How climate change can affect human and natural systems

A summary of key impacts of increasing global temperatures identified by the 2007 IPCC report:

Water

- Billions of people will be exposed to stresses on their water supplies.
- Climate change will exacerbate water stress in some regions and alleviate it in others.
- Developing nations with little capacity to manage water resources will be hardest hit.
- Areas that depend on water supplies stored in glaciers and snow cover (more than 16% of world population) face scarcities as glaciers continue to melt and eventually disappear.

Food

- Increased temperatures, heat waves, precipitation changes, drought, and pests will harm agricultural production over much of the globe, though some regions will benefit.

Coasts

- Coastal populations will be exposed to more flooding, erosion, and inundation from rising sea levels and more intense storms, especially in low-lying areas and on small islands.

Health

- Rising temperatures and heat waves will increase the number of heat-related deaths (outweighing a decrease in deaths from cold exposure).
- Higher ozone levels will increase the frequency of cardiorespiratory disease.
- Climate changes will help spread vector-borne and pathogenic diseases such as malaria, dengue fever, and cholera.
- Increased flooding will harm human health directly, and also indirectly—by facilitating the spread of disease and damaging health infrastructure.

Ecosystems

- About 20% to 30% of plant and animal species are at increased risk of extinction.
- Progressive acidification of the oceans will have negative impacts on marine organisms critical to the ocean food web.
- Widespread mortality of biodiverse coral reefs is expected.
- Decreased rainfall in some regions will increase the risk of wildfires.

Economic Costs

- Damages from climate change are likely to be significant and increase over time. Global mean losses could be 1% to 5% of gross domestic product for a likely 4°C warming over the next century.

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IPCC reports on "The Physical Science Basis," "Impacts, Adaptation and Vulnerability," and "Mitigation of Climate Change" are available at www.ipcc.ch.

Climate Change

Highlights of the Intergovernmental Panel on Climate Change (IPCC) 2007 report and Woods Hole Oceanographic Institution research on the ocean's role on climate change

The IPCC 2007 report assesses the state of our understanding of climate change. It represents six years of work by 800 contributing authors, 420 lead authors, and 2,500 scientific reviewers, from 130 countries. Here is a summary of significant findings of the report:

While natural forces have influenced Earth's climate (and always will), human-induced changes in atmospheric greenhouse gas levels are playing an increasingly dominant role.

The significant increase in average global temperatures over the past half-century can be attributed to human activities with a certainty of more than 90 percent.

Temperature rises have already affected various natural systems in many regions.

Continued greenhouse gas emissions at or above current rates would cause further warming and induce climate changes during the 21st century that would very likely be larger than those observed during the 20th century.

Temperatures & CO_2 levels are rising

- CO_2 levels have risen 35 percent since the industrial revolution began in the mid-18th century and are likely at their highest levels in the past 20 million years. The main source is the burning of fossil fuels, such as oil, natural gas, and coal.
- Earth's average temperature has been increasing over the past century (albeit not uniformly), with warming accelerating over the past 50 years. Of the hottest 12 years since temperatures began to be measured in the 1850s, 11 have occurred in the past 12 years.
- No known natural forcing can account for the recent severe warming.

How much excess carbon dioxide can the oceans hold?

WHOI geochemist Scott Doney and colleagues are leading efforts to measure the ocean's ability to continue to absorb excess greenhouse gases and help offset global warming.

Iron fertilization and the ocean's 'twilight zone'

WHOI biogeochemist Ken Buesseler has shed light on the "twilight zone," a dim ocean layer that acts as a critical gateway allowing some carbon-filled particles to sink to the depths. The research is key for assessing strategies to mitigate climate change by fertilizing the oceans with iron—to promote blooms of photosynthetic marine plants and transfer more CO_2 from the air to the deep ocean.

Do jelly-like animals help shunt CO_2 to the deep sea?

WHOI biologist Larry Madin is investigating salps, small transparent ocean creatures that swarm by the billions. Salps may transport tons of carbon per day from the ocean surface to the deep sea and keep it from re-entering the atmosphere.

Precipitation patterns have changed

- Changes in precipitation amounts have been detected over large portions of the world.
- Warmer air temperatures induce more evaporation, drying some areas of the globe.
- Warmer air also holds more water vapor, leading to heavy rains, when this higher water-content atmosphere drops its moisture.

Air-sea interactions that drive weather and climate

WHOI physical oceanographers Lisan Yu and Bob Weller are integrating observations from satellites, moorings, ships, and models to advance understanding of critical air-sea exchanges of heat, fresh water, and momentum that affect evaporation and rainfall patterns.

Sensitive but tough sensors to get precise, essential data

The WHOI Upper Ocean Processes Group has developed integrated systems for moorings that can measure heat, sunlight, wind speed and direction, precipitation, barometric pressure, humidity, air temperature, sea surface temperature, and salinity—key data computer models needed to calculate climate.

Oceans are warming; salinity is changing

- Increased evaporation leaves some areas of the ocean more salty, while increased rainfall adds fresh water to other areas.
- Oceans in the mid- and high latitudes show evidence of freshening, while those in tropical regions have increased in salinity.
- Global mean sea surface temperature increased 0.9°F in the 20th century, and the IPCC stated that "global ocean heat content has increased significantly since the late 1950s."

Tracking ocean changes over the past half-century

WHOI physical oceanographer Ruth Curry and colleagues are analyzing temperature and salinity data collected throughout the oceans to investigate whether climate change is affecting ocean circulation and the global water cycle, and vice versa.

Monitoring the global water cycle

WHOI physical oceanographer Ray Schmitt and engineer Bob Petitt are designing a self-cleaning sensor to solve the hurdle of biofouling. Used on drifters, the sensor will be able to obtain extensive salinity measurements that reveal patterns of evaporation and precipitation over the ocean.

Rising temperatures, rising disease?

WHOI biologist Rebecca Gast is exploring whether warming ocean temperatures, among other factors, may make it easier for human pathogens to survive in coastal waters.

WHOI scientists Don Anderson and Dennis McGillicuddy are investigating links between climate changes and harmful algal blooms.

Extreme weather events are more frequent

- Since 1950, cold days and nights and frost days have become less frequent, while hot days and nights and heat waves have become more frequent.
- Heavy precipitation events have increased and droughts have become more intense, particularly in the tropics and subtropics, because of higher temperatures and changes in precipitation patterns.
- The combination of increasing air temperatures and sea surface temperatures can increase the energy of tropical storms.

Reconstructing the history of droughts & tropical storms

WHOI geologist Jeff Donnelly has systematically collected evidence from around the world to piece together a long-term chronicle of tropical storms and hurricanes in preindustrial times as a means to better predict the frequency and intensity of future storms. Reconstructing the history of water levels in lakes from Cape Cod to New York over the past 11,000 years, he has found long-lasting droughts that could foretell future conditions in the Northeast in an era of global warming.

This document, with related Web links to WHOI projects, is available at: www.whoi.edu/topics/climatechange/highlight_brochure.

Ice and snow cover are disappearing

- Glaciers are retreating and ice and snow cover are disappearing in many regions around the world.
- Melting ice exposes land or water, both of which reflect less solar radiation than ice. That reinforces rising temperatures, which melt more ice. Once such loops begin, their endpoint is hard to predict.
- Increased melting of the vast Greenland Ice Sheet may make it vulnerable to sudden, catastrophic breakup.

What's causing the Greenland Ice Sheet to surge?

WHOI geologist Sarah Das has established ice camps on Greenland to investigate a theory that warmer temperatures are creating more and larger lakes atop the ice sheet, which cause fractures in the ice that leak water to the glacial base and lubricate slippage into the sea. Once started, the phenomenon could be hard to reverse.

The Arctic region is vulnerable

- Glaciers are melting, permafrost is thawing, land is subsiding, the snow season has shortened, and sea ice is thinning and shrinking.
- Little to no sea ice is expected in the Arctic's summers by 2100.

Under-ice instruments to reveal Arctic Ocean circulation

WHOI physical oceanographer Al Plueddeman is using robotic vehicles to learn how waters entering from the Pacific are modified to help create the Arctic halocline—a layer of cold, salty water that shields sea ice from deeper, warmer water that could melt it. Changing climate potentially could cause the halocline to weaken or disappear.

WHOI physical oceanographer Bob Pickart is tracking waters over the Alaskan continental shelf and into the Arctic Ocean interior, using the Arctic Winch, a device that can get sensors in and out of ice-infested surface waters from below.

WHOI physical oceanographer Andrey Proshutinsky established a long-term observing network for the Beaufort Gyre, the "flywheel of Arctic climate," which alternately holds and releases large amounts of cold, relatively fresh water.

WHOI physical oceanographers John Toole and Rick Krishfield are deploying Ice-Tethered Profilers, long-term moorings installed on drifting ice floes that measure water properties below and send data back daily.

Will climate change upset the Arctic's fertile ecosystem?

WHOI biologist Carin Ashjian is investigating the oceanographic and biological conditions that sustain the Arctic's delicately balanced food web—from phytoplankton to whales and Iñupiat societies.

Sea levels are rising

- As ocean temperatures increase, water expands, causing sea levels to rise. Once sea level begins to rise because of thermal expansion, it will continue to do so for centuries regardless of mitigative actions.
- Sea levels have risen 7 inches over the 20th century, and nearly 1.5 inches between 1993 and 2003.

How fast can sea level rise?

WHOI geologist Bill Thompson is examining links between past changes in sea level and climate. Corals are excellent indicators of sea level because they must grow in sunlight near the sea surface. Developing new methods to precisely date corals, he is finding that sea level has risen more frequently and abruptly in the past than previously suspected.

Ocean acidity is changing

- Increased atmospheric CO_2 is absorbed in the ocean where it combines with water to form carbonic acid.
- Forecasts project the increase in acidity over the coming century to be three times as great as the increase over the past 250 years.
- Higher acidity could have a major impact on ocean life by preventing the formation of shells and skeletons of abundant and important zooplankton. Coral reefs are particularly vulnerable.

Potential severe consequences for living marine resources

WHOI geochemist Scott Doney has led research and public outreach efforts warning that corrosive chemical conditions in the ocean could be reached within 50 to 100 years.

WHOI researcher Anne Cohen is investigating ocean acidification's impacts on corals' ability to build their skeletons.

Biologist Sonya Dyhrman is examining potential impacts on coccolithophores—abundant, ecologically important one-celled marine plants that surround themselves with calcite plates.

Abrupt climate change is a wild card

- For many years it was believed that climate changes have been gradual—that the Earth gradually cycles between glacial periods and warm interglacial periods. We now know this is not always the case.
- Such abrupt climate changes could make future adaptation extremely difficult, even for the most developed countries.

Past and future ocean and climate changes

WHOI paleoceanographers Jerry McManus and Delia Oppo's studies of seafloor sediments—and geochemist Laura Robinson's analyses of deep-sea corals—provide clues to past ocean circulation and climate changes, and their potential in the future.

Monitoring the ocean's response to climate change

WHOI established and maintains Line W, a long-term ocean observatory located at a strategic junction of northbound and southbound North Atlantic currents that play a major role in regulating climate.