Global Impacts

What Happens in the Arctic Doesn't Stay in the Arctic

The area encompassed by the Arctic Circle is approximately 6 percent of Earth's surface area, about the same as the area covered by the African continent. Yet, no part of the planet is untouched by this unique and rapidly-changing region.

FIGURE 9. During Superstorm Sandy in 2012, storm surges brought water inland and flooded the coastline of New Jersey, causing billions of dollars in damages. *Source: U.S. Air Force/Master Sgt. Mark C. Olsen*

MELTING LAND ICE CAUSES SEA LEVELS TO RISE.

The Arctic's melting land ice and glaciers contribute to the sea-level rise happening around the world. As this ice melts, much of it ultimately flows into the sea, adding volume to the world's oceans.

According to measurements from a variety of sources, the average global sea level has risen about 20.3 cm (about 8 inches) since 1901. The pace of sea level rise is increasing. Over the past two decades, sea level has risen globally at a rate of 3.1 mm (0.12 inches) per year on average. Between 2003 and 2008, melting Arctic glaciers, ice caps, and the Greenland Ice Sheet contributed 1.3 mm (0.05 inches) — more than 40 percent — of the total global sea level rise observed each year.

If greenhouse gas emissions continue to increase on their current trajectories, scientists project

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that global sea level may rise by an additional 0.3–1.3 m (1 to 4 feet) by 2100. About 40 percent of the world's population lives within 100 km of the world's coasts. Sea-level rise (and associated storm surges) poses significant threats to human lives and infrastructure, especially in these vulnerable and densely-populated coastal areas. Many places are already experiencing its effects. For example, storm surge associated with Superstorm Sandy resulted in billions of dollars of damage to coastal homeowners, businesses, and transportation infrastructure (Figure 9).

ARCTIC CHANGES RIPPLE THROUGH THE OCEANS AND ATMOSPHERE.

Although the movement of wind and water around Earth may seem random to the untrained eye, there are actually patterns and processes that influence our weather and climate in relatively predictable ways. Recent changes in the Arctic, however, may be disrupting those patterns, making weather and climate harder to predict.

Which way does the wind blow?

Changes in the Arctic have the potential to affect weather thousands of miles away.

One of the most prominent factors influencing weather in the Northern Hemisphere is the jet stream, a meandering air current that flows around the globe in a generally eastward direction (Figure 10). It results from the collision of colder air masses from the Arctic with warmer air masses from the tropics.

Because temperatures are increasing faster in the Arctic than at the tropics, the temperature gradient that drives the jet stream is becoming less intense. Some scientists have suggested that this could cause the jet stream to become weaker and more meandering, causing weather patterns to become more persistent — that is, to stick around longer — in the mid-latitudes. This could result in longer droughts, heat waves, and cold snaps in many heavily-populated areas of North America and Europe.

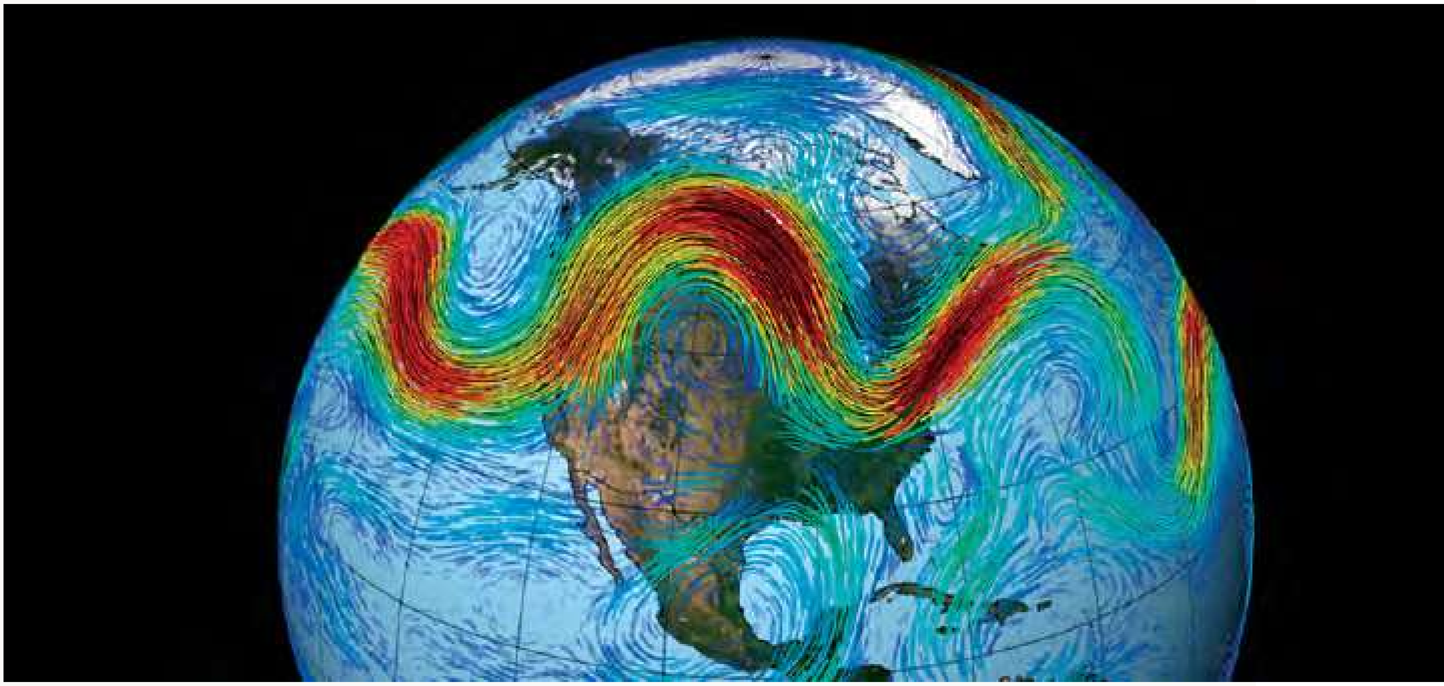

FIGURE 10. The jet stream — an air current generated when colder air masses from the Arctic meet warmer air masses from the tropics — is a major influence on weather in the Northern Hemisphere. *Source: NASA*

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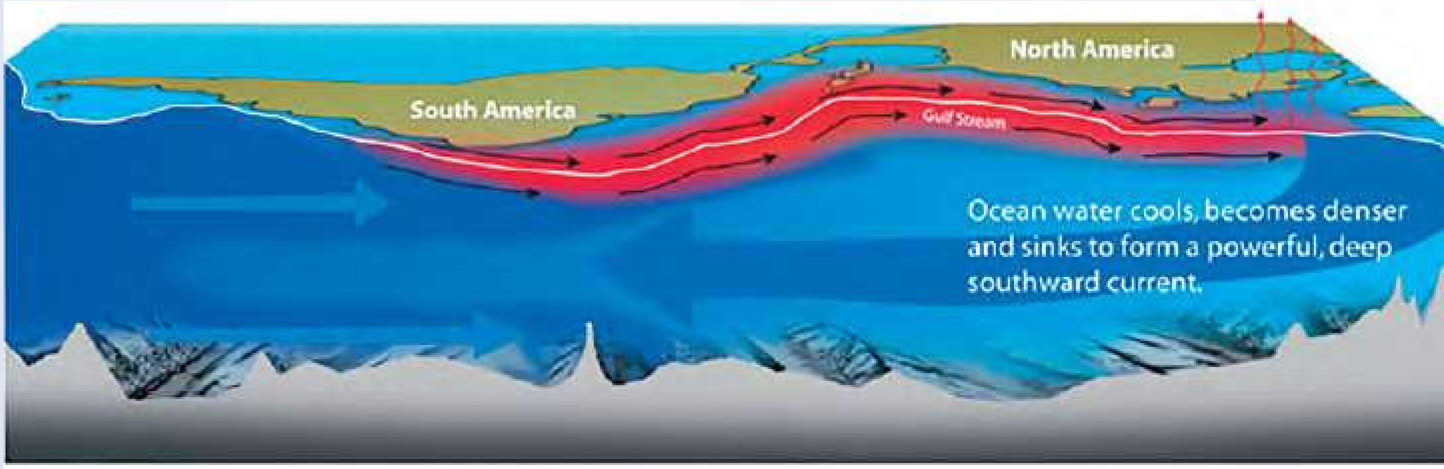
North Atlantic Ocean Circulation Today

Ocean releases large amount of heat to atmosphere



The Atlantic meridional overturning circulation (AMOC) carries a tremendous amount of heat from the tropics northward, warming the North Atlantic region. When the surface water cools at high latitudes, this large volume of cold, salty water sinks and flows southward, filling up the deep Atlantic Ocean basin and eventually spreading into the deep Indian and Pacific Oceans. Change within the Arctic could influence ocean circulation — and in turn, affect global climate. Examples of such impacts include sea level rise in the North Atlantic, a southward shift of tropical rain belts, restructuring of local marine ecosystems, ocean and atmospheric temperature and circulation changes, and changes in the ocean's ability to store heat and carbon. *Source: E. Paul Oberlander, Woods Hole Oceanographic Institution*

The 2014 National Research Council workshop report *Linkages Between Arctic Warming and Mid-Latitude Weather Patterns* summarizes presentations by meteorologists and climate scientists about how climate change in the Arctic might affect weather elsewhere in the world.

Side effects of a large dose of fresh water
Changes in the Arctic could affect the ocean's regular currents.

As Arctic ice melts, the Arctic Ocean is being flooded with fresh water. Because the circulation of ocean water is acutely affected by water temperature and salinity (saltiness), scientists believe this freshwater influx could have profound impacts on the circulation of ocean water worldwide. Ocean circulation, in turn, is a major driver for weather patterns, both in the Arctic and around the world.

Scientists cannot currently predict with a high degree of certainty exactly how climate change will affect ocean circulation. One possibility researchers are studying is whether changes in the Arctic Ocean might slow a major current in the Atlantic Ocean called the Atlantic meridional overturning circulation (AMOC). Some scientists believe that the AMOC is beginning to slow. Current models predict that the AMOC will slow, but not stop, during the 21st century. A significant change in the strength of the AMOC would alter winds, temperatures, and precipitation patterns around the globe, with potentially strong local effects along the east coast of the United States and the west coast of northern European countries.

Large-scale changes in ocean currents are not unprecedented. About 12,000 years ago, scientists believe a massive increase in freshwater influx from melting Arctic ice caused the AMOC to shut down entirely, contributing to a major shift of Earth’s climate.

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Norwegian fishing boat. *Source: Cliff Hellis*
INSET: Supermarket fish counter. *Source: Shutterstock/ Goran Bogicevic*

THE ARCTIC'S LIVING RESOURCES AFFECT GLOBAL HEALTH AND WELL-BEING.

If you eat seafood, it's likely that at some point you've enjoyed the resources of the Arctic marine ecosystem. Ten percent of the world's fish catch comes from Arctic and subarctic waters, and about half of the U.S. fish catch comes from subarctic waters. Changes in the Arctic marine environment could have important implications for this global food source, with potential effects on local communities, regional labor markets, and international trade.

On one hand, some changes in the Arctic could improve the outlook for fishermen. As sea routes open earlier in the spring and freeze later in the fall, it gets easier for fishing boats to access the Arctic's marine bounty. In addition, some favorite southern species are becoming more common farther north. For example, as populations of Pacific salmon have moved into Arctic waters, they may become an important food source for subsistence fishermen along Alaska's north coast.

On the other hand, new species entering an existing ecosystem may threaten existing populations. Atlantic cod, for example, have been displacing the endemic polar cod in the waters surrounding the Norwegian archipelago Svalbard. In addition, rising temperatures and an influx of fresh water from melting ice can cause rippling effects through the marine food chain. In the North Atlantic, for example, scientists project that ocean warming will cause shifts in the spawning and feeding grounds of several economically-important fish populations, including Arctic cod, herring, and capelin.

The fishing industry has long grappled with fluctuations in fish stocks. But some of the adaptations that have worked to keep up with ecological changes in the past and in other places — such as flexibility in fishing location, timing, and species — may be more challenging to employ in the Arctic due to environmental, economic, and management constraints.

In addition to their contributions to the global food supply, Arctic ecosystems are valuable for the biodiversity they represent. When species become extinct and the world's biodiversity decreases, we may lose the opportunity to benefit from important biological resources that could yield benefits in medicine, engineering, materials design, and other applications. Some areas of the Arctic are so remote and inaccessible that their ecosystems have not been studied at all. As the Arctic continues to warm and ecosystems reorganize, it is quite possible that unique Arctic species could disappear without our even knowing it.

FEEDBACK LOOPS ACCELERATE THE PACE OF CHANGE.

Many of the shifts underway in the Arctic are likely to contribute to further climate changes — both in the Arctic and around the globe. Positive feedback loops can amplify the initial temperature change, causing further warming.

Tracing the albedo effect

Walk barefoot across asphalt on a hot summer day and you'll quickly find that dark surfaces trap more heat than light-colored surfaces.

That principle plays out on an enormous scale in the Arctic. As the area covered by reflective, white snow and ice shrinks, darker surfaces like tundra and water — which absorb much more sunlight — are left behind. As a result, the reflectivity, or *albedo*, of the region decreases, causing more heat to be absorbed and the surface and air temperature to rise. In turn, these rising temperatures cause more snow and ice to melt, and the cycle begins again (Figure 11).

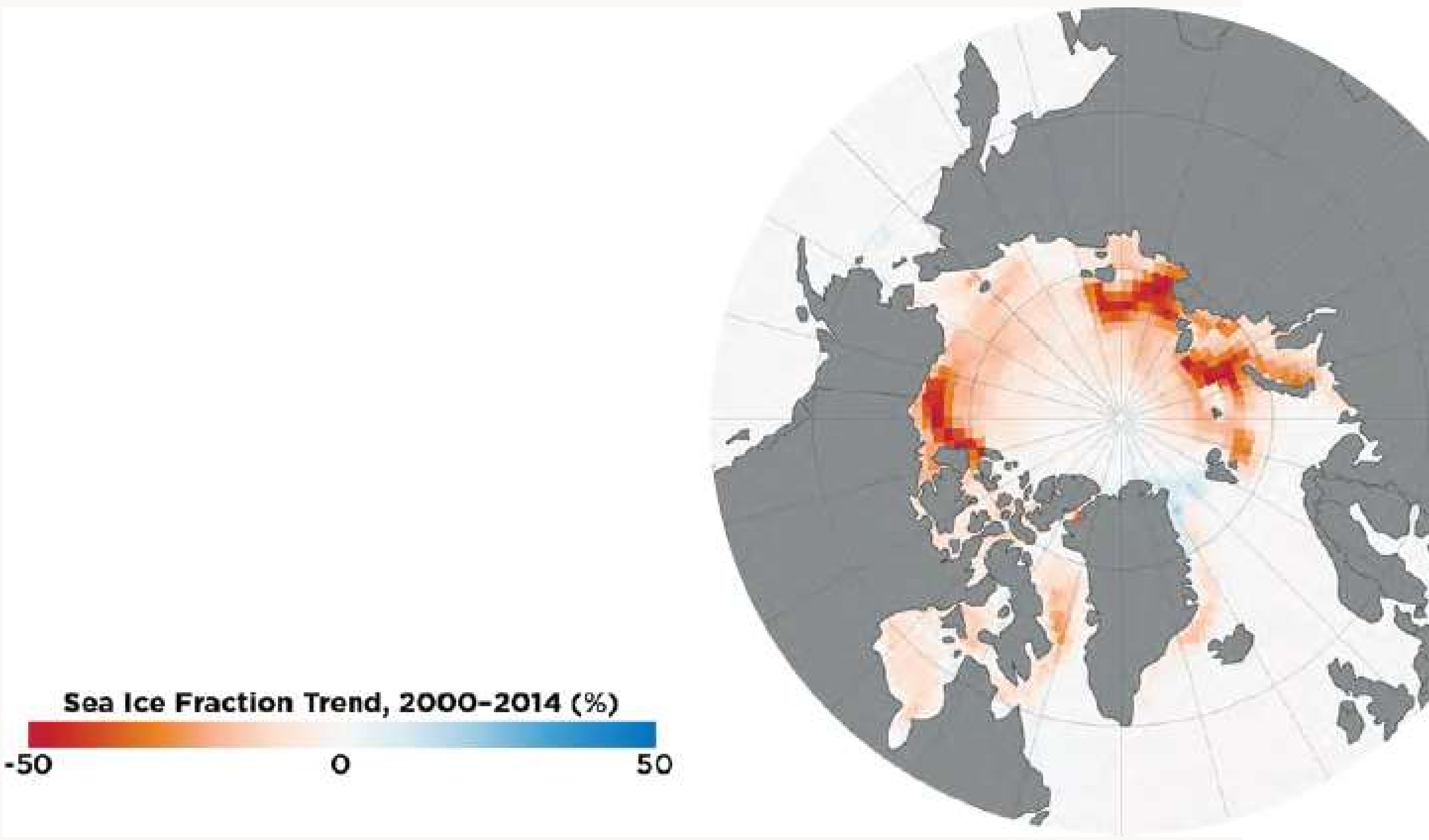

FIGURE 11. While sea ice is mostly white and reflects sunlight, ocean water is darker and absorbs more of the Sun's energy. A decline in Arctic albedo (reflectivity) has been a key concern among scientists since summer Arctic sea ice cover began shrinking in recent decades. As more solar energy is absorbed by the ocean, air, and icy land masses, it enhances the ongoing warming in the Arctic region, which is more pronounced than anywhere else on the planet. This map shows the net change in sea ice cover from 2000 to 2014. Shades of red depict areas with less ice cover.
Source: NASA Earth Observatory

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Thawing permafrost has the potential to release huge quantities of carbon into the atmosphere in the form of carbon dioxide (typically from dry environments) and methane (typically from wet environments). *Source: NASA Earth Observatory.*

Scientists believe the albedo effect is one of the major reasons why the Arctic is warming more quickly than the rest of the planet. Some scientists have suggested that this effect may be exacerbated by soot from burning fuels and vegetation in the Arctic, as well as in the lower latitudes, which finds its way into the Arctic, and darkens the remaining snow and ice. In addition, warmer air holds more water vapor, which traps even more heat in the lower atmosphere.

The 2013 National Research Council report *Abrupt Impacts of Climate Change: Anticipating Surprises* explores the potential for the albedo effect and other climate factors to contribute to rapid changes in physical, biological, and human systems around the globe.

Releasing ancient stores of greenhouse gases

Locked within the Arctic's ancient ice and permafrost are vast quantities of carbon, frozen as either plant matter or within icy crystals of methane gas. If warming temperatures were to release these ancient carbon stores into the atmosphere, they would exacerbate the greenhouse effect and have a potentially massive impact on the Earth's climate.

The carbon stores in Arctic soil are there due to the enterprising plants that grow in the thin layer of unfrozen soil atop permafrost. Plants are essentially made of carbon. When a plant dies in a temperate area, it decomposes, releasing some of its carbon into the air and some into the soil. But when a plant dies in a place too cold for decomposition, it simply stays put, locking its carbon in place. Plant by frozen plant, that carbon adds up. If large areas of permafrost were to thaw, all of that previously-frozen plant matter would begin to decompose, releasing huge quantities of carbon into the atmosphere in the form of carbon dioxide or methane.

Scientists think that much of the carbon stored in the Arctic is frozen within icy crystals called

methane clathrate. These crystals form under specific conditions of high pressure and low temperature that can occur either deep in Earth or under water. Scientists are not sure how much clathrate is in the Arctic, but as ice and permafrost continue to degrade and collapse, the clathrates could release more of this methane into the atmosphere.

Although both carbon dioxide and methane are greenhouse gases, they behave differently in the atmosphere. Carbon dioxide persists for a long time in Earth’s atmosphere and is the major driver of long-term, irreversible climate change. Methane is many times more potent as a greenhouse gas than carbon dioxide over short time scales. Thus an abrupt release of a large quantity of methane could cause larger, more rapid climate changes, but the magnitude of the effect would taper gradually as the methane breaks down in the atmosphere to form carbon dioxide.

Wildfire on frozen ground

Wildfires can and do happen in the Arctic. In recent years, scientists and Arctic residents have watched with alarm as wildfires have begun spreading into some permafrost regions. Studies suggest these fires, which are made possible by the increasingly dry conditions resulting from local climatic changes, are unprecedented over the past 10,000 years.

Wildfires could exacerbate climate change in three ways. First, because they burn plant material, they release carbon. Second, the dark, charred ground they leave behind increases warming because of the albedo effect. Finally, if a fire is severe enough to burn the surface organic layer of soil, it can speed the thawing of permafrost below, accelerating the release of carbon from the previously frozen soil.

Wildfire burns near Currant Creek in Lake Clark National Park, Alaska. *Source: National Park Service, Alaska Region*