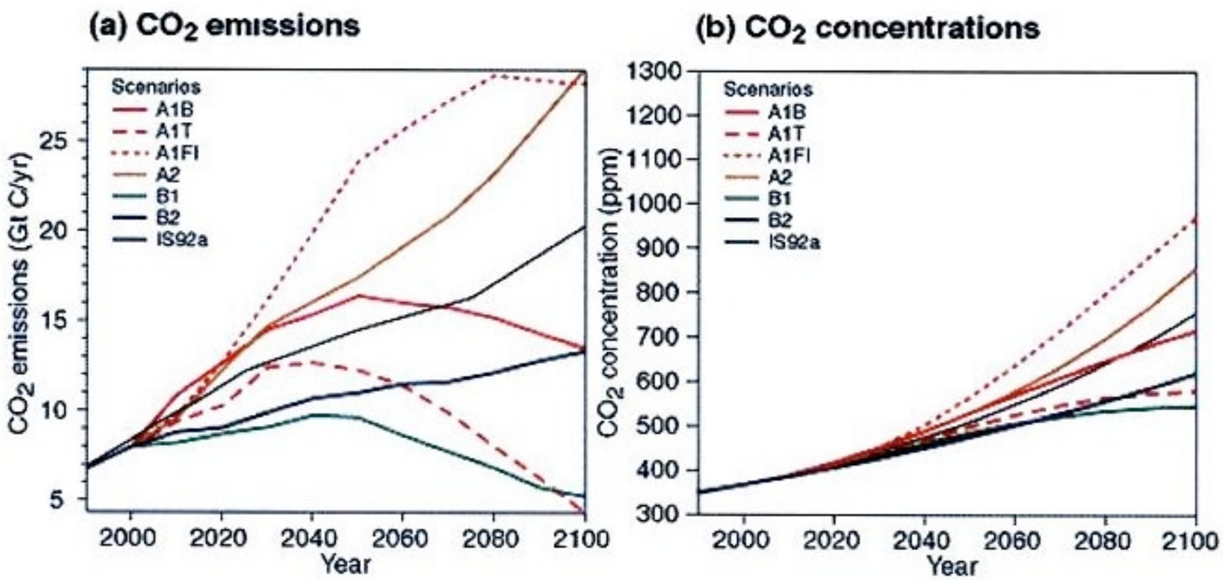
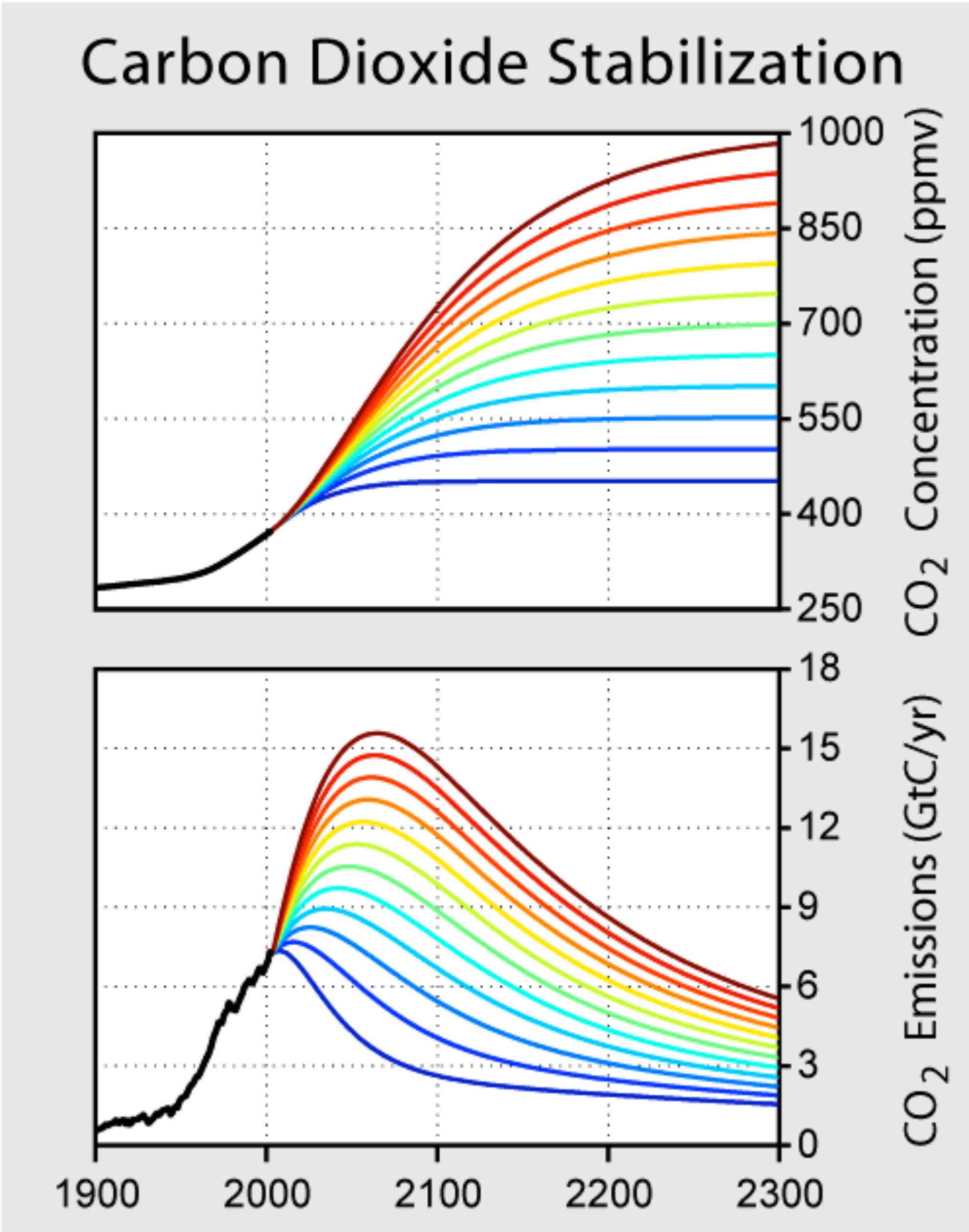
Module 6 - Lecture 16b

This is the second part of our coverage of climate change. In the first lecture, we learned that the atmospheric concentration of carbon dioxide has been increasing since the mid 1700s and that there has been almost a 1°C increase in the earth's global average surface temperature over the past 150 years or so. Many scientists believe the temperature increase has been caused by an increase in carbon dioxide and other greenhouse gases. In this lecture, we will examine additional aspects of climate change and some of the predictions for the next 100 years or so.

Atmospheric carbon dioxide concentrations are currently about 385 ppm (ppm stands for parts per million) or 0.0385%. Computer model predictions show that this could increase to between about 550 and 950 ppm by 2100 (source). The amount of the carbon dioxide increase will depend upon future changes in population and how quickly we can develop new technologies and shift to alternative sources of energy. The various scenarios used in the predictions are described in more detail here. The right graph shows that the atmospheric carbon dioxide concentration will continue to increase during the twenty first century even after significant reductions in carbon dioxide emissions.



To see when atmospheric carbon dioxide amounts might eventually stabilize at a constant level you need to look further out in time as shown in the figure below (created by Robert A. Rohde for Global Warming Art). Maintaining a carbon dioxide concentration below 1000 ppm will require that carbon dioxide emissions peak before the end of the 21st century and eventually be cut to less than present day emission rates. The most optimistic scenario (the lowest curve on the graph) shows that with an immediate cut in carbon dioxide emissions and a decrease to about 25% of current values would result in the concentration stabilizing at about 450 ppm.



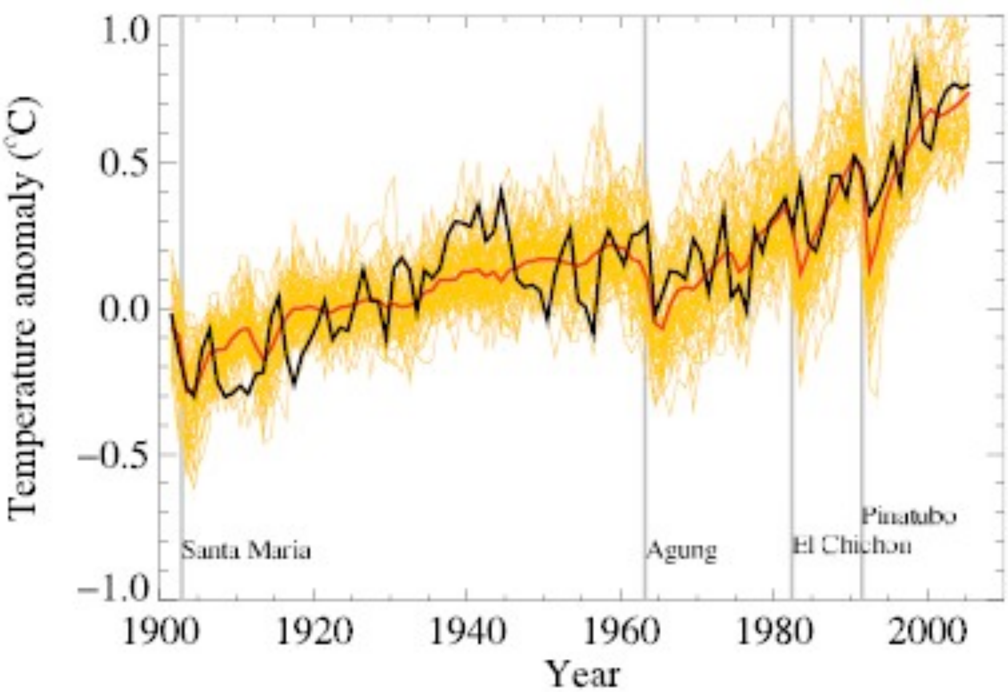
Carbon Dioxide Stabilization
1000
850
700
550
400
250
CO_2 Concentration (ppmv)
18
15
12
9
6
3
0
CO_2 Emissions (GtC/yr)
1900
2000
2100
2200
2300

Global Temperature

Sophisticated computer models are used to forecast changes in climate. Before we look at model results, we need to know whether we have any confidence in the ability of these models to make accurate predictions. One test would be the ability of the computer models to accurately reproduce past changes in the earth's temperature.

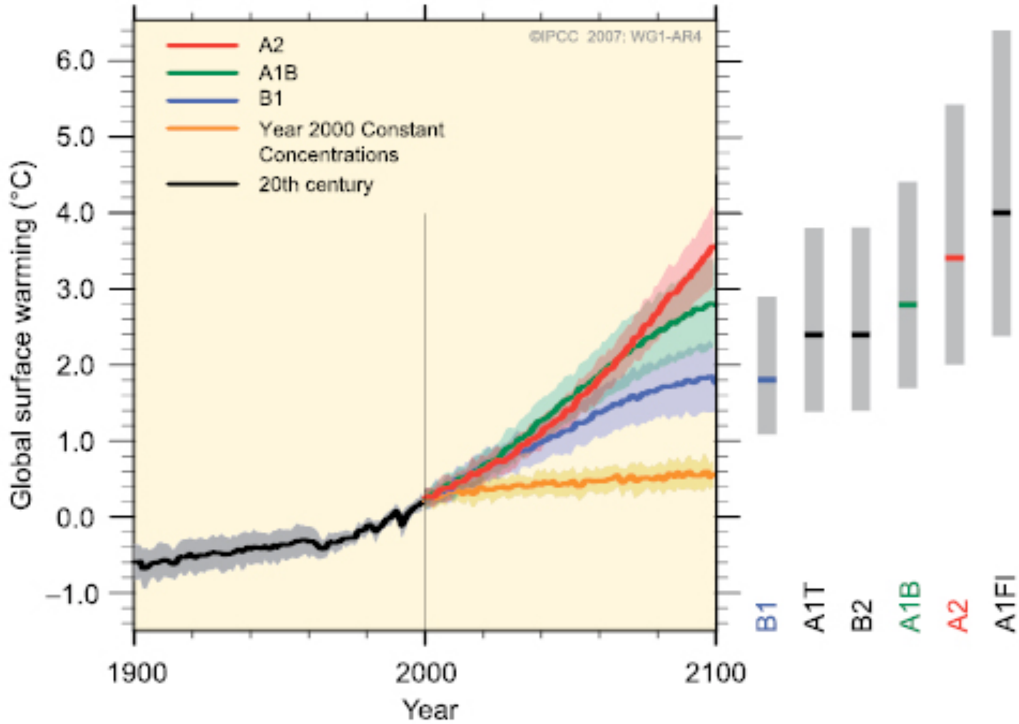
The figure below shows results from 58 such simulations using 14 different climate models (source). The model results are the light gold colored lines, the red line shows the mean of the model simulations, and the black line the observed temperature variations. The temperature changes on the y-axis are relative to the 1901-1950 mean. Both natural and anthropogenic factors have been included. The four vertical lines indicate major volcanic eruptions, a natural process that causes short duration cooling.

The relatively good agreement between predictions and observations adds support to the claim that the models are able to realistically simulate the complex physical processes that determine climate.

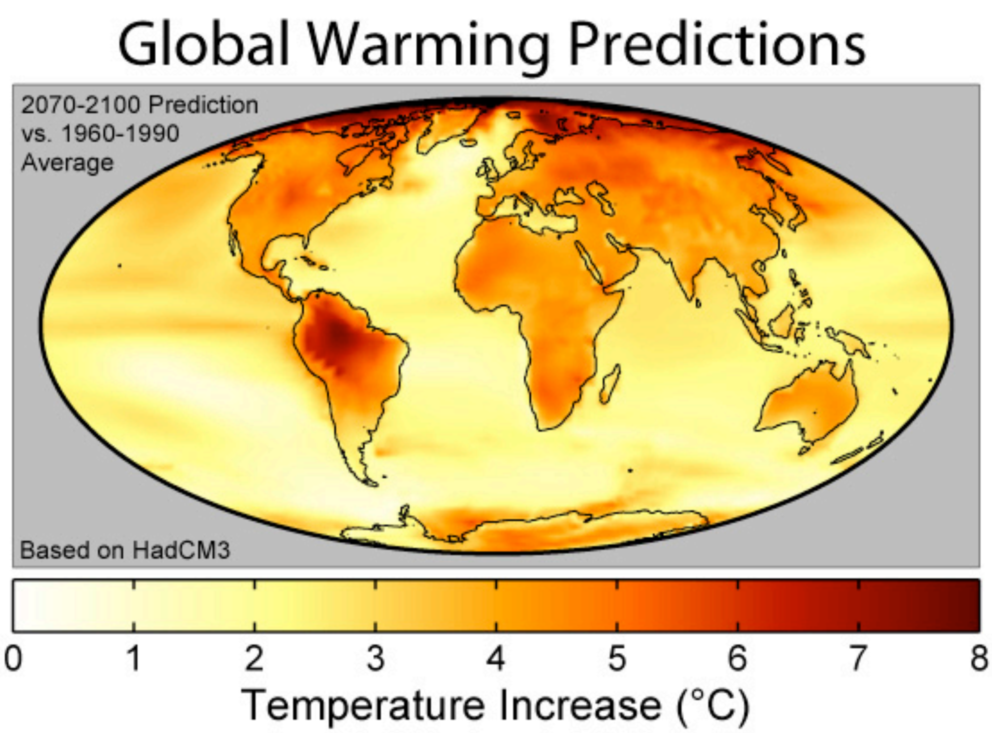


The figure below shows the predicted increase in global average surface temperature relative to the 1980-1999 mean (source). Estimates range from about a 0.6^0C increase (the orange line which assumes that future greenhouse concentrations remain at the 2000 levels, a best case scenario) to about 4^0C (the A1F1 scenario which assumes continued intensive use of fossil fuels, a worst case estimate). These are the same emissions scenarios mentioned earlier.

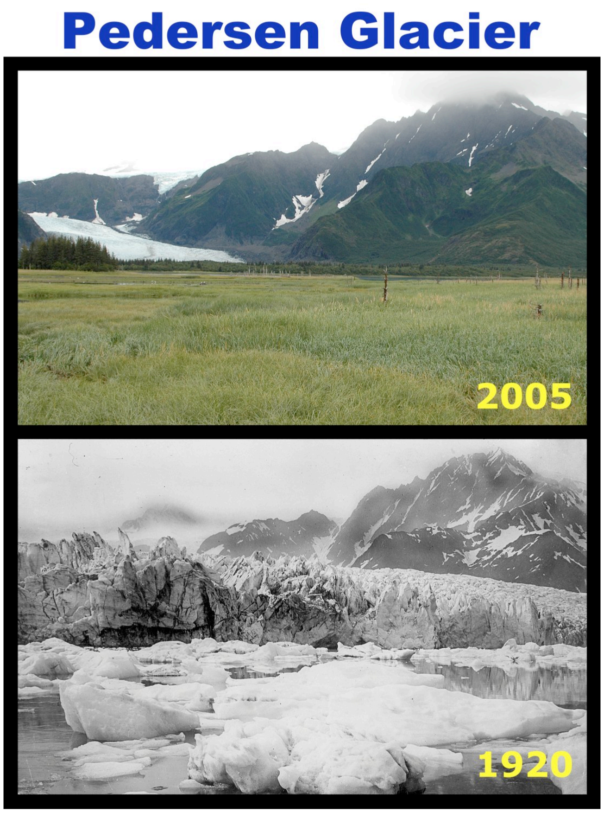
This figure was prepared for [Global Warming Art](#) by Robert A. Rohde.



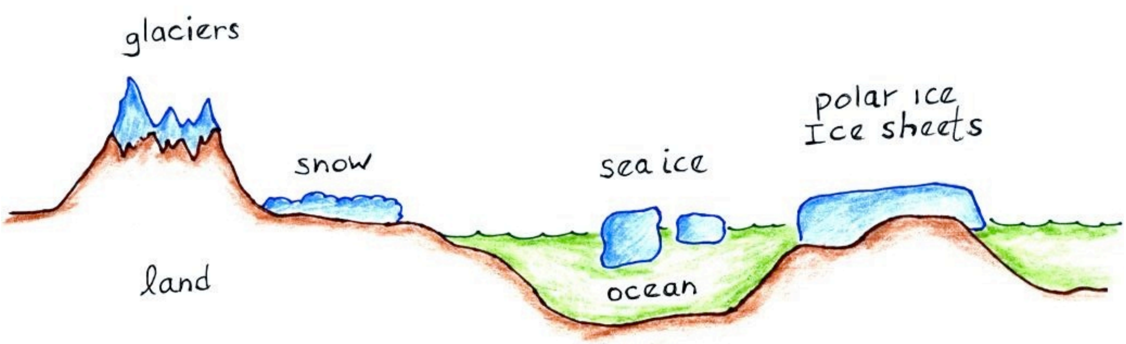
The warming is not expected to be uniform but will occur mainly over land and at higher latitudes.



Melting of Snow and Ice, Sea Level Rise
The images that global warming most often brings to mind perhaps are melting glaciers and polar ice, rising sea level, and the flooding of coastal communities. Pederson Glacier is in the Kenai Fjords National Park, Alaska. This is another images created by Robert A. Rohde for Global Warming Art.

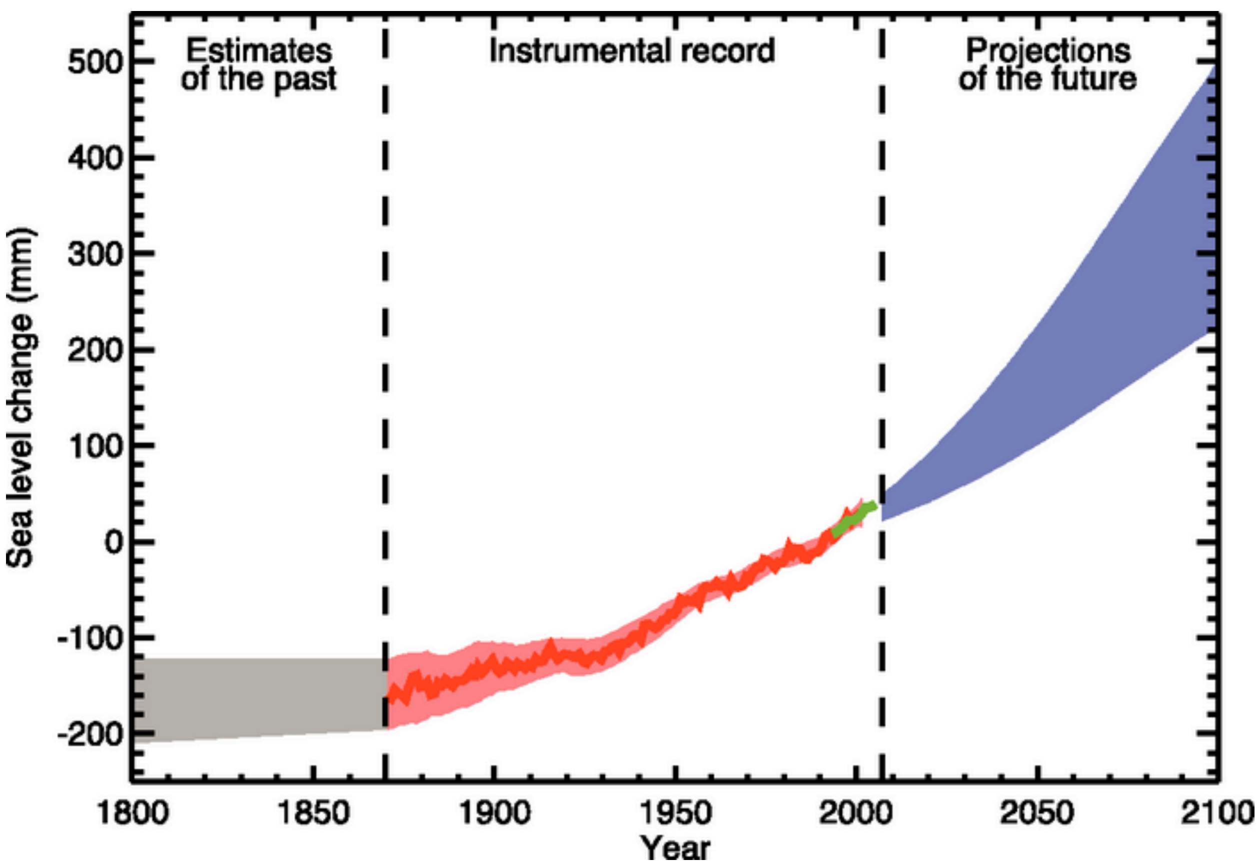


Ice covers about 10% of the earth's land surface (mostly in Antarctica and Greenland) and about 7% of the earth's oceans (the North Pole). Snow covers almost half of North America in the winter. If glacial ice, polar ice sheets or snow melts, the sea level will rise. Melting of sea ice (floating ice) will not. This is something you can verify for yourself by putting several ice cubes in a glass then filling up the glass to the brim with water. The glass will not overflow once all the ice has melted.



Observations indicate that the amounts of ice and snow have been decreasing, especially since about 1980. From 1993 to 2003, the melting of ice and snow increased the sea level by 0.6 to 1.8 millimeters (mm) per year. Past, present, and predicted sea levels are shown in the next figure (source). The predicted rise in sea level comes not only from melting ice but also from the thermal expansion of the ocean water.

Several hundred million people live in coastal areas that are at risk from rising sea level (see this gallery of images). If sea levels rise, coastal supplies of fresh water can become contaminated and coastal ecosystems harmed. The decline in mountain snow and ice can cause serious water shortages for nearby communities and cities.

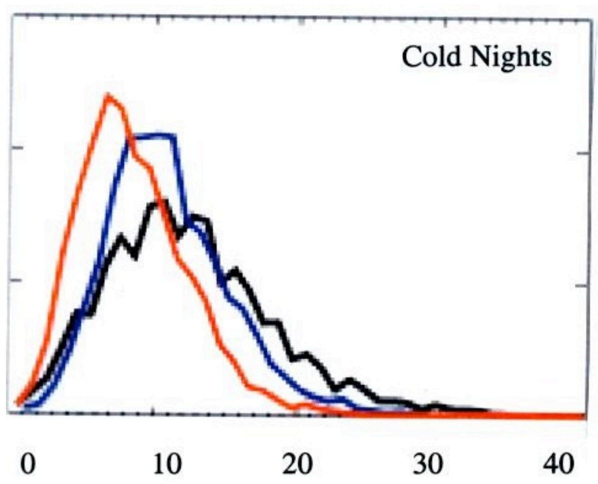


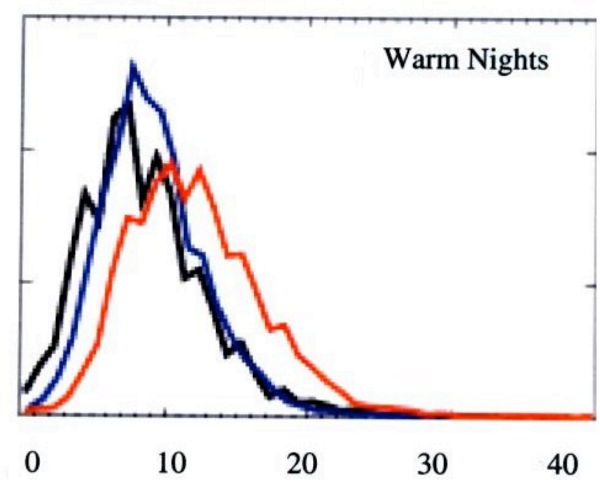
Changes in Climate and Frequency of Extreme Weather Events

The following table lists some of the changes that may already have occurred and/or are expected to occur in the next 100 years or so (source).

Condition or event	Have changes already occurred?	Have human activities contributed to the observed change?	Is the observed change expected to continue during the 21st century?
Fewer cold days & nights over land areas	Very likely	Likely	Virtually certain
More frequent hot days & nights over land areas	Very likely	Likely (warmer nights)	Virtually certain
More frequent warm spells/heat waves	Likely	More likely than not	Very likely
Frequency of heavy precipitation events increases	Likely	More likely than not	Very likely
Increase in area affected by droughts.	Likely in many areas since 1970	More likely than not	Likely

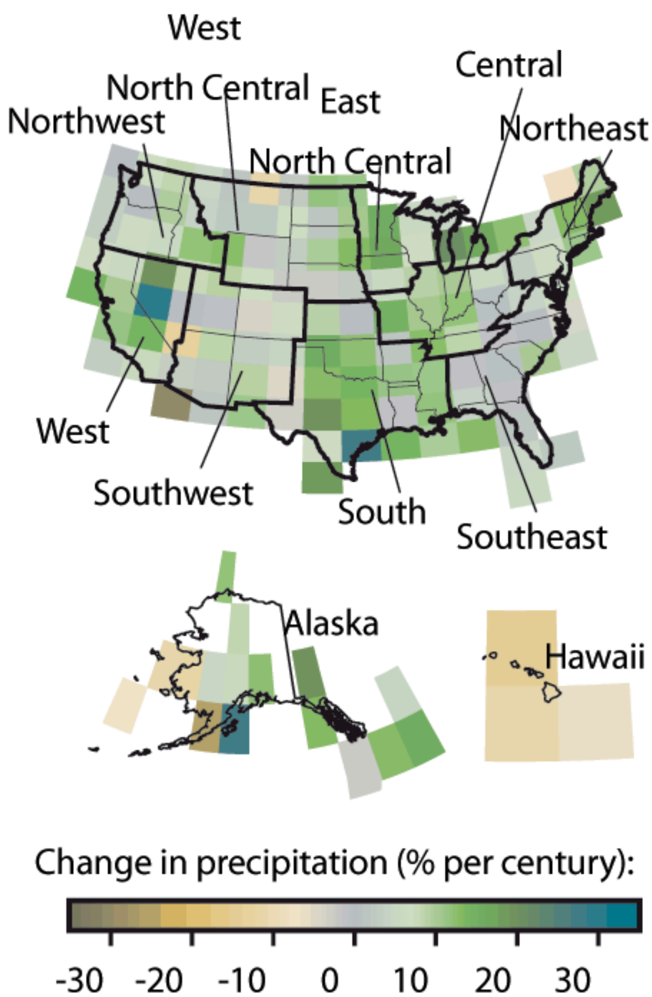
The graphs below show changes in the frequency of unusually cold nights and unusually warm nights. Data come from about 200 weather stations located around the world. The black, blue, and red curves are for the time periods 1901-1950, 1951-1978, and 1979-2003, respectively. The red curve lies to the left of the other two curves on the plot at left. This indicates that cold nights were less frequent in 1979-2003 as compared to the other two time periods. The red curve has moved to the right of the other two curves in the figure at right. Warm nights were more frequent in the 1979-2003 (source).





Extreme cold and heat are the two deadliest weather-related causes of death in the US (although there is some uncertainty about which is deadlier). The [Chicago Heat Wave of 1995] killed approximately 750 people and the [2003 European Heat Wave] killed approximately 40,000 people. It is tempting to use the data above to suggest that the incidence of cold events might decrease while the occurrence of heat spells might increase. This is an example of both good and bad effects coming from climate change. While the 2003 event cannot be blamed on climate change, the possibility of similar situations becoming more common in the future will hopefully lead to advance preparations that can reduce fatalities.

During the past 100 years, there appears to have been an increase in precipitation over land north of 30^{o} latitude. Globally there has not been a significant increase in precipitation. This figure shows changes in precipitation amounts over the US for the time period 1901to 2005 (source). Somewhat surprisingly, Hawaii is the only location where there has been an overall decrease in precipitation. Global warming could cause dry regions to become even drier because warmer temperatures would increase evaporation. Wet regions could also become wetter because increased evaporation will add more moisture to the air and warmer air can hold more moisture.



Here is an example of model precipitation predictions from the NOAA Geophysical Fluid Dynamics Laboratory (source). This model predicts a global increase in precipitation due to increases in precipitation near the equator and at middle latitudes. The subtropics will experience a decrease in precipitation. There is some concern that global warming will make hurricanes stronger and more frequent. We will consider that question in the section on hurricanes.