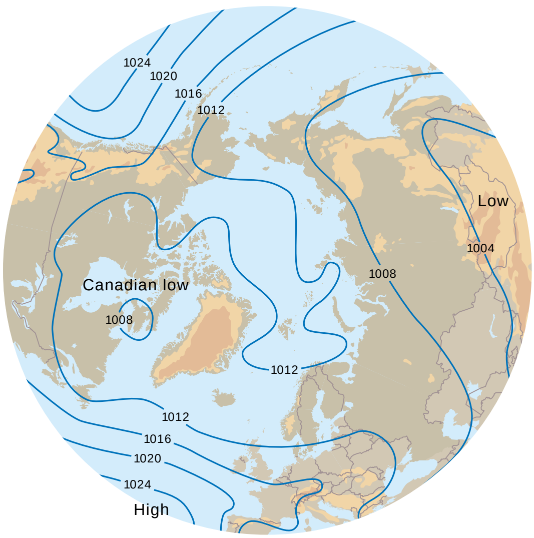
Weather in the Arctic can be more extreme than in most other areas of the world, with low temperatures and strong winds. The region includes some of the coldest places on Earth, but temperatures and weather patterns vary greatly among different regions of the AMAP area.

A cold reservoir in a global heat machine

One basic feature of the Arctic climate is that the sun never reaches high in the sky, even in summer, which limits the total amount of incoming solar energy. Moreover, in snow-covered areas as much as 90 percent of the incoming solar energy is reflected back to space by the snow and ice. Furthermore, the area loses heat back to space as infrared radiation. This is compensated by heat exchange in the atmosphere and ocean currents that carry relatively warm air and water masses northward and cold air and water southward. The Arctic region also imports moisture from surrounding areas.

Seeing the polar area as a refrigerator in the equator-to-pole transport of energy is important in understanding weather patterns. For example, the mid-latitude jet streams and the low- and high-pressure systems embedded in them are results of the on-going heat exchange. The stronger the temperature differences, the stronger the jet streams. Therefore, the strongest storms occur in winter. The heat exchange between the Arctic and areas farther south is also important for understanding contaminant transport and global climate change as described in later chapters.





Patterns of high- and low-pressure systems in winter and summer.

The High Arctic is cold and dry

The temperature over the Arctic Ocean is moderated by heat released through the ice from the underlying water, but winter air temperatures over the permanent ice pack still fall to –30°C . The cold air cannot hold much moisture. Together with the lack of open water, this creates very dry conditions in the High Arctic, making a cold desert environment. It might snow often, but little falls each time, so the total accumulation of snow is relatively low in winter. Precipitation on northern Greenland, for example, is hardly more than 100 millimeters per year. Powerful high-pressure systems in the Arctic often create clear, cold days in late winter and spring.

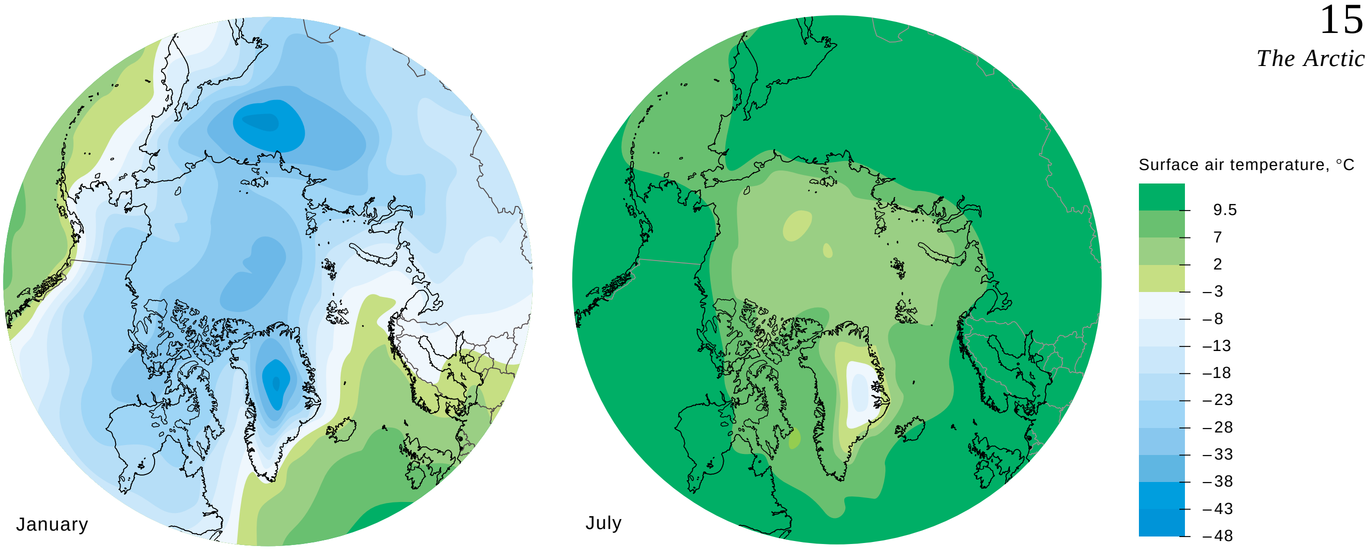
Summers in these far-north areas are usually gray and foggy as mild, humid air moves in over the cold water. Cloud cover in summer ranges from 70 to 90 percent. The amount of precipitation is still low, however, and temperatures remain between –10 and +10°C, with temperatures most commonly around freezing.

Coastal and continental climates can be very different

Farther south, average temperatures and precipitation are governed by the major movement of air masses and the proximity to open water. For example, winter circulation patterns bring cold air from the Arctic Ocean southward over North America. Over the continental parts of the Arctic, stable, cold high-pressure systems prevail during typical winters. These are particularly well developed over Siberia and northwestern Canada.

The winter high-pressure systems are accompanied by weak winds and thermal inversions, allowing cold air to gather in the lower one-to-two kilometers of the atmosphere. The lowest temperatures are usually recorded in typical continental climates, such as the inland areas of Alaska, Siberia, eastern Arctic Canada, and Greenland. Minimum winter temperatures across inland areas in the Arctic range from –20 to –60°C.

There are large temperature differences between winter and summer over the continents. In some parts of Siberia and in the interior of Alaska, temperatures can range from less than –50°C in winter to above +30°C in summer.



Surface air temperatures in winter and summer.

Coastal areas often have a maritime climate. Around the Norwegian and Barents Seas, for example, winter temperatures are on average only just below freezing because of the warm North Atlantic Current. Even as far north as Svalbard, mean winter temperatures are only about –12°C, about 20°C higher than those at the same latitude in the Canadian Arctic Archipelago. As in most maritime climates, the temperature difference between summer and winter around the Norwegian and Barents Seas is not as great as in inland areas. Other areas with typical maritime climates are Iceland and the south coast of Alaska.

Semi-permanent low-pressure systems govern winds and precipitation

Wind patterns and precipitation in the Low Arctic are governed by the low-pressure systems that form over the North Atlantic and the Bering Sea, bringing warm, moist air northward. These weather systems, the Icelandic and Aleutian lows, gather moisture over open water and dump it as precipitation when the air is forced to rise. The windward sides of mountainous areas often have daily rain or snow. Southern Iceland and parts of the Norwegian coast can thus get extreme yearly precipitation, exceeding 3000 millimeters. In the warm seasons, the Icelandic and Aleutian lows weaken considerably.

Inland areas of the Low Arctic are generally dry, with decreasing precipitation from south to north. East Siberia, Northern Canada, and Greenland receive less than 140 millimeters per year.

Winds have a great impact on the polar environment because they aggravate the chilling effect of low temperatures. The open Arctic landscape does not slow the winds, which are also important in mobilizing snow, causing scouring in exposed areas and deposition in sheltered locations. In the marine environment, wind affects sea surface stability and increases mixing in the water column. It also produces ocean currents and influences ice drift and the formation of polynyas.

In winter, unstable conditions in the cold air over the open, relatively warm oceans north of the polar front often trigger the formation of polar lows. They are much smaller than the more permanent lows, but they bring stormy weather and high winds farther south.

Temperature inversions over ice sheets on land can create local, extremely strong winds in the winter, as cold air surges downhill, usually from the ice toward the sea. Such katabatic winds are frequent and persistent around Greenland.


KNUT BRY

Svalbard.


KNUT BRY

Norilsk, Russia.

STAFFAN WIDSTRAND

Baffin Island, Canada.

A circumpolar voyage

As a result of the combined effects of geology, ice, and climate, the lands covered in the AMAP assessment are very diverse. Circling twice around the Arctic, first among the islands and then through the continents, gives the traveler a sample of features that are typical of the different regions..

Icy island outposts

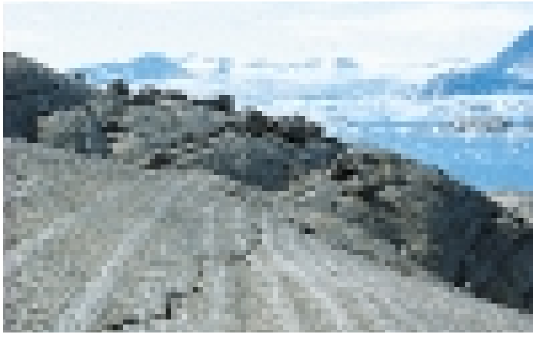
The archipelagos of northern Canada, Greenland, and the islands north of Scandinavia and Russia form the terrestrial outposts farthest to the north.

Canada's northernmost area is the world's largest archipelago, with 20 large and many smaller islands, some of which are covered by extensive glaciers. The Canadian Arctic Archipelago starts with flat to rolling plains in the west (Banks, Melville, Victoria, Bathurst, and Prince of Wales Islands), building up to rugged, ice-capped mountains in the northeast (Baffin, Devon, Axel Heiberg, and Ellesmere Islands) toward Greenland. The northernmost land is Ellesmere Island, where the Agassiz ice cap covers much of the central part of the island. The fjords and straits between the islands are often blocked by pack ice.

STAFFAN WIDSTRAND

Ellesmere Island, Canada.

Greenland, which is geologically a part of North America, is a mountainous island. Most of it is covered by a permanent ice cap, which reaches elevations of 3000 meters. Many of the glaciers extend all the way to the sea, and western Greenland produces icebergs at a rate of 300 cubic kilometers per year. The Jakobshavn Isbrae alone creates 25 cubic kilometers of icebergs per year as the ice tongue glides



MINEK ROSING

Kangerlusuaq, East Greenland.

MINEK ROSING

Narsaq, southern West Greenland.

forward at an average rate of 20 meters a day. In areas where the ice does not reach the sea, meltwater flows into abundant lakes and river systems.

Along the coasts, conditions are governed by water temperature. The south-flowing East Greenland Current brings cold water and ice down from the Arctic Ocean. As much as six million tonnes of ice travels down the coast per year, almost blocking it from open water. Farther south, the warm Irminger Current has created a more favorable climate. The current mixes with colder water, but still manages to bring relative warmth to the coastal areas around Baffin Bay and southwest Greenland. The coastal waters from Qaqortoq to Sisimiut


MINEK ROSING

Isua, West Greenland.

on the west side of Greenland can be open year-round, and winter sea ice does not become the norm until Disko Bay and farther north.

Most of Greenland that is not covered by glaciers is barren rock with only small patches of low shrubs or grass. The main tracts of ice-free land in Greenland are in the southwest, the north (Peary Land), and the northeast. The southwestern coast features some grazing land for sheep, and vegetation that includes small trees.

The Svalbard and Franz Josef archipelagos, the northern island of Novaya Zemlya, and Severnaya Zemlya are extensively ice-clad, mountainous islands, with glaciers calving icebergs into the sea. Most of the ice-free land is bare and rocky, since cold and lack of water have not allowed much soil to form. The southern Novaya Zemlya island is mostly an ice-free coastal plain with continuous permafrost. All of the Eurasian island outposts are mountains rising from the wide continental shelf. Novaya Zemlya is an extension of the Ural Mountains. The highly productive sea around the islands supports huge populations of sea birds.

North Atlantic islands: weather ruled by the sea

Iceland was created by volcanic activity along the mid-Atlantic ridge some 20 million years ago. New volcanic rock is constantly forming, and volcanoes erupt regularly. About one tenth of Iceland is covered by lava deposited since the last ice age. More than half of the surface does not have any vegetation. About one tenth of the land is covered by glaciers. The climate on Iceland is warmed by the Irminger Current. The extent of sea ice along the coast varies but does not normally block shipping.

Another island on the mid-Atlantic ridge is Jan Mayen, with its 2300-meter-high volcanic mountain Beerenberg. It erupted as recently as 1970.

The North Atlantic part of the AMAP area also includes the Faroe Islands, situated 300 kilometers north of Scotland and approximately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Svalbard.


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Heimaey, Iceland


KUBUS

The Faroe Islands.

Sarek National Park, Sweden.

ANNIKA NILSSON

Saariselkä, Finnish Lapland.

ERKKI OKSANEN

Kolyma River delta, Russia.

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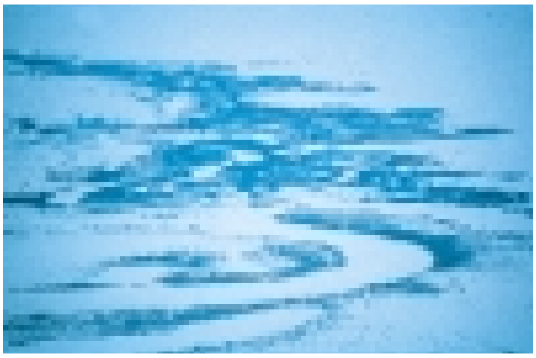

Koyuk River, Russia.

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half-way between Iceland and Norway. This archipelago has a landscape of low, bare mountains, with plenty of grazing land for sheep. The climate is oceanic: humid, changeable, and windy. The ocean temperatures are well above freezing.

Fennoscandia and Kola: subarctic climate, lakes and forests

Fennoscandia, which includes Finland, Norway, and Sweden, rests on old bedrock that has been worn down to low hills and coastal flats. The Norwegian coast features deep fjords. Along the border between Sweden and Norway, younger mountains form peaks as high as 2000 meters, while the landscape generally flattens toward the north and east. The area features an abundance of lakes.

The climate in this region is greatly influenced by the warm North Atlantic Current. The coasts have a long ice-free period and, except on high mountains, the snow melts in summer. Glaciers build in areas with high precipitation, where summers are too short to melt the snow in spite of fairly warm temperatures. Farther inland, on the Norwegian Finnmarksvidda and in Swedish and Finnish Lapland, the climate is continental, with warmer summers than along the coast, but considerably colder winters.

The vegetation represents a transition between the Arctic and the boreal forest with many subarctic species. The boreal forest reaches its northernmost point at Finnmarksvidda in northern Norway, a little south of 70°N. There are only patches of permanently frozen ground.

The Russian Arctic: vast expanses of tundra, wetlands and mountains

The Arctic area of the Russian plains (west of the Ural Mountains) has been shaped by repeated build-up and retreat of glaciers that have left a flatland rich in sediments. The permafrost has created a tundra landscape along the coast and some forest-tundra closer to the Arctic Circle. Summers are cool, wet, and short, while the winters are long, fairly mild, and snowy.

Going east toward the Ural mountains, the climate becomes more severe with abundant snow in the winter. Summers are cool. Most of the northern Ural landscape is tundra, with small glaciers in the mountains. Immediately east of the Urals, the landscape is again flat, but moving farther eastwards in Siberia, mountains reappear.

Much of Arctic Siberia was never glaciated, so pre-glacial soils were never disturbed and thus provide a cover over the bedrock that sustains forests. Siberia has one of the most severe climates in the Arctic, with extremely cold winters. Most years, even large rivers freeze to the bottom for several months. Permafrost prevails, with vast wetland areas and numerous shallow lakes. The landscape is transected by several large north-flowing rivers. Many of these create deltas where they meet the ocean. The coast is ice-bound for most of the year.

The northeastern corner of Russia has a mountainous landscape. In a zone of active low-pressure systems, its climate is more temperate than farther west. In the Chukotka mountains, the peaks reach elevations up to 1500 meters.

Alaska: rugged mountains, coastal plains and volcanic islands

Alaska's landscape covers a wide range of terrains and climates. Rugged mountain ranges stretch across the state in the north and south, reaching 6194 meters at Mt. McKinley. There are several active volcanoes in the Alaska Range, and extensive glaciers in the south-central and southeastern mountains. Wide coastal tundra plains extend along the northern coast and the southwest. The interior, drained by the Yukon river, is forested and has a continental climate, with extreme temperature variation between summer and winter.

From the west coast, the Aleutian chain stretches westward across the Pacific. The climate on the Aleutian Islands is milder than in the interior of Alaska, but strong winds are common and can create severe weather throughout the year.

Permafrost is extensive across the northern third of Alaska, and is discontinuous for much of the rest of the state. Along the northern coast (the Chukchi and Beaufort Seas), sea ice is common even in summer.

Canada: from forests to a frozen archipelago

At the westernmost boundary of Canada's mainland Arctic is the Yukon Plateau, consisting of rolling uplands with valleys and isolated mountains. The climate in this region is subarctic and supports forests.

Southwest of this plateau are the Coast Mountains with extensive glaciers. To the northeast of the Yukon Plateau are the Mackenzie Mountains. These mountain ranges give way to the interior lowlands covered by extensive wetlands and transected by the Mackenzie River. The Arctic climate becomes more pronounced because of the cold air moving down from the Arctic Ocean. Most of the ground is permanently frozen.

The large Great Bear and Great Slave Lakes extend from the interior lowland eastward into the Canadian Shield. The shield continues to the east coast and contains numerous lakes and the vast expanse of Hudson Bay.

Toward the north is the Canadian Arctic Archipelago.

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Chukotka, Russia.

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Kobuk Valley, Alaska.

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Brooks Range, Alaska.

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Ivavik, Yukon, Canada.

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Hudson Bay, Canada.