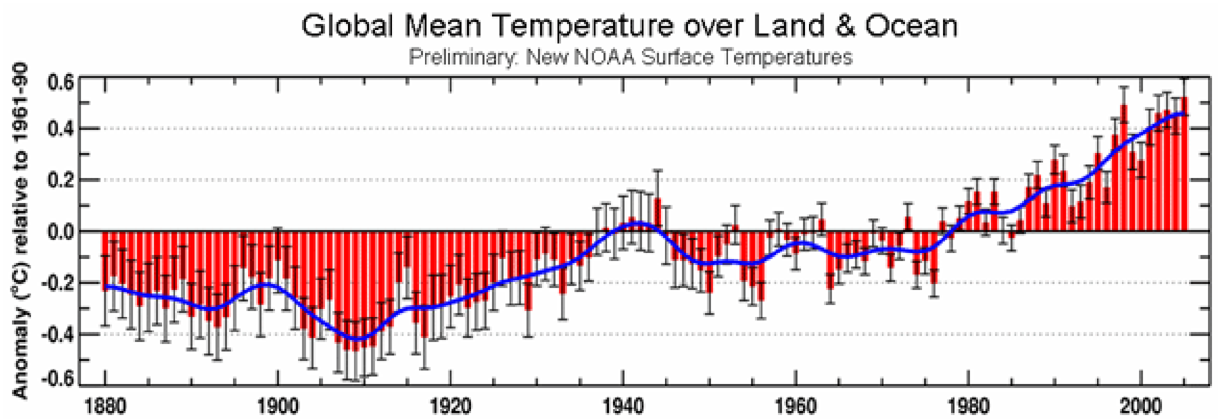
Direct Observations of Recent Climate Change

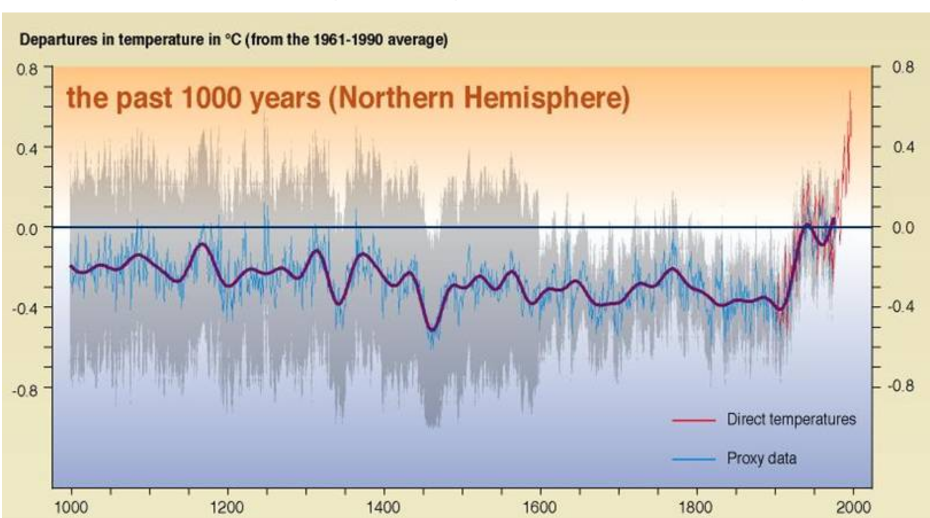
Temperature/Warming

According to the Intergovernmental Panel on Climate Change (IPCC), human activities have contributed to global warming since about 1750. Eleven of the past twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850). There is no doubt that Earth's global average temperatures are on the rise: the linear warming trend over the past 50 years is 0.13°C per decade, and the 100-year linear trend (1906-2005) shows an increase in global average temperature of 0.74°C. Also, changes in extreme temperatures have been observed over the past 50 years: cold days, cold nights and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent.

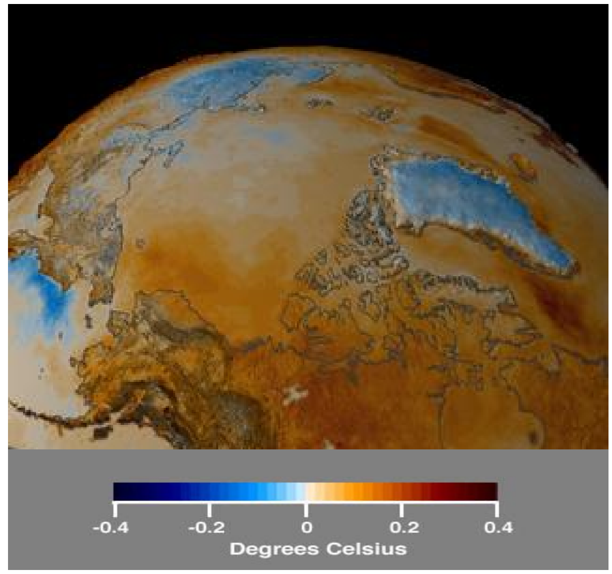
Scientists know that atmospheric carbon dioxide (CO_2) levels and surface temperatures have fluctuated throughout earth's history. The NOAA figure below, from the National Climatic Data Center, shows how CO_2 levels and temperature changes follow similar patterns. The far-right side of the graph shows a recent positive deviation from historic average temperatures, indicating an increased trend in global warming. It is important to note that warming has not been globally uniform—the recent warming has been greatest between 40°N and 70°N latitude, though some areas such as the North Atlantic Ocean have cooled in recent decades.



The United States is not immune to climate change and global warming. According to the IPCC, average Northern Hemisphere temperatures since 1950 were higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years. The graph to the left shows a clear trend for the Northern Hemisphere—the average surface temperature has steadily increased since the late 19th century and more so over the past 40 years.



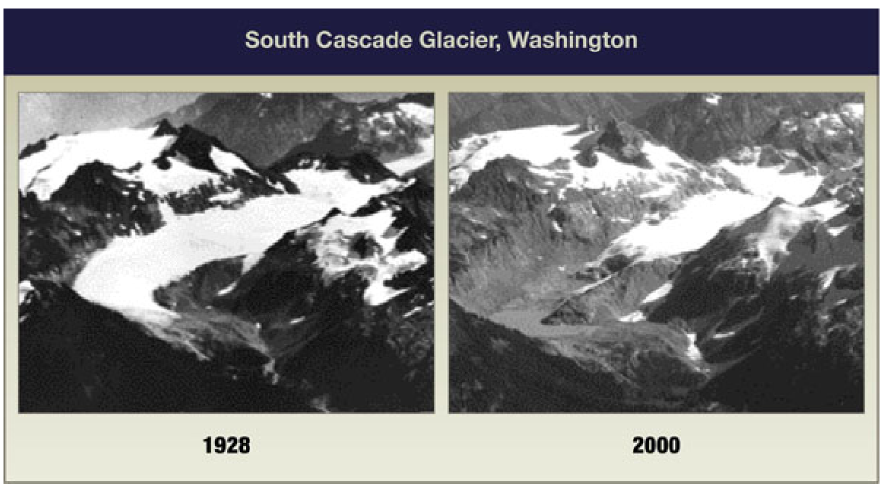
Surface air temperatures are not the only temperatures on the rise. Observations since 1961 show that the average temperature of the global ocean has increased to depths of 3000 meters and that the oceans have been absorbing more than 80% of the heat added to the climate system. This warming causes seawater to expand (a process called "thermal expansion"), directly contributing to sea level rise. Perhaps more striking, average arctic temperature increased at almost twice the global average rate in the past 100 years. The picture to the right shows the 20-year surface temperature trend over the Arctic region. Blue hues indicate cooling regions; red hues depict warming. Light regions indicate less change while darker regions indicate more. Click here to see a video clip of changing arctic temperatures over time.



Source: NASA Goddard Flight Center

Land and Sea Ice Cover and Sea Level Rise

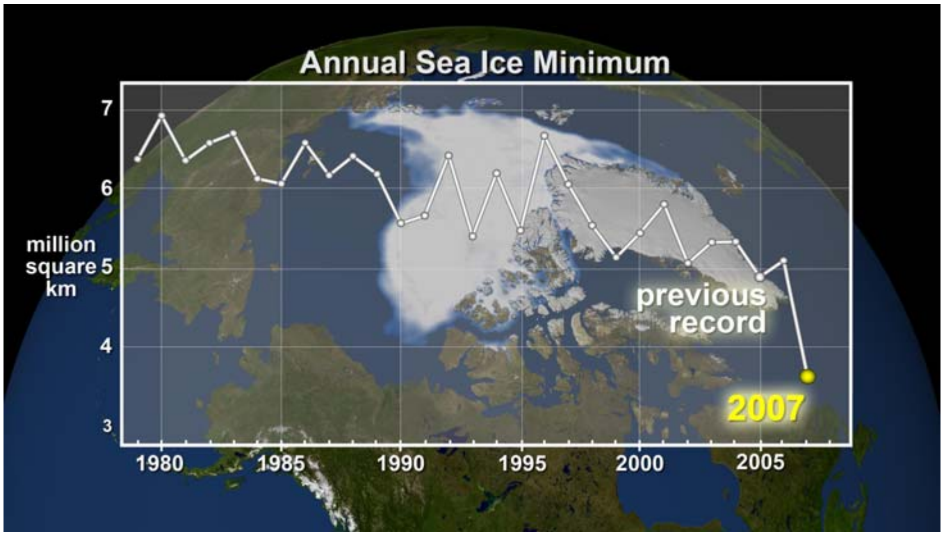
According to the IPCC, mountain glaciers and snow cover have declined on average in both hemispheres. Sometimes, photographs can offer striking visual evidence of changes to mountain glaciers over time. For example, the photos below, taken by the United States Geological Survey (USGS), show evidence of glacial retreat in the U.S. over the past century.



Source: Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2006., The US Global Change Research Program.

Glacial retreat is happening in many different locations around the world. Significant loss of glaciers in Central Asia began around the 1930s. The photo below documents the shrinking of Fedchenko Glacier in the Pamirs of Tajikistan. The Fedchenko Glacier has retreated by more than 1 km since 1933 and its height has diminished by about 50 m since 1980.

Photo Credit: V. Novikov (taken in summer 2006); data from the Tajik Agency on Hydrometeorology. Designer: Hugo Ahlenius, UNEP/GRID-Arendal available here.

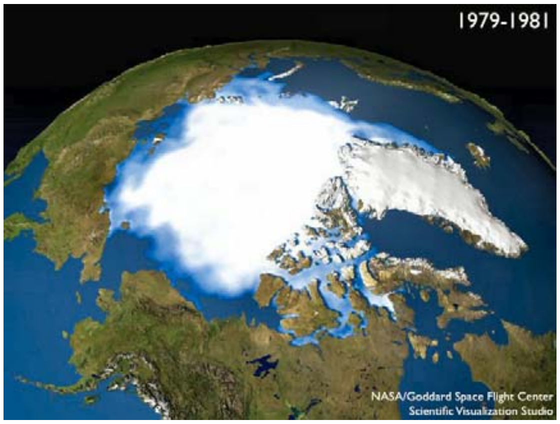


Source: NASA Goddard Flight Center

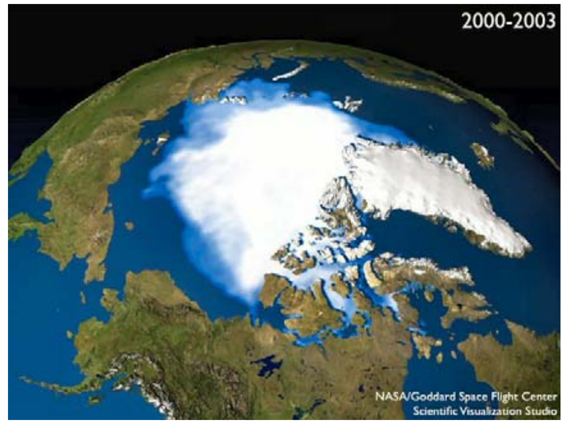
In addition to photographic evidence, satellite imagery can be used to track changes in surface snow and ice cover. Satellite data since 1978 show that annual average arctic sea ice extent has shrunk by 2.7%, with larger decreases of 7.4% per decade occurring during the summer. The figure to the left shows annual sea ice minimums. Notice that new minimum ice records are now being set on a regular basis—clear evidence of warming in the arctic.

Recently many scientists have expected that all the summer polar ice would be melted by the end of the century. However, a new study using computer models of climate and ice loss predicts that summer Arctic sea ice could be gone by 2040 (Holland, Bitz and Tremblay 2006). Click here to view a video of this prediction. In any event, the exact timing of this occurrence is immaterial—continuing on our current course, Arctic sea ice will probably be eliminated by the end of this century.

The visualizations below offer telling visual evidence of polar ice loss. The left visualization is composed from three years of satellite pictures, 1979 through 1981, of the polar ice cap. The visualization on the right is about twenty years later, for 2000 through 2003. The photos were taken in September, the time of minimum ice, and the three years' images were averaged by the NASA/Goddard Space Flight Center Scientific Visualization Studio. A multi-year average is used because the yearly summer minimum fluctuates year-to-year.



Source: NASA Goddard Flight Center



Source: NASA Goddard Flight Center

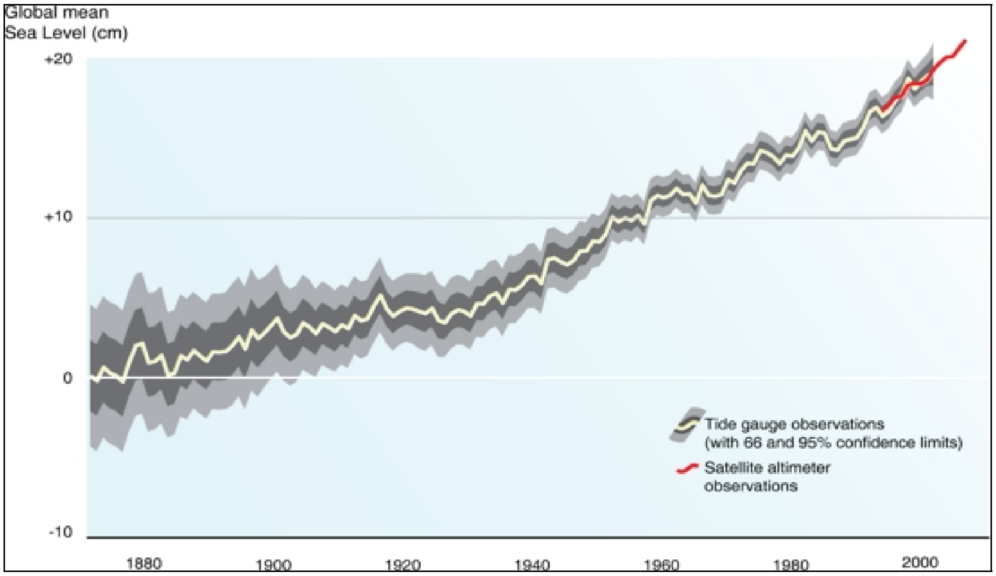
New data also show that losses from the ice sheets of Greenland and Antarctica have very likely contributed to sea level rise since the early 1990s. According to the IPCC, there is greater than a 90% chance that the Greenland Ice Sheet shrunk between 1993 and 2003, and that thickening in the central regions was more than offset by increased melting in the coastal regions. In other words, the ice on Greenland is melting faster than it can accumulate.

The picture below shows a melt water stream during the Greenland summer. Typically, ice accumulates in the middle of Greenland and melts at the edges. During the 1990s the rates of melting and accumulation were roughly in balance; however, in recent years the shift has been toward greater melting. The current estimate is 155 Gigatons (Gt) of ice loss per year, less 54 Gt of ice accumulation, for a net ice loss of 101 GT per year (see Luthcke et al., 2006). Gt stands for gigaton—a gigaton is 1,000,000,000 metric tons, or 1,000,000,000,000 kilograms. The rate of melting can be expected to increase as the planet warms.

A complete loss of Greenland ice could raise the global average sea level by 7 meters. Large masses of ice like Greenland melt slowly, though, so even with ice melt accelerating because of continued climate change, total melt time could take several hundred years to a thousand years or more. The complete melting of the Greenland and Antarctic Ice sheets would cause substantial sea level rise and devastate many parts of the world, especially low-lying coastal areas. Although these ice sheets are not in danger of completely melting anytime in the near future, some research indicates that we could *commit* to melting Greenland (i.e. there is no "going back") within the next 50-100 years if global greenhouse gas emissions are not reduced substantially (see Gregory et al., 2004). Currently the melting of ice sheets around the world is contributing slightly to sea level rise. But global warming also heats ocean waters, causing the oceans to expand (a process called "thermal expansion), directly impacting sea level.

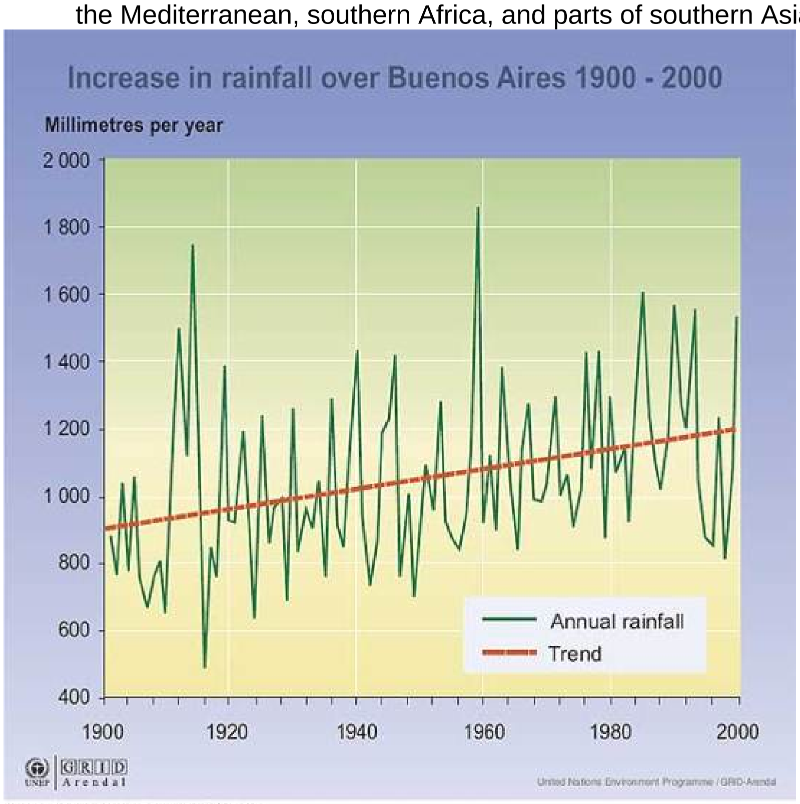
According to the IPCC, global average seal level rose at an average rate of 1.8 mm per year over 1961-2003. The rate was faster over 1993-2003, at 3.1 mm per year. The total 20th-century rise is estimated to be 0.17 meters. The graph below presents coastal and island tide-gauge data showing sea level rise over the past 120 years. From 1993 to the end of 2006, near-global measurements of sea level (between 65°N and 65°S) made by high precision satellites indicate global average sea level has been rising at a rate of

3.1 ± 0.4 mm per year. (Source: Church, J.A. and White, N.J. 2006. A 20th century acceleration in global sea-level rise. *Geophysical Research Letters*, 33, L01602. Designer: Hugo Ahlenius, UNEP/GRID-Arendal, available here)



Changes in Precipitation

Climate change also can impact precipitation patterns. According to the IPCC, long-term trends from 1900 to 2005 have been observed over many regions. For example, increased drying has been observed in the Sahel, the Mediterranean, southern Africa, and parts of southern Asia. More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapor.



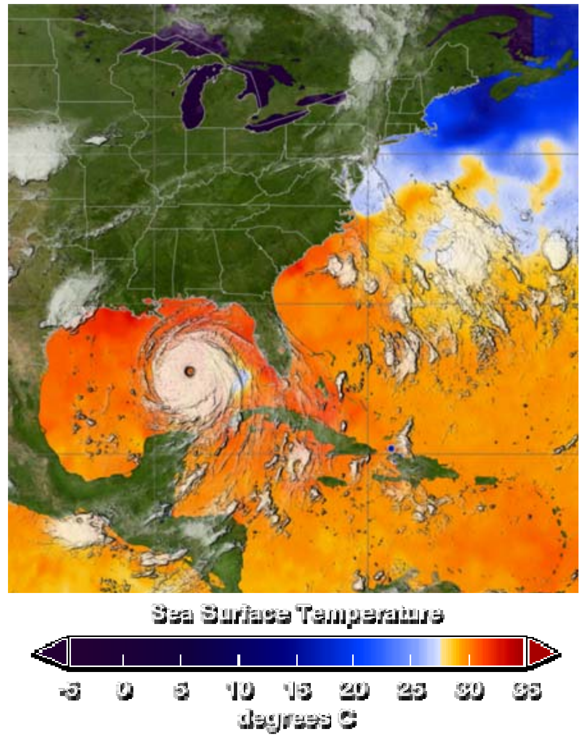
Source: Argentinian Meteorological Service

A significant increase in precipitation has been observed in eastern parts of North and South America, northern Europe and northern and central Asia. In Argentina, for example (see Left), precipitation increases have been observed over Buenos Aires over the last hundred years. (Source: Argentinian Meteorological Service. Designer: Hugo Ahlenius, UNEP/GRID-Arendal, available here.)

Hurricanes

The active hurricane season of 2005 caused many people to speculate that global warming has been causing more hurricanes to form, and that the warming of surface ocean waters has led to more intense hurricanes than those seen in the past. According to the IPCC, currently there is no clear trend between global warming and the annual *number* of tropical cyclones. However, there is evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970. This intensity is positively correlated with increases of tropical sea surface temperatures.

Scientists are continuing to gather information to determine how climate change will influence tropical cyclone activity into the future. Presumably, warmer surface ocean waters will result in ever-stronger hurricanes. This makes sense because hurricanes are "fueled" by the warm ocean surface waters found in the tropical bands north and south of the equator. [Right: Hurricane Katrina located in the warm waters of the Gulf of Mexico, August, 2005. Source: NASA Goddard Flight Center]



References for this section:

Gregory, Jonathan M., Philippe Huybrechts, and Sarah C.B. Raper. 2004. Threatened loss of the Greenland ice-sheet. *Nature*, Vol 428, April 8, 2004.

Holland, Bitz and Tremblay 2006. Future Abrupt Reductions in the Summer Arctic Sea Ice. *Geophysical Research Letters*, December 12, 2006.

Luthcke, S. B., H. J. Zwally, W. Abdalati, D. D. Rowlands, R. D. Ray, R. S. Nerem, F. G. Lemoine, J. J. McCarthy,D. S. Chinn. 2006. Recent Greenland Ice Mass Loss by Drainage System from Satellite Gravity Observations. *Science*, November 24, 2006:Vol. 314. no. 5803, pp. 1286 – 1289

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Soloman, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press.

NASA, NASA Goddard Scientific Visualization Studio, available at: http://svs.gsfc.nasa.gov/index.html

NOAA, National Climatic Data Center, available at: http://www.ncdc.noaa.gov/oa/ncdc.html

UNEP/Grid-Arendal, Maps and Graphics Library. Available at: http://maps.grida.no/

USGCRP (US Global Change Research Program). Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2006. Available at: http://www.usgcrp.gov/usgcrp/default.php