Executive Summary

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Few parts of the world demonstrate such extreme seasonal shifts in temperature, land and ocean cover, ecological processes, and wildlife movement and behavior as the Arctic. These extreme shifts across the annual cycle are a source of the Arctic region's heightened sensitivity to climate changes and climate-related disturbances. The Arctic is also a region of sparse in-situ observations, especially relative to its importance in understanding the Earth's changing climate and associated societal consequences.

The 2022 Arctic Report Card (ARC2022) provides an updated annual view into the state of the Arctic by checking in on key *vital signs*—eight defining elements of the Arctic's climate and environmental system. This report also samples critical and emerging topics across the Arctic, bringing into focus diverse collections of observations that help to assess the overall trajectory of Arctic change.

ARC2022 reveals an Arctic experiencing widespread shifts in seasonal climate. Many observations throughout the Report Card are organized within periods of the year defined by predictable climatological or ecological conditions (e.g., the "snow season" or the "breeding season" for a particular animal species). These periods are shifting, and in turn, altering ecological and landscape processes, and increasingly misaligning with human expectations and decision-making. For example, June snow cover extent in the Arctic is rapidly declining at a rate of -18.9 ± 6.6% per decade, marking a dramatic shift in how the snow season is defined and experienced across the North. In early September 2022, the Greenland Ice Sheet experienced an unprecedented late-season surface melt event across 36% of the ice sheet surface. This was followed by a small but again unprecedented late September melt event caused by the remnants of Hurricane Fiona, challenging how researchers define the Greenland summer melt season.

As seasons shift, climate-driven disturbances, such as wildfires, extreme weather, and unusual wildlife mortality events, become increasingly difficult to assess within the context of what has been previously considered normal. To better track changing climate and remain well positioned to assess accelerating change and disturbances, ARC2022 has implemented a new climate baseline period across its *vital sign* essays. The Report Card now uses 1991-2020 as the new 30-year baseline, updated from the previous 1981-2010 baseline. This shift also aligns our reporting with other leading climate science organizations that monitor climate trends on Arctic to global scales, such as the World Meteorological Organization.

Arctic annual surface air temperatures during October 2021-September 2022 were the sixth warmest dating back to 1900, continuing a decades-long trend in which Arctic air temperatures have warmed faster than the global average. Strongly driven by this warming, Arctic sea ice continues to decline in thickness and extent. Increasingly, the Arctic provides powerful glimpses into what ice loss may mean for the future of communities and ecosystems, as well as shipping and marine access in the far north. In summer 2022, both the Northern Sea Route and Northwest Passage were open while unusually low ice concentrations and areas of open water were observed near the North Pole.

What does this mean for the future of Arctic shipping? The emergence and availability of satellite-based ship data since 2009 are helping to address this important question. As of 2022, satellite-based records reveal increasing maritime ship traffic within all Arctic high seas and national exclusive economic zones, aligning with the "ship-ice hypothesis," which posits that Arctic shipping will increase as sea ice diminishes. This raises important questions on topics ranging from the future of Arctic trade routes to the introduction of enhanced anthropogenic stresses on Arctic Peoples and ecosystems. The Arctic Ocean and peripheral seas are remote, ecologically sensitive, and environmentally variable waters where socio-economic and geopolitical realities cannot be ignored.

Sea ice loss is also intricately connected to other key Arctic marine *vital signs*. Arctic sea surface temperature (SST) is a valuable indicator of the role of the ice-albedo feedback cycle. As sea ice melts due to warming, much more incoming solar heat is absorbed by the exposed darker ocean surface and, in turn, the warmer ocean melts more sea ice, or impedes ice thickening throughout fall and winter. August average SSTs show warming trends since records began in 1982 for most regions of the Arctic Ocean that are ice-free, with the northern Barents Sea as a notable exception due in part to a period of warm SSTs during the 1980s and '90s. In 2022, SSTs showed unusually cool August SSTs in the Chukchi Sea, coincident with late-summer sea ice in the region that was kept in place by persistent north winds.

Ocean temperatures are not only rising at the surface, but also at depth, further influencing Arctic environments, such as the Greenland Ice Sheet. Findings from the NASA *Oceans Melting Greenland* mission confirmed the important role that warming ocean temperatures play in influencing ice loss through glacier melt at the ice sheet margins. These types of observations give us new insights into the processes affecting a melting Greenland. With melt occurring at the ocean boundaries and across the ice sheet surface, the Greenland Ice Sheet again lost ice in 2022, the 25th consecutive year of ice loss.

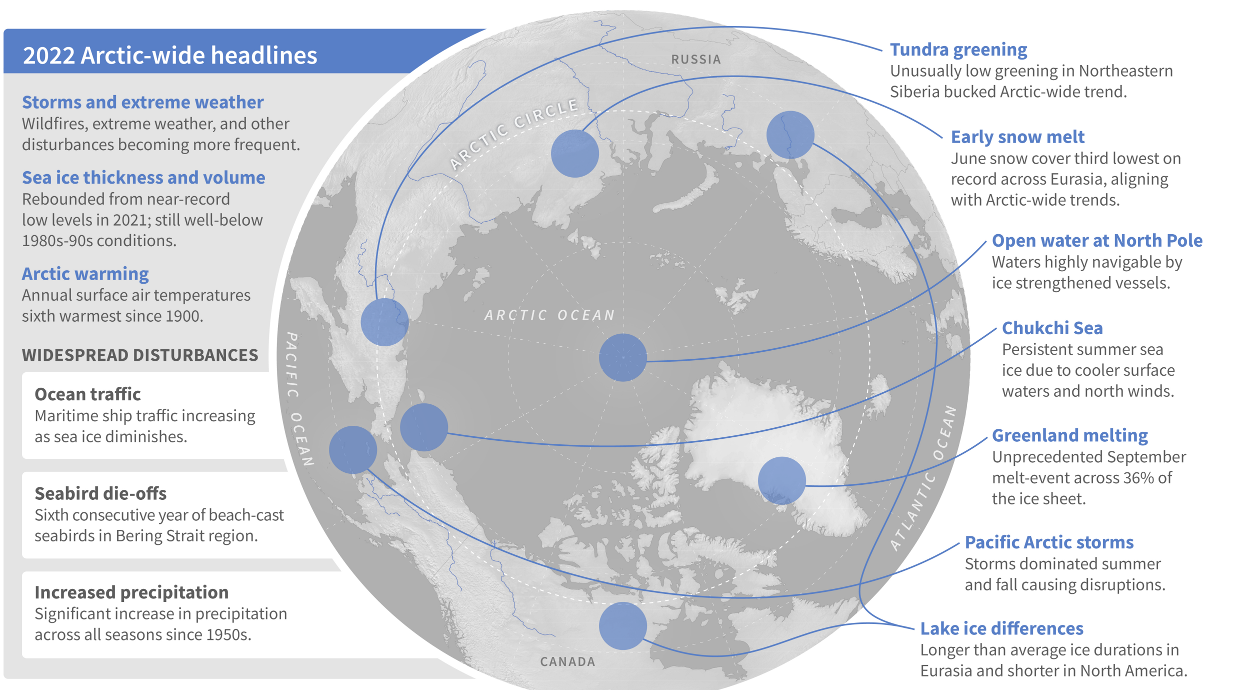
ARC2022 includes the inaugural *vital sign* essay on Arctic precipitation. Using reanalysis data products, which allow scientists to overcome the challenges of sparse gauge measurements in the Arctic, this new essay assesses variations and the emergence of trends in Arctic precipitation. Significant increases in Arctic precipitation across all seasons since the mid-1900s are detected, consistent with observed increases in global total atmospheric moisture. However, regional variations exist across the Arctic, with some regions experiencing notable seasonal decreases in precipitation (e.g., the Bering Sea during spring and summer).

Summer storms played a substantial role in shaping 2022 Arctic events. For example, storms in the Bering Sea may have been responsible for the satellite-observed higher-than-average primary productivity (i.e., the transformation of dissolved inorganic carbon into organic material) in the region due to enhanced vertical mixing of nutrients. These same storms in the Pacific Arctic also disrupted ship-based measurements of nutrients and primary productivity during summer 2022 that are critical for complementing satellite observations. Five of the nine monitored Arctic regions showed high productivity in 2022, with the Arctic overall in line with the long-term positive trend over the satellite record (2003-22).

Typhoon Merbok—fueled by unusually warm water in the North Pacific—was another storm that dramatically shaped 2022 in the Bering Sea region. In mid-September, hurricane-force winds, 50-foot waves, and far-reaching storm surge impacted coastal and river communities along over 1,000 miles of coastline. Homes, roads, and infrastructure were damaged, and the storm severely disrupted the communities' fall hunting and harvesting in preparation for the oncoming winter.

Long-term precipitation records also suggest important connections to other ongoing changes in the Arctic. For example, an increase in prolonged wet periods (measured as consecutive wet days) across a large area spanning from Svalbard eastward through the Siberian seas to the Chukchi Sea generally coincides with reduced sea ice coverage during the warm season of the year when moisture is readily transferred from the ocean to atmosphere. The new precipitation essay also provides an annual and seasonal overview of Arctic precipitation anomalies in the context of long-term changes. For this past year (October 2021-September 2022), wetter-than-normal conditions predominated over much of the Arctic. Summer 2022 was an exception, with generally dry conditions across the North. In Alaska, these dry conditions fed severe wildfires in early summer.

The Arctic's intensifying hydrologic cycle and warming air temperatures are key drivers of many changes across the Arctic terrestrial environment—from snow cover to lake ice break-up to tundra vegetation productivity. During the 2021-22 season, despite an above-average accumulation of snow, the Arctic overall experienced an early and rapid snow melt, consistent with the expected changes to snow cover in a warmer Arctic. For example, the spring snow-free period across much of Eurasia was 30-50% longer than normal. North America and Eurasia experienced the second and third lowest June snow extents, respectively, in the 56-year record. However, for Arctic lakes in 2022, striking differences were observed between lake ice durations in North America and Eurasia, with predominantly shorter ice durations in North America and substantially longer durations in Eurasia. On the tundra, vegetation productivity (greening) in 2022 declined from the record-high values of the previous two years, but still represented the fourth highest value since observations began in 2000.



A sample of notable events and widespread disturbances from across the Arctic. Image by Climate.gov.

ARC2022 includes a discussion on climate consequences felt by Arctic Peoples. This essay from the Study of Environmental Arctic Change (SEARCH) illuminates how people experience change as the combined effects of altered physical conditions, infrastructure vulnerability, access to resources, and local to global economic drivers. This lesson is not only true of human well-being; environments, animals, and the Arctic system itself are experiencing multiple stressors, and it is the combined, cumulative effect that sustained Arctic observing aims to understand.

Northern migratory animals in particular are unique as they experience environmental, climatic, and anthropogenic stresses accumulated across many different regions, often well beyond the Arctic. Drawing on observations from a network of Tribal, State, and Federal partners in Alaska, seabird die-offs across the northern Bering Sea and southern Chukchi Sea were reported for the sixth straight year in 2022, maintaining concerns that massive ecological shifts in a warming and less ice-covered ocean are stressing these top predators in the food chain.

Arctic Geese, like seabirds, serve as important indicators of environmental changes and disturbances, including the spread of disease. In 2022, despite an outbreak of highly pathogenic avian influenza in North America and variable spring weather conditions, Arctic geese have remained high and stable in population. Given the scale and pace of change across the Arctic, however, there is a need for monitoring across a broad range of climate-sensitive indicator species, not just top predators. For example, this year's report showcases the critical function that pollinating insects play in Arctic ecosystems and the status of inventorying their populations internationally.

Overall, ARC2022 provides 15 essays highlighting an Arctic in transition. Long-term trends are reinforced by another year of observations, while regional differences across the Arctic are increasingly apparent. The Arctic remains a varied and expansive region to monitor. To understand its transition, local to international partnerships, especially with Arctic Peoples and Indigenous communities, are vital to the use of diverse observations and knowledge, as well as to identifying solutions to long-term climate impacts and abrupt disturbances.

ARC2022 explores observations from geographic regions and locations across the Arctic. The ARC2022 map provides a reference for notable locations mentioned in this year's report. Please also visit About Arctic Report Card 2022 for more information about the report.

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