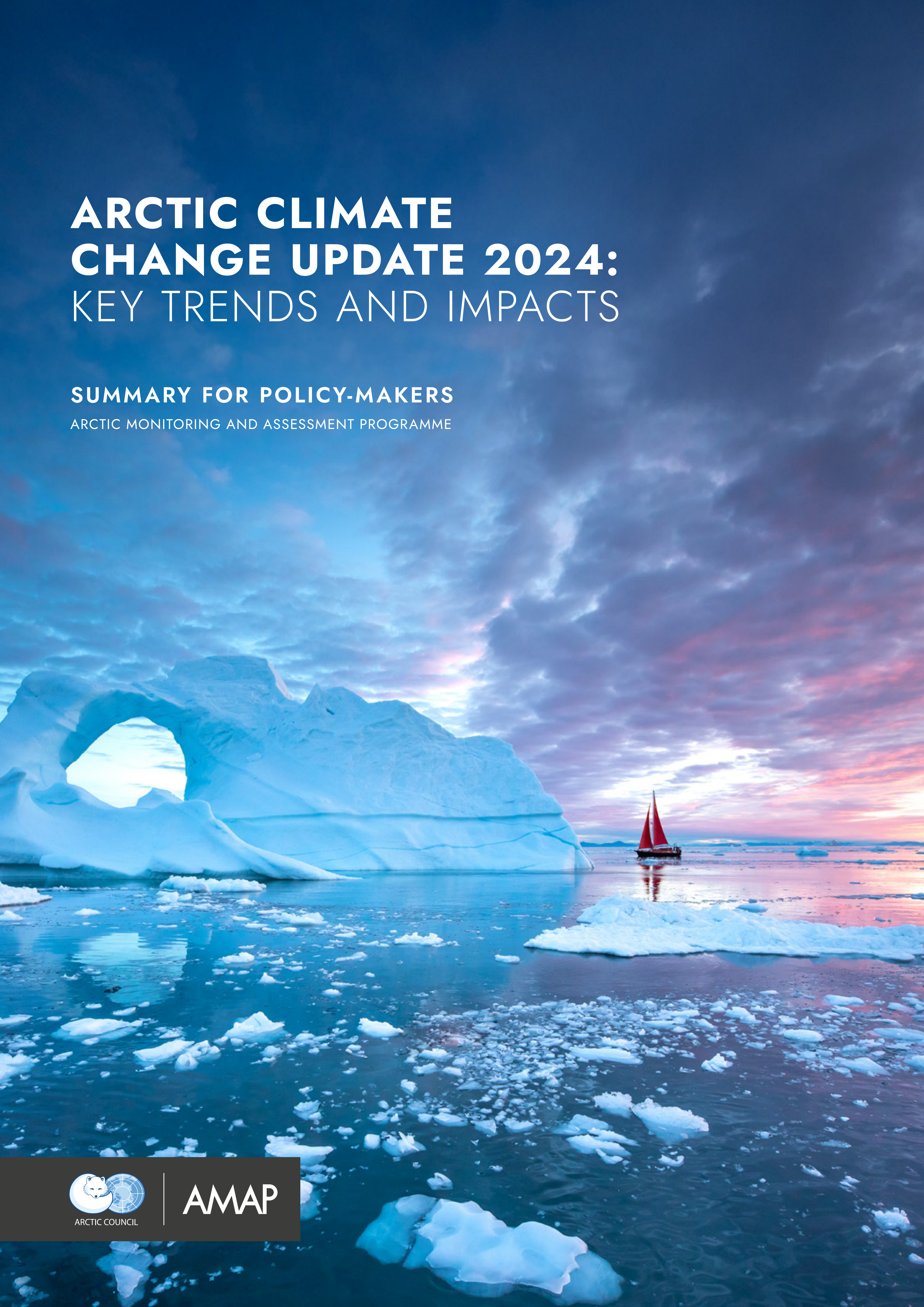


ARCTIC CLIMATE CHANGE UPDATE 2024: KEY TRENDS AND IMPACTS

SUMMARY FOR POLICY-MAKERS

ARCTIC MONITORING AND ASSESSMENT PROGRAMME

ARCTIC COUNCIL

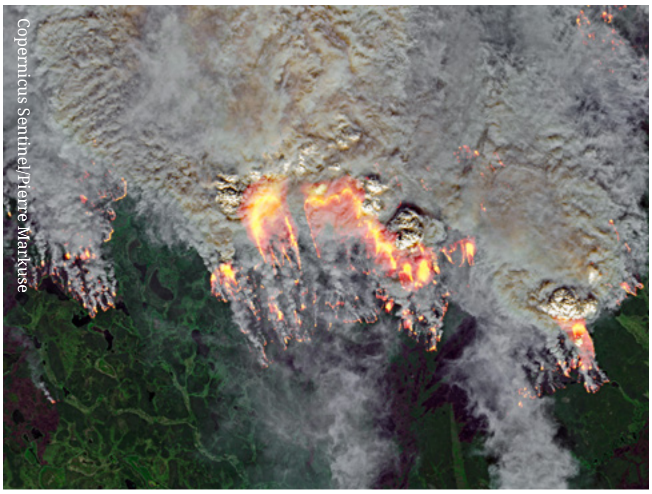
AMAP

KEY FINDINGS

Jason Box

THE ARCTIC'S CLIMATE IS CHANGING AT AN ALARMING RATE

- Between 1979 and 2023, the Arctic warmed three times faster than the global average. Arctic annual air temperatures have risen by 3°C since 1971. Arctic surface air temperatures are increasingly rising above the freezing point of 0°C.
- Precipitation in the Arctic increased by 2–10 percent[1] between 1979 and 2023; with most of the increase coming in the form of rain at the expense of snow. The surface area with daily precipitation in the Arctic has also increased, hence precipitation has become both more intense and widespread.



Copernicus Sentinel/Pierre Markuse

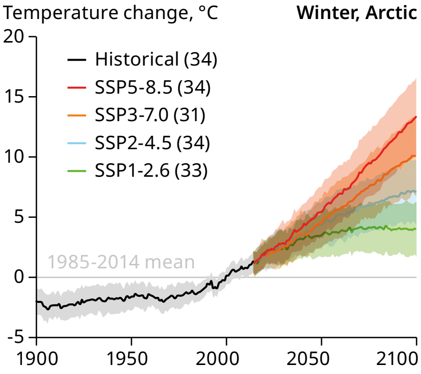
RECORD-BREAKING EXTREME WEATHER EVENTS AND WILDFIRES HAVE BECOME COMMON IN THE ARCTIC

- Many extremes in air and sea-surface temperatures, snow and ice melt, wildfire extent, and other physical and ecological events recorded in the past five years are unprecedented in the observational record: for example, the ice melt across Svalbard in June and July 2022 was 1.5 times larger than the previous record set in 2018.
- Satellite observations of extreme wildfires around the world from 2003–2023 show that the largest regional increase was in the Eurasian Arctic, where the number of extreme wildfires increased by more than a factor of four.

[1] AMAP's analysis examined precipitation trends from two datasets: the Global Precipitation Climatology Project, which shows a 2-percent increase from 1979–2023, and the European Global Reanalysis, version 5, which shows a 10-percent increase.

THE ARCTIC CRYOSPHERE IS SHRINKING

- Ice losses from Arctic glaciers accounted for most of the world's land-ice loss from 1979–2023, making the Arctic the largest regional source of global sea-level rise. From 1992–2020, the rate of land-ice loss from Greenland was nearly twice that of Antarctica, with an averaged loss rate exceeding 5,000 metric tonnes per second.
- Sea-ice extent from 2007–2024 was the lowest in the 44-year satellite record.
- Lakes and rivers are rapidly losing ice across the Northern Hemisphere, with later ice-on dates and earlier ice-off dates, and freshwater discharge from rivers to the Arctic Ocean increased by 13 percent from 1974 to 2023.
- Spring snow cover in the Arctic (from May through June) decreased by 26.7 percent from 1979–2023, with the largest decrease (28 percent) over Eurasia.
- Permafrost across the Arctic has warmed by 2–3°C since the 1970s, with temperatures over the past decade being among the highest on record. Permafrost temperatures in 2022 were the highest on record at 11 of the 25 sites monitored in the Arctic.
- The increased melting of ice and permafrost thaw are consistent with the increase in Arctic surface area with air temperatures above 0°C and the freezing point.
- Climate-induced population displacement in response to impacts related to the shrinking cryosphere is expected to be one of the greatest climate adaptation challenges for Indigenous Peoples, and other Arctic communities.



THE LATEST CLIMATE MODELS PROJECT FASTER RATES OF CHANGE IN THE ARCTIC THIS CENTURY

- The Arctic is projected to warm faster and lose more sea ice by the year 2100 compared with previous estimates. Projections also indicate continued declines in sea ice (with a nearly ice-free summer potentially occurring as early as 2040), reductions in permafrost extent, increases in Arctic precipitation (with a one- to two-decade earlier transition to a rainfall-dominated Arctic in summer and autumn than previously estimated), and stronger and deeper ocean acidification. Precipitation events currently regarded as extreme are expected to become routine over the course of this century.

THE ARCTIC OCEAN IS BECOMING MORE ACIDIC, POSING RISKS TO MARINE SPECIES AND THE INDIGENOUS AND COASTAL COMMUNITIES THAT DEPEND ON THEM

- From 1994 to 2021, the Arctic Ocean acidified three to four times faster than other ocean basins in the world, due mainly to reduced sea-ice cover which promotes the rapid uptake of atmospheric CO_2 in seawater that was previously shielded from the atmosphere by ice. Some regions have already reached conditions that may negatively affect marine life, ultimately affecting the livelihoods and food security of Arctic Indigenous Peoples, and coastal communities.

OVERVIEW

Jason Box

This Summary for Policy-makers discusses high-level findings from *Arctic Climate Change Update 2024: Key Trends and Impacts*, AMAP's second report on climate change in the Arctic since the publication of the *Snow, Water, Ice and Permafrost in the Arctic (SWIPA) 2017* assessment report.

The 2024 report provides status updates on key indicators of climate change in the Arctic along with updated findings for recurring topics such as extreme events (including wildfires) and Arctic/midlatitude linkages. It also provides new information on landscape hydrology and ocean acidification in the Arctic, which were not discussed in the 2021 report. The cryosphere chapter provides an extensive discussion of permafrost, which is an issue of growing concern for Arctic Indigenous Peoples, and other Arctic communities, and policy-makers.

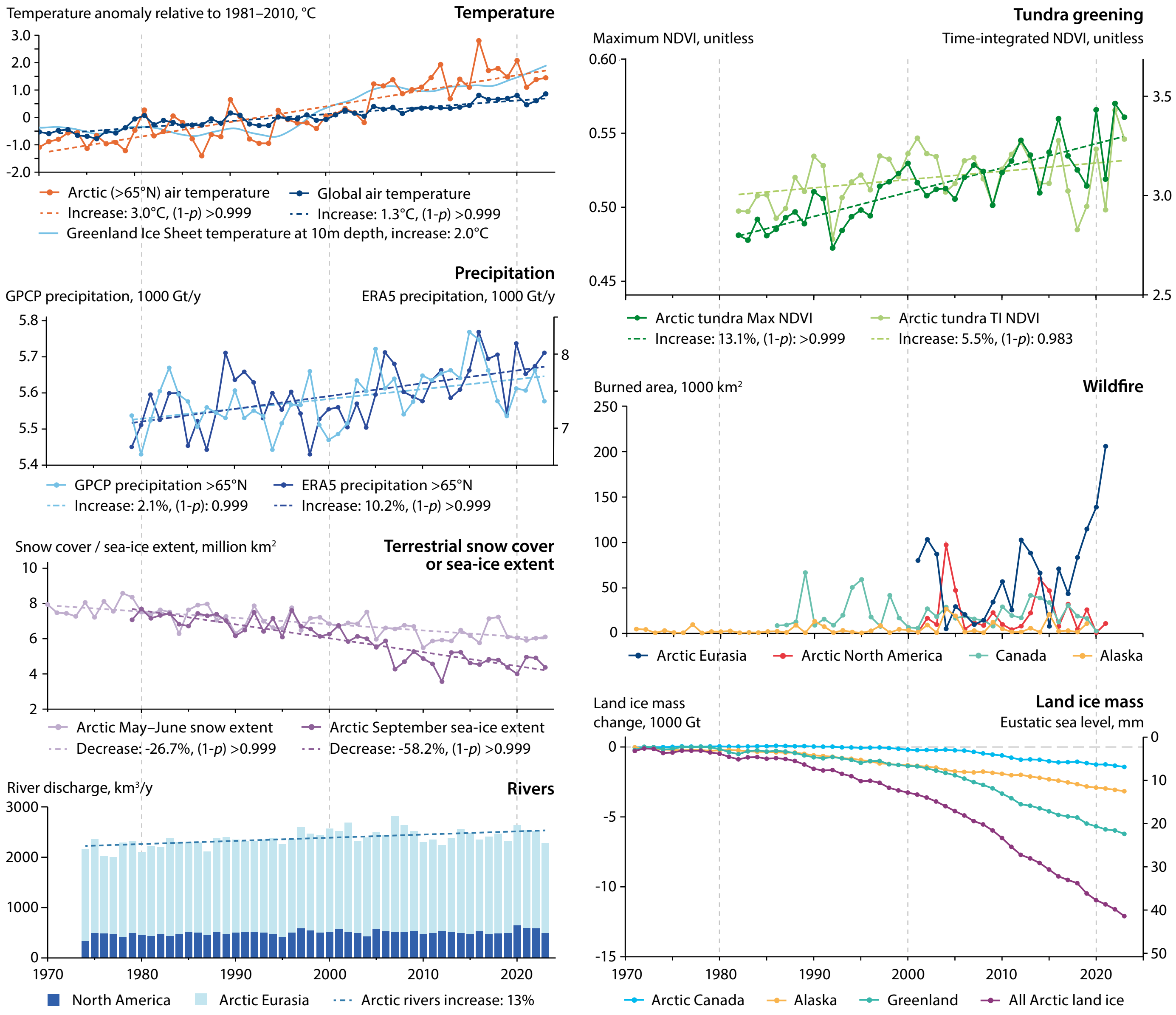
AN ALARMING PACE OF CHANGE

The trends reported by AMAP in *Arctic Climate Change Update 2021: Key Trends and Impacts* have continued, with each new year of data adding to the weight of evidence that the Arctic environment is in a state of profound transition.

THE WARMING ACCELERATES

Rising temperatures are the underlying driver for most of the climate-related changes under way in the Arctic. The rate of warming in the Arctic has increased since 2016 (see figure below). The greatest increase in temperature was observed in October through May, and the largest near-surface warming was in marine environments due to declining sea ice, which allows more heat to escape from the ocean into the atmosphere. Warming is concentrated in the winter months, due to an increase in atmospheric heat and moisture influx from lower latitudes. The Arctic surface area with above-freezing temperature has also increased with the general warming and is connected to a more widespread melting of ice and thawing of permafrost.

Summary of trends in key Arctic indicators



A SHIFT TOWARD RAIN

In addition to an overall increase in precipitation in the Arctic, the number of days with rainfall has increased at the expense of snow. Increasing Arctic precipitation is an expected consequence of atmospheric warming, due to poleward moisture transport, enhanced Arctic amplification of warming, and the loss of sea ice. Furthermore, an increase in the fraction of the Arctic surface area that receives precipitation in any 24-hour period suggests that precipitation has become both increased in magnitude and more geographically widespread. Changes in precipitation can have wide-ranging impacts: for example, changes in stream and river flow affect riverine and coastal ecosystems, and increases in precipitation can lead to flooding and erosion.

ARCTIC GREENING

The “shrubification” and greening of the Arctic continues with a 13-percent increase since 1982 in the Maximum Normalized Difference Vegetation Index (which uses satellite data to monitor greenness), correlating with rising air temperature and precipitation increases and a shorter snow cover season. Concurrently, relatively limited areas of the Arctic (especially northeastern Siberia) continue to experience periods of vegetation browning.

INCREASES IN EXTREME EVENTS

Extreme weather- and climate-related events in the Arctic are increasing and often set new records (see box at right). For example, occurrences of unusually warm (90th percentile) days and nights have increased in northern land areas since 1950; and the intensity, duration, frequency, and areal coverage of Arctic marine heat waves increased from 1982 to 2020.

From 2017–2022, the Alaska-based nonprofit Local Environmental Observer Network, which gathers observations from Indigenous Peoples, local residents, news articles, and topic experts about unusual events across the Arctic, catalogued 212 reports of extreme temperatures, 190 reports of changes in sea ice, 185 reports of changes in seasonal timing, 165 reports of changes in snow cover, 111 reports of extremes related to permafrost thaw, 106 reports of species declines, and 65 reports of wildfires.

In 2022, national meteorological services associated with the Arctic reported 20 heat waves and nearly as many heavy rain events, along with reports of damaging wind events, extreme snowfall, extreme cold, wildfire, low sea ice, and freezing rain.

Because extreme events across the Arctic are increasingly breaking records, they have no historical analogues and their probability cannot be estimated. Taken together these multiple, independent events indicate that the Arctic climate has entered a new state. Increasing but intermittent extreme events may be in store for the future, and Arctic communities need to find ways to adapt.

WILDFIRES

The rapid changes in high-latitude climate are driving an increase in the number of wildfires in the Arctic. Factors affecting wildfire risk include changes in precipitation and soil moisture, thawing permafrost and poleward shifts in vegetation (which can create more fuel for fires), and changes in the polar jet stream. Climate change may also be driving a poleward shift in high-latitude lightning activity, further increasing the risk of wildfire ignitions.

Wildfires affect air quality as well as ecosystems and the physical landscape. Fine particulate matter ($PM_{2.5}$) poses respiratory health risks to humans. One study found that $PM_{2.5}$ from wildfires in the Arctic mostly affects populations close to the fires, but health impacts have been decreasing overall due to a northward shift in wildfires away from more densely populated areas. Smoke from wildfires in lower latitudes—even as far south as the tropics—can be transported to the Arctic, potentially affecting air quality.

Wildfires are also a source of atmospheric mercury and volatile organic compounds (VOCs). Particulates and other components of wildfire smoke can increase local air temperatures and be deposited on snow and ice, darkening them and accelerating melting. The mental trauma associated with wildfires can further affect health.

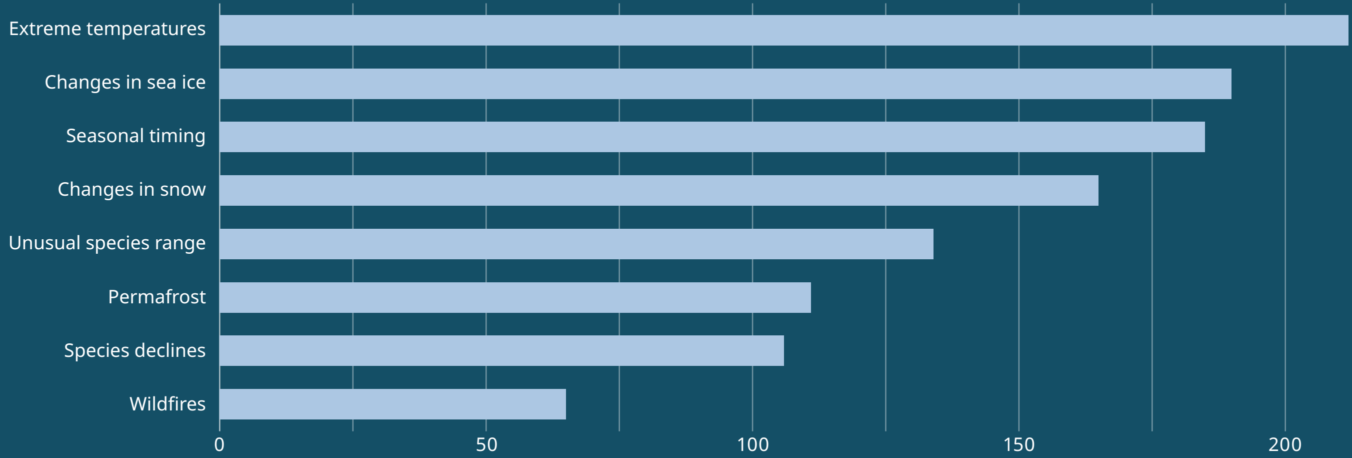
The distribution, frequency, and severity of Arctic wildfires vary strongly from year to year. Carbon, mercury, and VOC emissions from Arctic wildfires were especially high in 2019 and 2020 (carbon emissions[2] were approximately 35 million metric tonnes in 2019 and 60 million metric tonnes in 2020, roughly equivalent to the annual emissions from the Netherlands or Spain in 2023, respectively). Emissions in 2021 and 2022 were lower, but increased again in 2023. During 2024, the number of fires (and emissions from wildfires) above the Arctic Circle was higher than from 2021 to 2023.

[2] Carbon emissions are calculated from emissions of carbon dioxide, carbon monoxide, methane, organic matter and black carbon.

EXAMPLES OF RECENT RECORD-BREAKING EXTREME EVENTS IN THE ARCTIC

- In 2022, wildfires in Alaska had burned nearly 4,050 square kilometers (equivalent to roughly 4 percent of the area of Iceland) by 18 June, the earliest date on which this extent occurred in the 32-year observational record. This was followed by a period of record rainfall, with Anchorage receiving 184 mm of rain between mid-July and mid-August, compared with the 1991–2020 average of 66 mm during these two months.
- The Bering Sea experienced unprecedented minimum winter sea-ice coverage in 2017–2018 and again in 2018–2019, with impacts on ecosystem dynamics and human food security lasting at least through 2021.
- Greenland experienced record high temperatures in September 2022—up to 8°C higher than average—and record melt was observed on the Greenland Ice Sheet.

UNUSUAL OR UNEXPECTED ARCTIC EVENTS (2017–2022)



Source: Local Environmental Observer Network

THE SHRINKING CRYOSPHERE

NASA Earth Observatory

Since the 1980s, the area of the cryosphere—which includes glaciers, ice caps, ice sheets, permafrost, sea ice, land ice, and snow—has been diminishing, and the timing of the melt-freeze cycle has been shifting to earlier melt and later freeze. The rapid increases in Arctic temperature are resulting in thawing permafrost, reductions in snow and ice cover, and reductions in land ice, all of which can exert amplifying feedback effects on local, regional and hemispheric climate systems, with impacts on ecosystems, Indigenous Peoples, other Arctic communities, and industries.

SNOW

The area covered by snow in May through June declined by 26.7 percent across Arctic land areas from 1979–2023, from about 8 million square kilometers to around 6 million. The decline in the Eurasian Arctic is higher at 28 percent, with the North American Arctic snow area declining by 13 percent. The snow-covered area has also declined in October and November across the Arctic as a whole. Changes in snow cover can disrupt the lives of northern residents and particularly Arctic Indigenous Peoples, who rely on the Arctic ecosystem for sustenance, culture and well-being, with impacts on travel, harvesting of traditional foods, mental health, food security, and livelihoods. Ecosystem impacts of declining snow cover include increased plant biomass, which may provide more fuel for wildfires.

LAND ICE

The rates of Arctic glacier loss have increased for all regions since the 1970s, with the overall Arctic ice loss contributing far more to global sea-level rise than any other region on Earth. Within the Arctic, ice reductions in Greenland contribute the most (roughly half) to sea-level rise, followed by Alaska and Arctic Canada. The rates of land-ice loss from Alaska and Arctic Canada increased after 2005. From 1992 to the end of 2020, Greenland's contribution to global sea-level rise was 1.8 times higher than Antarctica's, and between 2005 and 2020 it was 1.9 times higher.

SEA ICE

Sea-ice loss has been occurring across the Arctic in all seasons. The largest declines are reported in the month of September, with a 58-percent decrease in sea-ice extent from 1979–2023. The decline in sea-ice extent lengthened the summer open-water season by 4 to 14 days per decade in all regions of the Arctic Ocean from 1979–2016.

Sea ice has also become thinner and younger (i.e., persisting for fewer years). Since 1979, the proportion of area covered by thick ice at least 5 years old has declined by approximately 90 percent. One recent research expedition found that snow thickness on Arctic sea ice is low compared with historical data, and snow thickness on sea ice has been declining over the Arctic as a whole. Snow on sea ice plays a critical role in the evolution of sea ice through its effects on surface reflectivity and insulation from heat, as well as its role in the formation of melt ponds.

Changes in seasonal sea-ice extent and thickness are affecting Arctic wildlife, marine ecosystems, the mobility and food security of Arctic Indigenous Peoples, and shipping routes throughout the Arctic. The length of the season accessible for shipping has already increased in the Beaufort Sea region, north of Alaska, for example. Changes in sea ice may also affect weather patterns locally and globally. Climate models project continued shrinking and thinning of sea ice in the decades ahead; a recent study projected that a nearly ice-free Arctic in summer could be reached as early as 2040.

COASTAL EROSION

Coastal erosion is widespread across the Arctic, driven by permafrost degradation and the increase in wave action following declines in sea ice. Most coastal areas now have average erosion rates more than 50 percent higher than those during the last decades of the 20th century, affecting Arctic Indigenous Peoples, and other coastal communities. For example, a growing number of Indigenous Peoples along the Alaskan coast are considering relocation. The highest rates of coastline retreat this century (up to 17.2 meters per year) are occurring along the coast of the Alaskan Beaufort Sea; rates in the Russian Arctic coast have reached up to 9.5 meters per year.

PERMAFROST

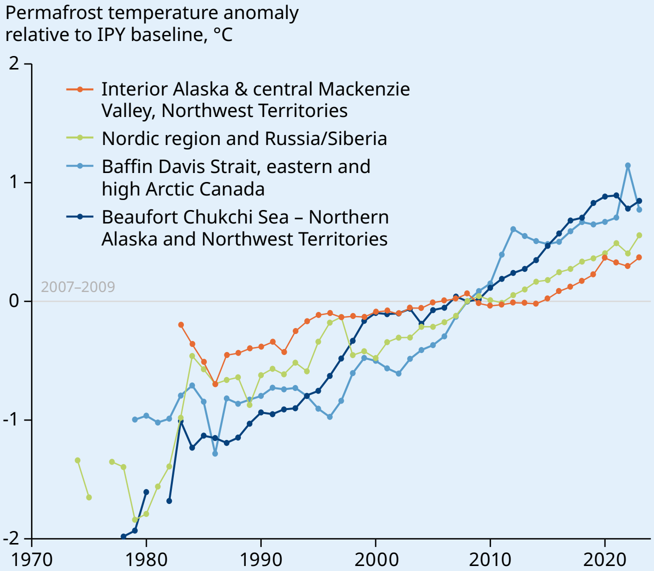
Permafrost is soil, rock, and organic matter that remains below 0°C for two or more consecutive years. Changes in permafrost can have important impacts on landscape stability (with impacts on buildings and infrastructure), hydrological systems, and ecosystems. Permafrost degradation affects Indigenous livelihoods and culture, including hampering access to land, and poses risks to travel, health, and food security.

Permafrost thaw can lead to increased uptake of carbon dioxide (through effects such as earlier green-up of vegetation) and methane (through changes in drainage), but it can also lead to increased emissions of carbon dioxide, methane, and nitrous oxide, with feedbacks to the climate system. Long-term observations at one site in Alaska show that thawing permafrost caused that ecosystem to shift from a net sink to a net source of carbon dioxide to the atmosphere; it also led to increased methane emissions.

Permafrost has warmed by 2–3°C since the 1970s. Subsurface snow and ice temperatures in the Greenland Ice Sheet have increased by 2°C since 1998, with the result that less warming in spring or summer is required to bring the surface to the melting point. Temperature increases are generally greater in colder permafrost than in warmer permafrost.

Although permafrost warming is correlated with increases in air temperature, other factors such as wildfires and changes in the depth of snow cover also contribute to changes in permafrost temperature. The highest rates of warming have been in the Canadian High Arctic, northern Alaska and Svalbard, and the western Russian Arctic; the magnitude of warming varies within each region. The thickness of the active layer (the seasonally thawed layer above permafrost) increased from 1990–2023 in some regions of the Arctic, especially at Russian, Nordic and interior Alaskan sites, where increases ranged from 0.9 centimeters per year to as much as 5 centimeters per year.

The thawing of permafrost is leading to changes in the Arctic landscape, including ground subsidence and the development of thermokarst (a topography characterized by irregular surfaces of marshy hollows and small hummocks), increases in lake area, and degradation of ice wedges, which can affect landscape drainage. Permafrost thaw can also mobilize mercury and other heavy metals. When mercury enters wetlands and other aquatic systems it can be transformed to methylmercury, which can bioaccumulate in aquatic food webs and reach concerning levels in traditional foods of Indigenous Peoples. One study found that methylmercury levels in the soils of recently thawed areas were ten times higher than in frozen peat plateaus.



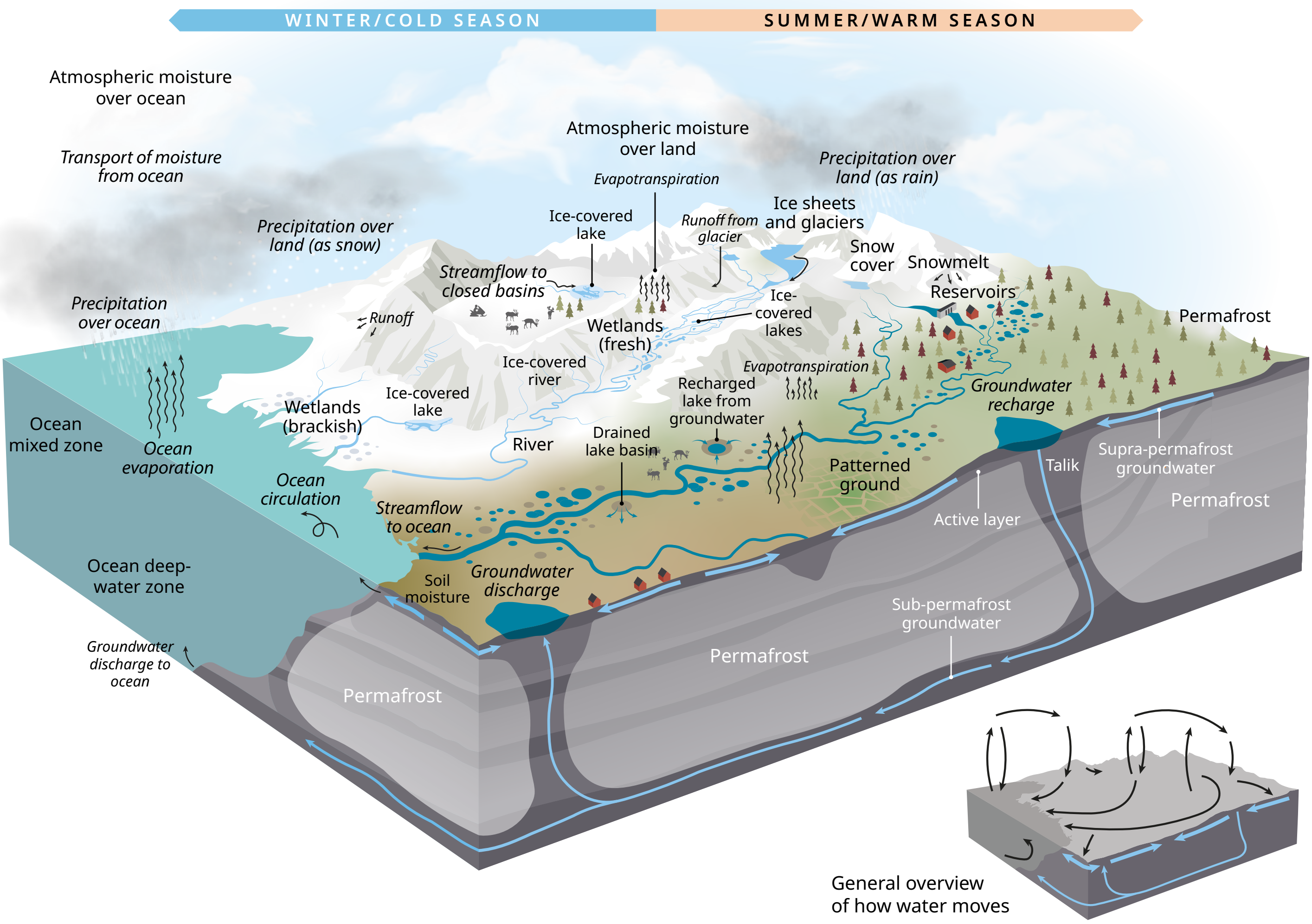
Average departures of permafrost temperature measured in the upper 20-30m from a baseline established during the International Polar Year (2007-2009) for various Arctic regions.

DISRUPTIONS TO ARCTIC HYDROLOGY

Climate change is having major impacts on Arctic freshwater systems and the water cycle, through the transformation of ice and snow into liquid water. These impacts in turn affect climate, ecosystems, landscapes, Indigenous Peoples, and northern communities. For example, the reduced duration of snow cover in northern Sweden has forced Indigenous Sámi reindeer herding communities to move to summer pasturing areas earlier in the spring so they can travel on snow before it melts.

Precipitation, which delivers freshwater to the Arctic, increased between 1950 and 2023, especially in the cold seasons. The increase has been stronger since 1979. In general, the Arctic has been receiving more rain in all seasons, whereas snowfall has decreased in summer but had spatially varying trends in winter.

Permafrost thaw drives changes in Arctic hydrology by increasing groundwater flow and storage, as well as other impacts, and the reduction of glaciers, ice caps, and the Greenland Ice Sheet is changing freshwater discharge into the ocean. Although the magnitude of the maximum discharge from rivers has not changed significantly,



high-water events related to snowmelt are occurring earlier in the spring throughout most of the Arctic. River flow to the Arctic Ocean accounts for about two-thirds of the total freshwater input to the ocean, affecting ocean salinity and sea ice formation; changes in freshwater input to the Arctic Ocean can also affect global ocean circulation.

River and lake ice, which among other things serves as an important transportation resource for Arctic Indigenous Peoples, and northern communities in winter, has declined in duration over the past several decades in cold regions of the Arctic. The trend has intensified since the beginning of the 21st century. Past significant declines in river ice thickness have essentially stabilized over the last two decades. The probability of ice jam floods is expected to decrease with thinner river ice, which could be beneficial for many communities.

Lakes, an important resource in the Arctic for ecosystems, drinking water, subsistence activities, and industrial operations, are changing in area, with some regions seeing declines and others seeing increases. These changes are due mainly to permafrost thaw and in some cases from melting glaciers and changes in evaporation from warming temperatures. Lakes are also rapidly losing ice across the Northern Hemisphere, with later ice-on dates and earlier ice-off dates.

The most recent climate models suggest larger and faster changes in precipitation in the decades ahead compared with previous projections. Models also project increases in the number and/or intensity of heavy precipitation events.

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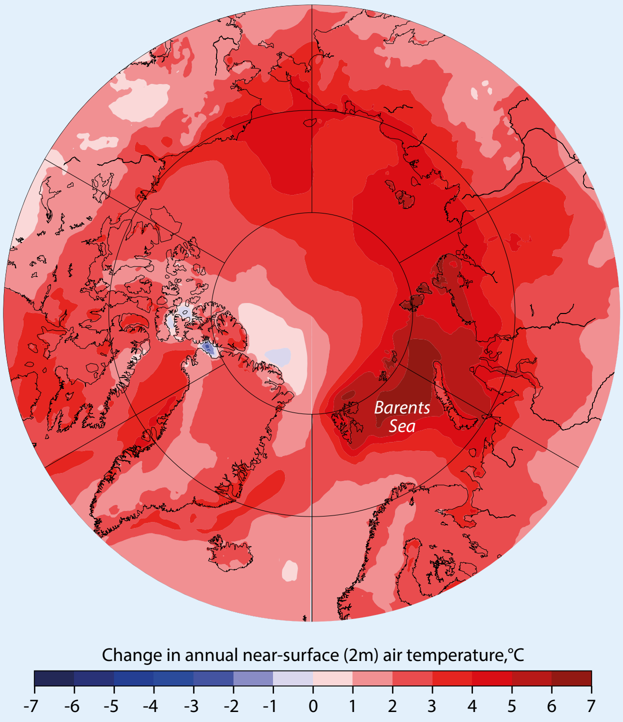
ARCTIC INFLUENCES ON MIDLATITUDE WEATHER AND CLIMATE

The potential for changes in the Arctic to affect weather and climate in midlatitudes is a topic of active research and societal concern. Although studies continue to find correlations and plausible relationships between Arctic conditions and midlatitude weather, multiple processes appear to be involved (e.g., movement of the polar vortex, atmospheric blocking, loss of sea ice, and natural variability) and it is still not possible to draw final conclusions, although clear examples are apparent.

Recent studies suggest that movements of the polar vortex over continents can help explain some Arctic/midlatitude weather connections, such as cold air outbreaks.

The overall conclusions from previous AMAP updates still apply: Arctic/midlatitude connections are an important and complex subject that requires continued study.



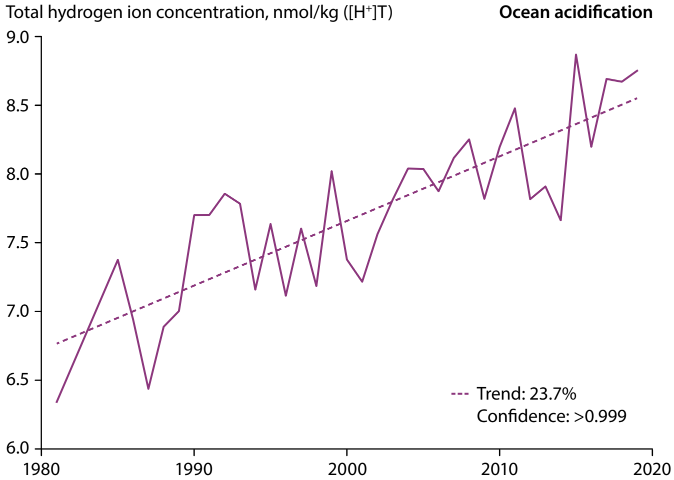
ARCTIC OCEAN ACIDIFICATION

As the ocean takes up more carbon dioxide from the atmosphere, it becomes more acidic which in turn reduces the concentration of carbonate ions in the water. Many marine species, such as plankton and corals, use carbonate ions to create their shells and skeletons.

Ocean acidification can lead to changes in ecosystem function, biodiversity, and the structure of habitats, which in turn may challenge the population dynamics of species that are of critical importance to the livelihoods, health, and cultural practices of Arctic Indigenous Peoples. The combined impacts of acidification and other stressors, such as ocean warming due to climate change, can be dangerous for sensitive marine organisms. The latest data indicate that the Arctic Ocean continues to acidify, and some regions have already reached conditions that may have negative impacts on marine life such as pteropods (free-swimming sea snails and sea slugs that are an important component of Arctic marine food webs) and ultimately the activities, well-being, and rights of Arctic Indigenous Peoples.

Ocean acidification in some regions, such as the East Siberian and Beaufort Seas, is quite advanced, and models project that these regions will reach critical thresholds of aragonite undersaturation (the point at which calcium carbonate is more likely to dissolve than form in seawater, requiring organisms to expend more energy to to maintain their shells and skeletons) by the end of this century under all climate scenarios. Under a severe climate change scenario, this threshold could be reached in all regions by 2080.

Pteropods, which are frequently consumed by Pacific salmon and other important fish species, are especially sensitive to acidification and can be considered an indicator species for monitoring the status and risks associated with ocean acidification. Several crab species in the Arctic, including economically important king crabs and snow crabs, have been shown to be sensitive to ocean acidification, with sensitivity varying across life stages. Acidification also acts as a stressor on polar cod, again with differences across life stages. Many other important species may be affected directly or indirectly by ocean acidification, but data are often limited or lacking; Indigenous Peoples could play an important role in filling these knowledge gaps and monitoring changing conditions.



Total hydrogen ion concentration in the Nordic Seas, 1981–2019. As CO_2 dissolves in the ocean it reacts with water to form hydrogen ions, which make the ocean more acidic.

The greatest future increases in ocean acidity in the world are projected for the Arctic Ocean, with differences across regions (e.g., the smallest increases are projected for areas such as the Beaufort Sea that are already at or close to reaching aragonite undersaturation; the largest increases are projected for the Norwegian Sea), reflecting impacts from surface ocean warming, loss of sea ice, increases in organic carbon from thawing permafrost and other land sources, and uptake of carbon dioxide from the atmosphere. Ongoing increases in methane in the ocean from thawing subsea permafrost and decomposing hydrates may also contribute to increasing ocean acidification.

Climate models project accelerating and deepening ocean acidification in the future, but they also show that ambitious mitigation of greenhouse gas emissions can limit future acidification and warming stress on Arctic marine ecosystems.

NEXT STEPS:
RECOMMENDATIONS FOR ACTION

Ingo Danielsen

In the 20 years since the release of the 2004 Arctic Climate Impact Assessment (ACIA), when Arctic Council Ministers first expressed their concerns about a changing Arctic and called for "timely, measured, and concerted action" to address greenhouse gas emissions, the pace of climate change has accelerated. The Arctic is now in a state of rapid transformation, and the need for timely action is stronger than ever.

Protecting the Arctic cryosphere is a matter of urgent global concern: many impacts on Arctic Indigenous Peoples, and other Arctic inhabitants, such as sea-level rise, extend far beyond the Arctic. Studies show that ambitious reductions in net emissions can slow the pace of change, but time is running out.

The widespread changes in the Arctic since 2004 reinforce the Arctic Council Ministers' calls for action and are consistent with the recommendations below, which are based on a foundation of science and Indigenous Knowledge. To further strengthen that foundation, AMAP also recommends actions to address knowledge gaps identified in this update.

POLICY RECOMMENDATIONS

These recommendations are addressed to Arctic States, Arctic Council Permanent Participants, and observer countries.

- Intensify efforts to reduce the emissions of greenhouse gases and short-lived climate pollutants across sectors and systems to slow the pace of climate change in the Arctic as well as globally.
- Develop flexible climate change adaptation strategies that are robust to a range of climate conditions and alternative futures. Monitor and evaluate the effectiveness of community responses to climate-related extreme events to improve resilience.
- Consider multiple knowledge systems, including Indigenous Knowledge and local knowledge, together with scientific information, at all levels of climate-related decision-making to capture a broader understanding of changes under way in the Arctic and their impacts.
- Ensure the participation and self-determination of Indigenous Peoples in research, so their perspectives and knowledge can be used to fill knowledge gaps and to inform policy development and decision-making relevant to Arctic people and their communities, and develop equitable solutions for communities that face fundamental risks from climate change.

SCIENCE RECOMMENDATIONS

These recommendations are addressed to governments of Arctic States and observer countries, along with international and national research funding agencies.

ADAPTATION AND MITIGATION

- Prioritize research on climate change adaptation and mitigation efforts in addition to improving scientific understanding of climate-related impacts.
- Recognize the importance of seeking the free, prior, and informed consent of Indigenous Peoples and guidance on matters occurring in, or related to, Indigenous homelands, as outlined in the United Nations Declaration on the Rights of Indigenous Peoples.

MONITORING (FOR ALL TYPES OF CHANGES)

- Support community-based monitoring initiatives, led by Arctic Indigenous Peoples, to fill gaps in local and regional observational data that can be used to inform decision-making.

WILDFIRE

- Intensify monitoring and other efforts to evaluate the impacts of wildfire smoke on human health and ecosystems. The integrated models used to project future wildfire conditions and their impacts should incorporate variations in fire regimes and fire management practices across the Arctic.

CHANGES IN THE CRYOSPHERE AND ARCTIC HYDROLOGY

- Improve the spatial coverage of observation networks for data on trends in precipitation, snow depth, snow properties, river discharge, changes in lake area, and river and lake ice timing and thickness across the Arctic.
- Expand permafrost monitoring networks to fill spatial gaps, and improve integration of satellite and airborne data with on-the-ground measurements to improve permafrost monitoring over larger areas. Research is also needed to improve understanding of the interactions between permafrost and climate, water, vegetation, and snow cover, and to integrate that information into models.

OCEAN ACIDIFICATION

- Improve the ability of climate models to project sea-ice decreases and other factors affecting future ocean acidification.

ARCTIC/MIDLATITUDE CONNECTIONS

- Improve understanding of atmospheric blocking and polar vortex movements in relation to midlatitude cold and warm air events to identify potential links between Arctic climate change and midlatitude weather.

AMAP, established in 1991 under the eight-country Arctic Environmental Protection Strategy, monitors and assesses the status of the Arctic region with respect to pollution and climate change. AMAP produces science-based policy-relevant assessments and public outreach products to inform policy- and decision-making processes. Since 1996, AMAP has served as one of the Arctic Council's six working groups.

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