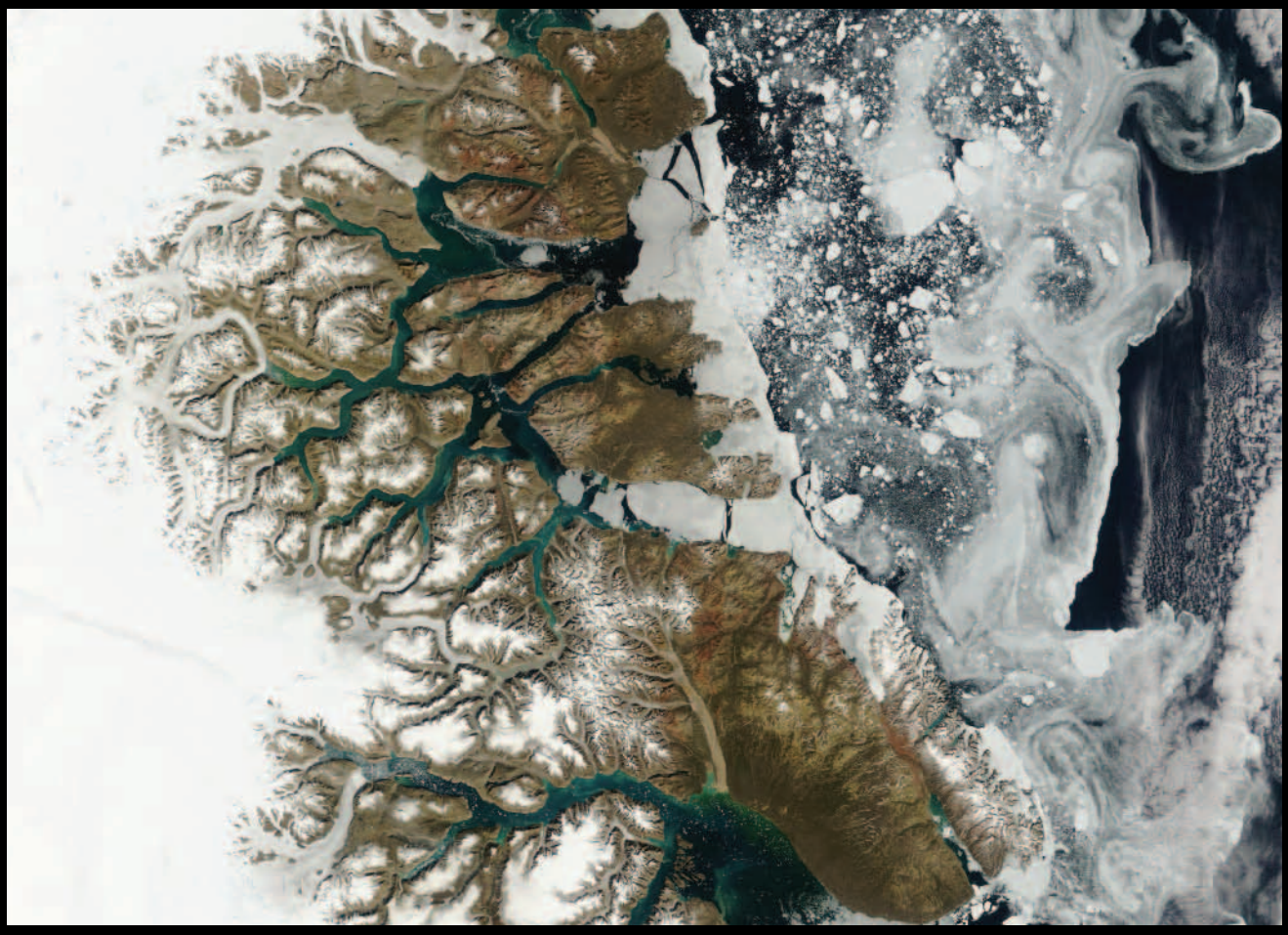
National Aeronautics and Space Administration



UNDERSTANDING EARTH

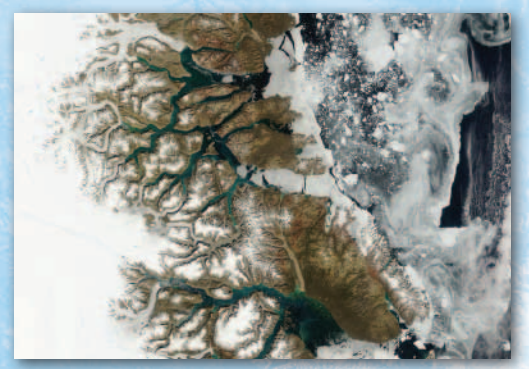
The Icy Arctic





In early July 2011, the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra satellite captured this natural-color image of the Arctic. Relatively clear skies allow the smooth, white surface of sea ice to be seen near the center of the image. Greenland's brilliant white ice sheet is also visible.

UNDERSTANDING EARTH:
The Icy Arctic



On the cover: Summer thaw was underway on the fringe of Eastern Greenland when the MODIS instrument on NASA's Terra satellite captured this image on July 13, 2007.



Photo credit: Kristin L. Laidre, University of Washington

[Above] A polar bear walks across the pack ice—a large mass of sea ice—in Baffin Bay west of Greenland.

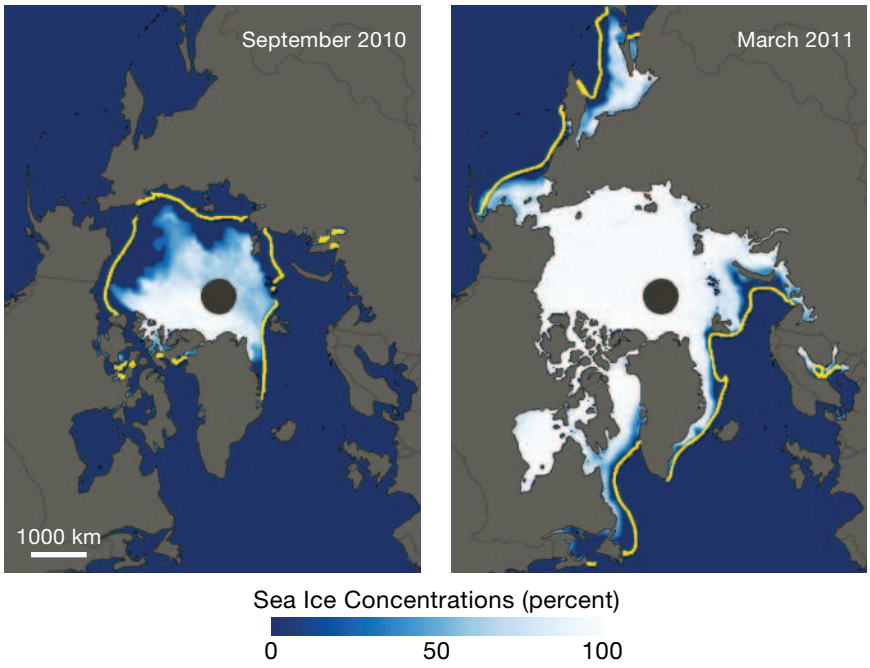
WHAT IS THE ARCTIC?

The Arctic is one of the coldest regions on Earth. Scientifically defined as the region north of the Arctic Circle (located at 66° 33' N latitude), the Arctic can be loosely defined by its icy waters largely bound by treeless land. The extent of sea ice atop the cool, nutrient rich Arctic Ocean expands and contracts in rhythm with the seasons, which oscillate between total darkness and total daylight, year after year. Cooler temperatures and frozen soil limit the number of trees and other shrubs that grow in the Arctic; in fact, our planet's northernmost tree line currently hovers near the Arctic's southern edge.

Over the last few decades however, the average global temperature has been on the rise. Temperatures in the Arctic have risen at nearly twice the rate as temperatures elsewhere on the planet, and as warmer temperatures creep northward, so too might vegetation.

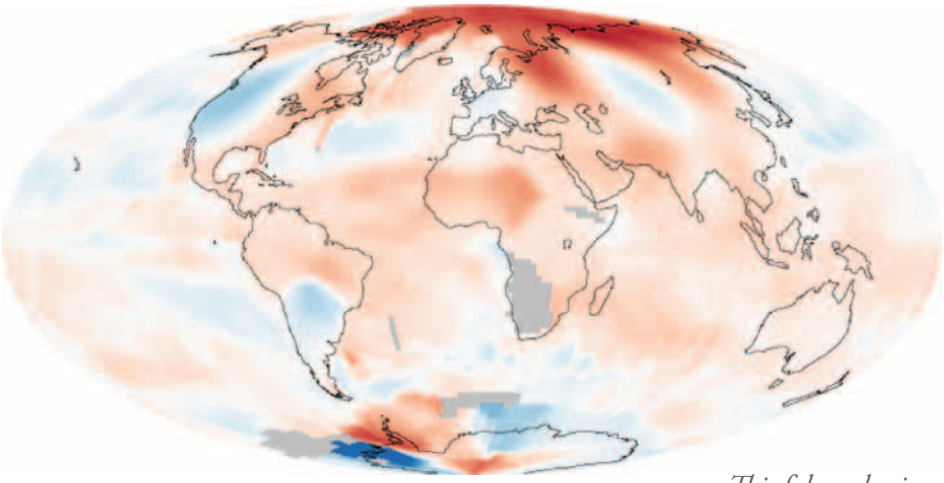
The image below shows the Arctic Circle, defined as 66° 33' N latitude. The region north of the Arctic Circle is the Arctic.



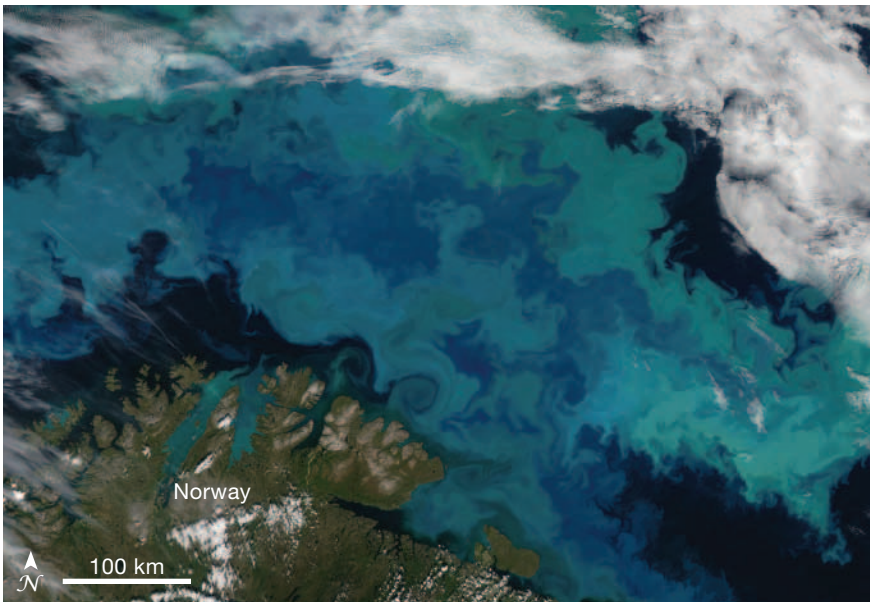


[Above] Each summer, Arctic sea ice melts considerably, usually reaching its minimum extent in September. From around September 22 to March 20, nighttime hours exceed daylight hours in the Northern Hemisphere, causing the Arctic to cool and the extent of sea ice to grow. Arctic sea ice usually reaches its maximum extent in March. This image pair shows Arctic sea ice concentrations for September 2010 and the following March. The yellow outline on each image shows the median sea ice extent observed by satellite sensors in September and March from 1979 to 2000. These images are made from a combination of observations from the Special Sensor Microwave/Imagers (SSM/Is) flown on a series of Defense Meteorological Satellite Program missions and the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), a Japanese-built sensor that flies on NASA's Aqua satellite.

[Below] In May 2010, temperature records assembled by the NASA Goddard Institute for Space Studies (GISS) showed wide expanses of slightly above-normal temperatures (shades of red) and slightly below-normal temperatures (shades of blue) over most of the globe. Note the concentration of warming over the Arctic (darkest shades of red) where temperatures were close to 5 °C (9 °F) above average. The Arctic is very vulnerable to warming. Both sea ice retreat and snowmelt reduce Earth's reflectivity, which can lead to increased warming and further melting that amplify the initial change.

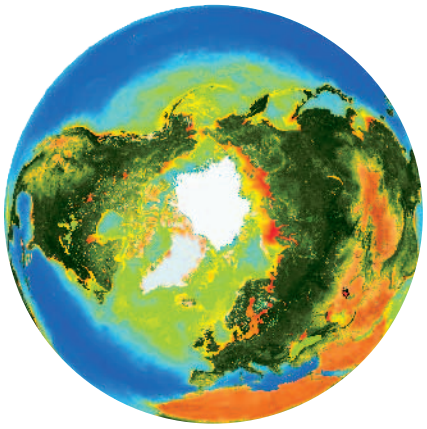


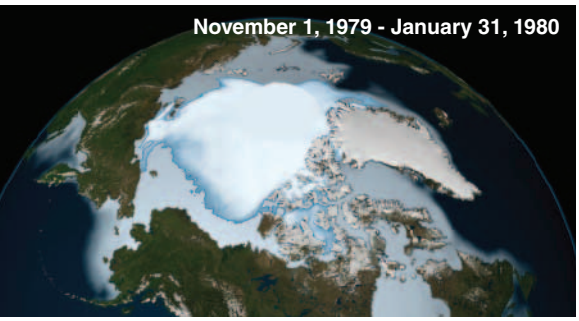
ICY FACT: Many species thrive in cooler ocean waters, which tend to be rich in nutrients and plant life.



[Above] Each spring, the nutrient-rich waters of the Arctic are exposed to abundant sunshine and the region becomes a breeding ground for phytoplankton—microscopic plant organisms that form the foundation of the aquatic food web. Vibrant shades of blue and green reveal a large phytoplankton bloom in the Barents Sea in this natural-color image taken on August 14, 2011, by the MODIS instrument onboard NASA's Aqua satellite.

This false-color image [below] made with data from the SeaWiFS, or Sea-viewing Wide Field-of-View Sensor, shows chlorophyll concentrations—indicating phytoplankton—during Northern Hemisphere summer. Over the oceans, red, yellow, and green show dense phytoplankton blooms while blue shades show where there is very little phytoplankton. Phytoplankton thrive along coastlines where runoff from rivers provides an abundance of nutrients. Data from SeaWiFS help scientists understand the spatial distribution of phytoplankton in the Arctic.





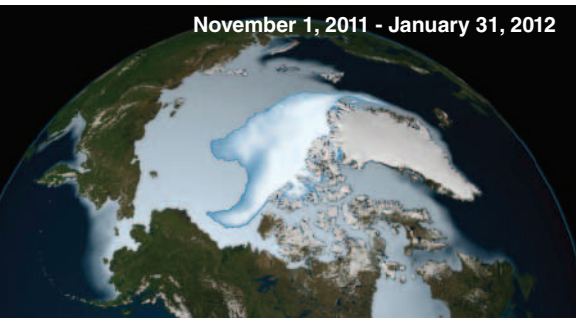


Image credit: NASA

The images above show Arctic sea ice coverage for November 1 to January 31 from 1979 to 1980 [top] and 2011 to 2012 [bottom] as observed by passive microwave sensors on NASA's Nimbus-7 satellite and by the Special Sensor Microwave Imager/Sounder (SSMIS) from the Defense Meteorological Satellite Program (DMSP). Multi-year sea ice—i.e., ice that has survived two or more melt seasons—is shown in bright white, while average sea ice cover is shown in milky white. Multi-year sea ice has been vanishing at a rate of -15.1% per decade. The disappearance of multiyear ice makes Arctic sea ice more vulnerable to further decline in the summer.

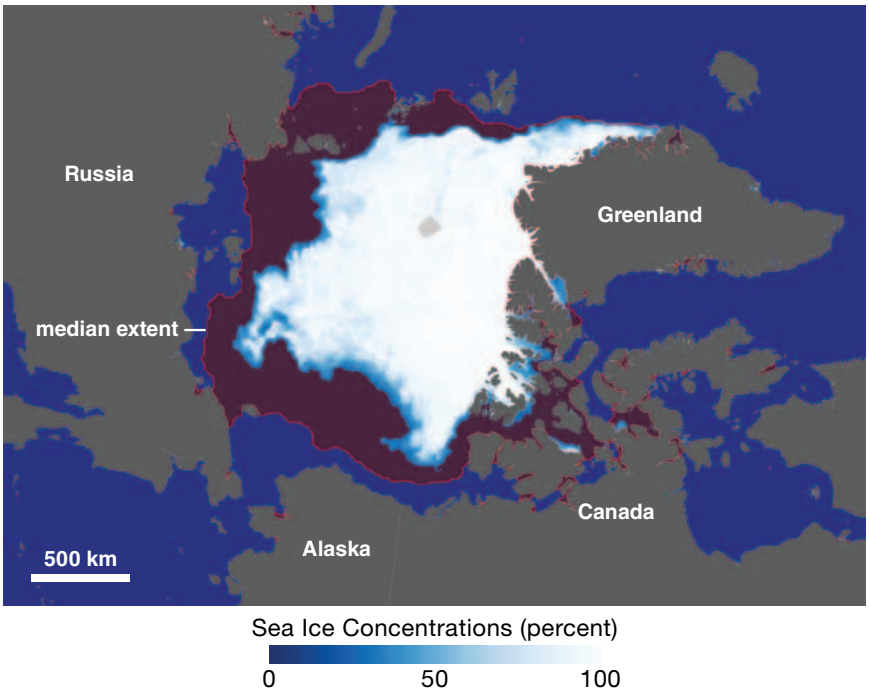
ICY FACT: Since 1979, the five lowest Arctic sea ice extents have all occurred between 2007 and 2011.

CHANGES IN THE ARCTIC

For the past several decades, Earth-observing satellites have enabled continuous global observations of our home planet, and have played an especially important role in revealing the magnitude of change in remote, difficult to access locations like the Arctic. Over the last decade, satellite data—often combined with data from other sources—have revealed that the Arctic is changing at rates faster than anywhere else on Earth. These changes include dramatic reductions in minimum sea-ice extent; alterations of landscape resulting from thawing of frozen soil, or permafrost; increases in phytoplankton productivity; changes in the extent and types of vegetation found in the Arctic; and changes in the intensity of storms impacting Arctic coasts.

As temperatures rise in the Arctic, the extent of sea ice declines. Sea ice is highly reflective of the Sun's energy; therefore, reductions in sea ice impact Earth's radiation budget. Rather than reflecting most of the Sun's energy, ice-free areas absorb sunlight causing subsequent warming of the ocean.

Warmer ocean temperatures in turn impact Arctic coastlines, which can cause permafrost to thaw and rates of erosion to accelerate. The warming can also change global ocean and atmosphere circulations that subsequently affect weather patterns. Changes in the Arctic environment are interrelated and have both long- and short-term effects on Earth's land surfaces, oceans, and atmosphere, ultimately impacting the Earth's climate system.



[Above] In September 2011, sea ice covering the Arctic Ocean declined to the second-lowest extent on record. This image depicts the average sea ice extent in September 2011 as observed by the AMSR-E instrument onboard NASA's Aqua satellite. The purple area shows the median extent for 1979–2000.

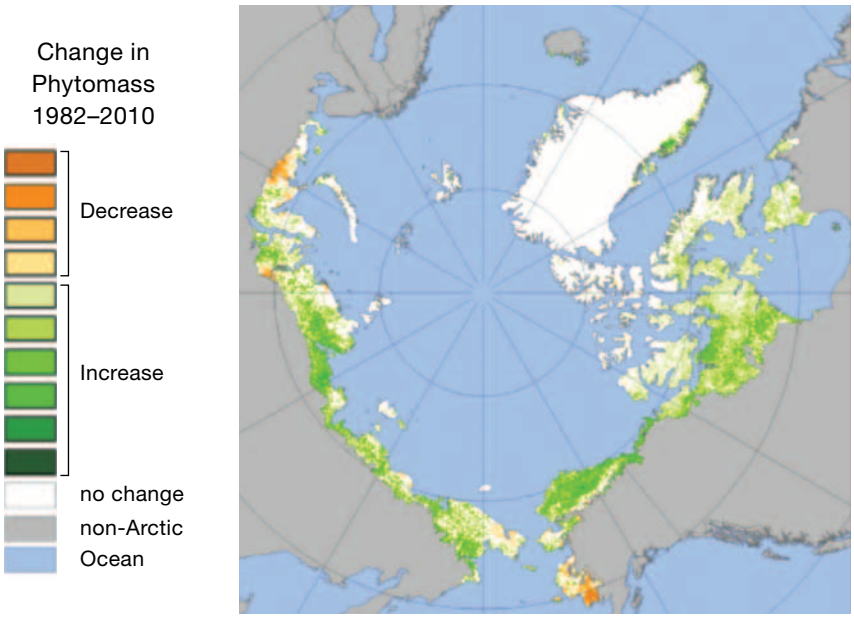


Image credit: Howard Epstein et al.

[Above] The Arctic is becoming greener and greener. In fact, scientists have discovered that vegetation in the Arctic—i.e., Arctic biomass—has increased nearly 20% from 1982 to 2010. Shades of green indicate areas where vegetation increased while orange indicates areas where vegetation decreased. The data used to create this image are from a 30-year Advanced Very High Resolution Radiometer Normalized Difference Vegetation Index dataset produce at NASA's Goddard Space Flight Center by Jorge Pinzon.



Photo credit: U.S. Geological Society

[Above] In the Arctic, permafrost—ground that remains at or near 0 °C (32 °F) for at least two years at a time—is beginning to warm and thaw, particularly along coastlines, and shifting inward. Ocean waves—especially in ice-free areas—undercut permafrost cliffs, which can cause large chunks of land to erode away. This image shows coastal erosion of mud-rich permafrost along the Beaufort Sea coastline.

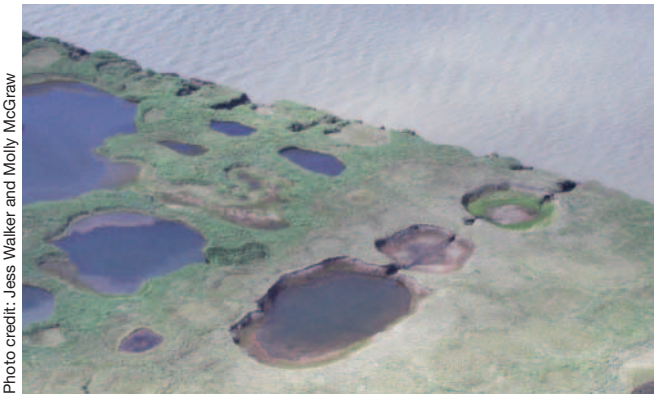


Photo credit: Jess Walker and Molly McGraw

[Left] Lakes near a riverbank in Arctic Alaska are being drained because of permafrost thawing and ice-wedge melting.

ICY FACT: Warming temperatures and subsequent melting of mountain glaciers, ice caps, and the Greenland ice sheet contributes to global sea level rise.

[Right] This image, created with data from the Gravity Recovery and Climate Experiment, or GRACE satellites, shows dramatic changes in Greenland's ice mass from 2003 to 2011. The darkest shades of blue indicate areas that lost the most ice mass—i.e., areas where the most net melting occurred. Greenland has been losing large amounts of water into the ocean as surface ice melts and glaciers discharge more ice into the sea.

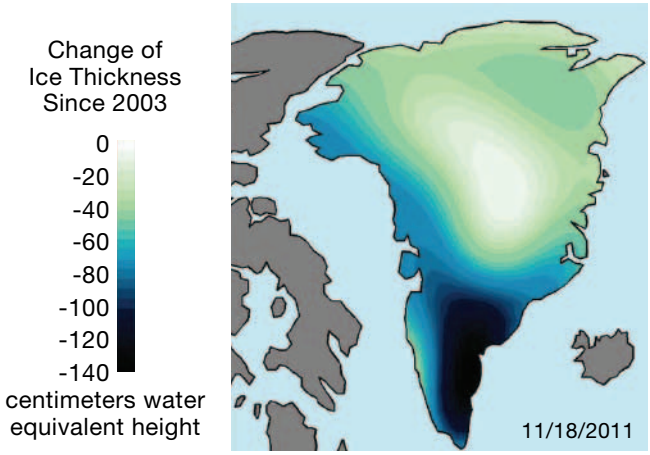


Image credit: NASA/Jet Propulsion Laboratory, California Institute of Technology, F. Landerer, J. Wahr



Photo credit: NASA/Kathryn Hansen

[Above] NASA's ICESCAPE mission, or Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment, was a NASA shipborne project aimed to study the impacts of climate change on ecosystems and chemistry in the Chukchi and Beaufort Seas along Alaska's western and northern coasts during summer months in 2010 and 2011. This is an image of the U.S. Coast Guard Cutter Healy, the official platform used during ICESCAPE.



Photo credit: NASA/Kathryn Hansen

[Above] As ice melts, the liquid water collects in depressions on the surface, forming melt ponds like the ones shown here. ICESCAPE science teams collected water samples from the ponds to examine water chemistry and to observe the colonies of plankton growing in the water and on the surfaces of the ice.

MONITORING THE ARCTIC

To understand the changes taking place in the Arctic, the scientific community must view the Arctic and the rest of the world as one large, interactive, coupled system.

To better understand the Arctic environment, scientists at NASA are working in collaboration with various experts from other federal agencies, universities, private companies, and not-for-profit organizations. From shipborne and airborne campaigns to decadal satellite missions, NASA keeps a close eye on the changes taking place in the Arctic.

Future missions such as ICESat-2 and GRACE Follow-On will continue to provide data that will help quantify changes in sea ice thickness and ice-sheet mass, identify the mechanisms that drive those changes, and determine the impacts of these changes on future global sea level.

ICESat and ICESat-2



Launched in 2003, NASA's Ice, Cloud, and land Elevation Satellite (ICESat) mission was designed to measure ice-sheet elevations, changes in elevation through time, height profiles of clouds and aerosols, land elevations and vegetation cover, and approximate sea ice thickness. ICESat's sole instrument—the Geoscience Laser Altimeter System (GLAS)—measured the vertical distance from orbit to the Earth's surface 40 times per second with a pulse of energy from a laser. When each pulse was fired, ICESat collected data for calculating exactly where it was in space using global positioning system (GPS) receivers. These data were used to calculate the elevation and position of each point measurement on Earth to determine the net amount of ice lost or gained each year for Greenland and Antarctica. The mission collected data until 2009, when the final laser within GLAS failed.

The second generation ICESat, or ICESat-2, is scheduled to launch in 2016. Until then, NASA's IceBridge mission will collect ice-sheet elevation and other data—see **Filling in the Ice-Cap Gap** on the next page.

ICY FACT: Satellite instruments such as the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) aboard the Aqua spacecraft, have provided a continuous, nearly complete record of Arctic sea ice extent since 1979.

Filling in the Ice-Cap Gap



Image credit: U.S. Navy

NASA's IceBridge mission is the world's largest airborne survey of polar ice. Through IceBridge, scientists are able to track changes in the extent and thickness of polar ice, important for understanding ice dynamics. The mission began in March 2009 as a means to fill the gap in polar observations between the loss of NASA's ICESat satellite—in 2009—and the future ICESat-2 mission planned for 2016. IceBridge is critical for ensuring a continuous series of observations.

The mission yields an unprecedented three-dimensional view of Arctic and Antarctic ice sheets, ice shelves, and sea ice. In the spring, IceBridge pilots conduct flights over the Arctic. The flights provide a yearly, multi-instrument look at the behavior of the rapidly changing features occurring in the world's icy Arctic.



Image credit: NASA/Michael Studinger

[Left] On May 12, 2011, IceBridge surveyed Barnes Ice Cap, which covers about 2300 square miles (6000 square kilometers) of Baffin Island in the Canadian territory of Nunavut. In addition to mapping its surface elevation, instruments also measured the bedrock topography, which will allow scientists to better model ice dynamics and estimate when the Barnes Ice Cap will be completely melted.

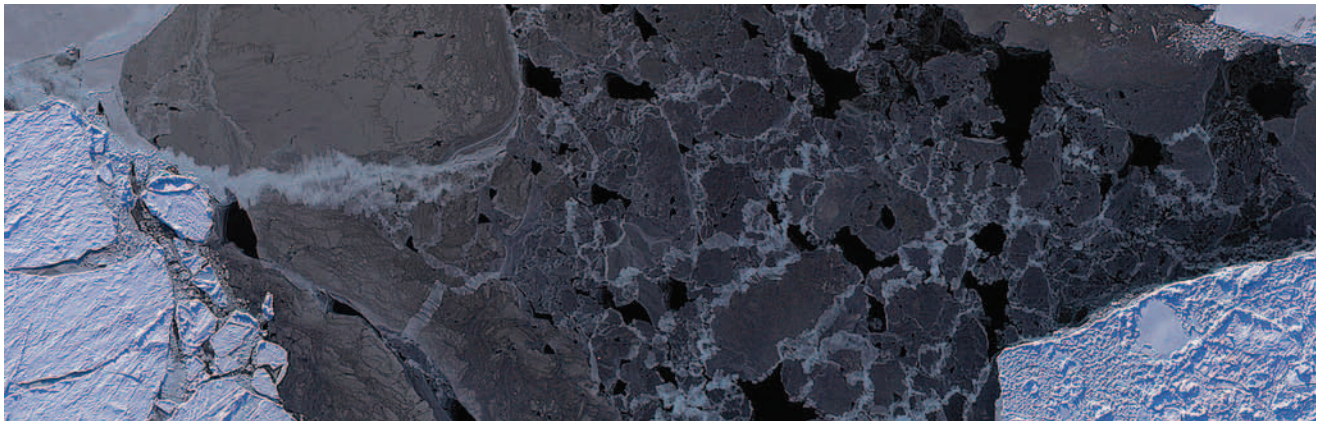


Image Credit: NASA/Eric Fraim

[Above] A variety of different types of sea ice are visible in this image taken on April 2, 2012 by the Digital Mapping System on NASA's P-3 aircraft during the fourth annual IceBridge campaign. The image depicts an area approximately 3083 feet (940 meters) across, and 672 feet (205 meters) wide.

THE ARCTIC AND YOU

The impacts of warming in the Arctic will be felt far beyond the local ecosystems and people who live in the region. Consider the recent decline in Arctic sea ice cover; it is likely that Arctic-shipping routes will become more popular if sea ice continues to decline. From international trade, to weather patterns, shipping routes, natural resource use, and more, there will be impacts on human life. Adaptation and mitigation strategies can be used to help lessen the impacts of warming in the Arctic on human life.



Photo credit: Ilovegreenland

[Above] Children stand clothed in traditional Greenlandic costume signifying their Inuit heritage. The Inuit—meaning "the people"—are indigenous peoples who inhabit the Arctic. Typically, children wear the traditional costume on the first day of school.

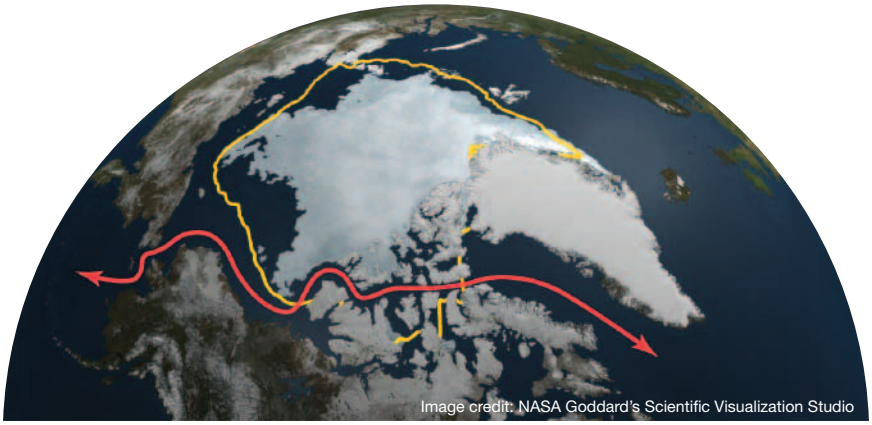


Image credit: NASA Goddard's Scientific Visualization Studio

[Above] In 2011, Arctic sea ice declined to the second-lowest extent on record. This image shows the 2011 minimum reached on September 9 as observed by the AMSR-E instrument onboard NASA's Aqua satellite. On this date, sea ice declined to a level far smaller than the 30-year average (yellow line) and opened up the Northwest Passage shipping lanes (in red).

ICY FACT: Sea ice in the Arctic is one of the main controls on weather for the entire planet. Changes in temperature and precipitation trends in North America for example, could impact agriculture and water supply in the United States.



Photo credit: USGS/Benjamin Jones

[Above] According to the Arctic Council, nearly four million people live in the Arctic. Unfortunately, coastal erosion and thawing permafrost have damaged foundations of homes, buildings, and other man-made infrastructures. This photograph shows a cabin along the Arctic Alaska coastline that was recently washed into the ocean because the land it was sitting on eroded away.

Scientists working in the Arctic *[top image]* are investigating bromine explosions—a cascade of chemical reactions that abruptly increases bromine monoxide (BrO) in the lower atmosphere. BrO depletes ground-level ozone and deposits toxic mercury on sea ice, snow, and land. Humans can ingest mercury that has been passed up the food chain from marine organisms that live in these areas. The bottom image shows BrO in the atmosphere observed by the European Space Agency's GOME-2 satellite on March 11, 2012, across the Alaskan North Slope looking south toward the Brooks Range at the horizon, which blocked the bromine from going further south into the Alaskan interior. The presence of BrO in the air is shown in a semi-transparent layer in shades of red-orange across the North Slope landscape where lakes are visible on the land surface. The BrO was originated from offshore sea ice and spread onto land along with the moving air mass.



Image credit: NASA/Jet Propulsion Laboratory-Caltech/University of Bremen

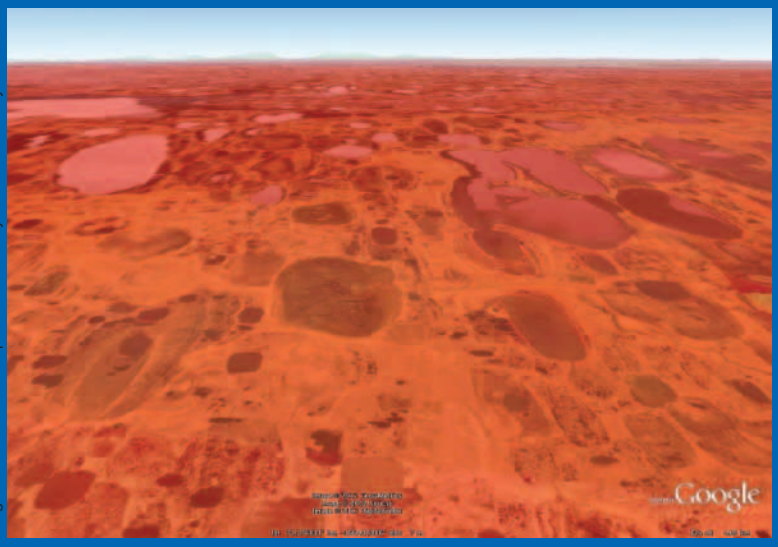


Image credit: NASA/Jet Propulsion Laboratory-Caltech/University of Bremen

REDUCE YOUR CARBON FOOTPRINT

Take action and go greener with these quick tips adopted from the Environmental Protection Agency's Global Climate Change website:

1. Reduce waste. Reduce, reuse, recycle, and choose products made from recycled materials whenever you can.

2. Power down. Conserve energy by unplugging cell phone chargers, laptops, video game consoles, etc. when not in use.

3. Travel green. When possible, walk, bike, skateboard, rollerblade, or take a bus.

4. Be water-wise. For example, turn off the water while brushing your teeth, and try taking shorter showers.

5. Consider buying local. The further your food travels, the more greenhouse gas emissions are produced in transporting the food from the farm to your plate.

These tips and more can be found online at *www.epa.gov/climatechange/kids/solutions/actions.*

NASA Resources:

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