Did You Know ?

1. The average temperature of the lower two miles of the air above the Earth’s surface has grown much warmer in the last 100 years, and especially in the last few years.
2. Wind patterns are changing on the Earth’s surface as some areas are getting much warmer and others much cooler.
3. Changes to Earth’s climate are changing the amount of sea ice in the Antarctic, which is causing Adélie Penguin populations to change.

How We Know About Climate Change

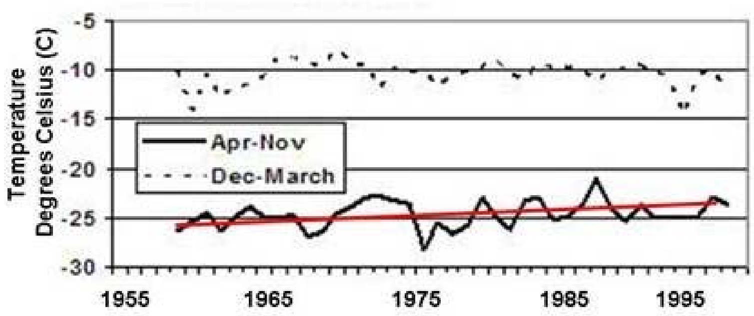
The hut that Shackleton’s men built at Cape Royds in 1909. The Steven’s box is on the little hill just above the hut to the right, and below the penguins in the background.

The 100-year-old Steven’s box at Cape Royds with Mt Erebus in the background. Thermometers were inside and an anemometer spun on the metal spoke sticking upwards from the top. The door long ago blew away; it had slats as well. A person had to open the door, read the dials and then record the data in a notebook.

Less than 200 years ago (1724), thermometers were invented and ever since then people have been keeping records about how warm or cold it is. About that time people began keeping records about how windy it was, too, but first they did this by a descriptive scale. For example, they would write that smoke from chimneys is going straight up (no wind); or it’s windy enough that the leaves of trees are rustling; and so on. It wasn’t until about 1850 that an instrument was invented to measure the actual speed of the wind. The instrument was called an anemometer. The wind causes a propeller to turn, which causes electricity to be generated (just like in a wind farm generator today, but at a much smaller scale); the amount of electricity produced increases with wind speed and this is measured on a dial. With this new tool, people began to keep numerical records of wind speed to go along with the temperature records. These are called weather records. Weather stations began to appear all around the globe for comparison of one place to another.

When Ernest Shackleton wanted to go to the South Pole in 1909, he organized an expedition from England to the Antarctic and his men brought a weather station. This station consisted of a wooden box, with slats on the side, so that air would circulate through it, but the sun light would not fall directly on the thermometers inside. If that happened the thermometer would rise higher than the actual air temperature. This is called a ‘Steven’s box’ after the weather man who invented it. On top of the Steven’s box was an anemometer.

When weather records are kept over a long time for a large region, this information tells us about climate. Climate describes the average temperature and wind patterns by season for a region, such as the western United States or the Ross Sea portion of western Antarctica (where Cape Royds is located). We've known about weather and climate in the Ross Region only since Ernest Shackleton's men began keeping records; we know about it now from the continuous records kept since the 1950s and the Automatic Weather Stations in place for the last 20 years. Comparing the winter temperatures in Shackleton's time with those from the last 10 years, we know that the average temperature in winter has increased by about 3°C (5°F). This information indicates that the climate has warmed.



Here's the record of temperature from Scott Base on Ross Island (near Cape Royds) for the last 50 years. In those 50 years, the average temperature in winter (April to November) has increased about 2 degrees (red line). Since Shackleton's day it has increased about 3 degrees.

Today in Antarctica, weather records are recorded automatically in what is called an Automatic Weather Station (AWS). Dozens are maintained by the University of Wisconsin. This AWS is located on the slopes of Mt Erebus about 1000 ft higher than Cape Royds. It has an electronic thermometer and an anemometer (the propellers on top). The data are sent to McMurdo Station by a radio signal through the antenna on the right. All the data automatically go into a computer for storage.

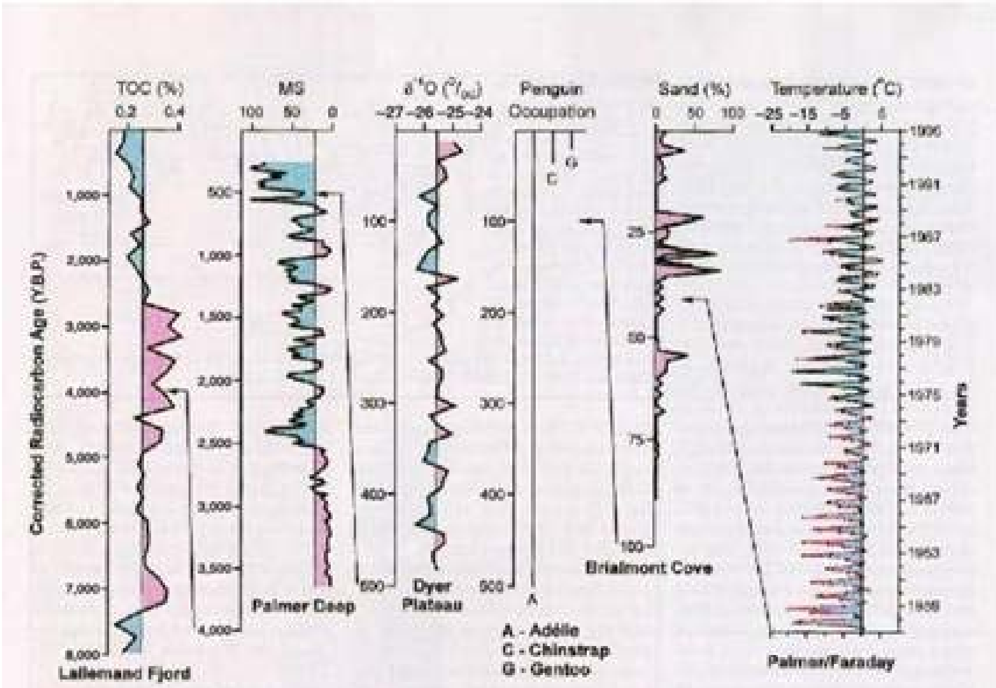
We know how climate has changed from other data we call 'climate proxies'. These are indirect measures of temperature and wind based on compounds that are incorporated into glacier ice. The ice is deposited in layers when it snows. In some places it snows more in summer, when it's warmer, than in winter. That layer would be larger. We know the periods with greater wind because there is more sea salt or dust in the ice layers. The wind picks up salt from the ocean surface and dust from the land and takes it high into the atmosphere. The higher the wind speeds, the more of this stuff is found in the atmosphere. This material combines with snow flakes. The snow falls and eventually turns to ice which form glaciers. Scientists then drill into the glaciers to extract long cores of ice. Holding the ice cores up to a bright light (inside a refrigerated room) they can see the layers. When they find a layer full of dust from a volcano, they know how old that layer is based on when that volcano erupted. They then count the layers away from that one to determine when each of the others was formed (remember, like tree rings, one layer every year).

Also trapped in the layers are traces of atmospheric gases. Snow flakes are made of frozen water, which is made of hydrogen and oxygen. The oxygen atoms come in several forms depending on the size of their nucleus. One kind is called oxygen-18 (O18) and another is called oxygen-16 (O16). O18 is heavier than 016, so when the water vapor crystallizes to form a snow flake O18 comes out of the atmosphere sooner than O16 depending on the temperature at the time. Scientists can then relate the amount of O18 in the ice to what the temperature was when the water evaporated from the Earth's surface and when it formed snow flakes in the atmosphere. Pretty cool, huh?

These ice cores, along with the sediment cores described in "Ageing Colonies", can be used to reconstruct changes in Earth's climate as well as the effects of those changes on the ocean and sea ice.

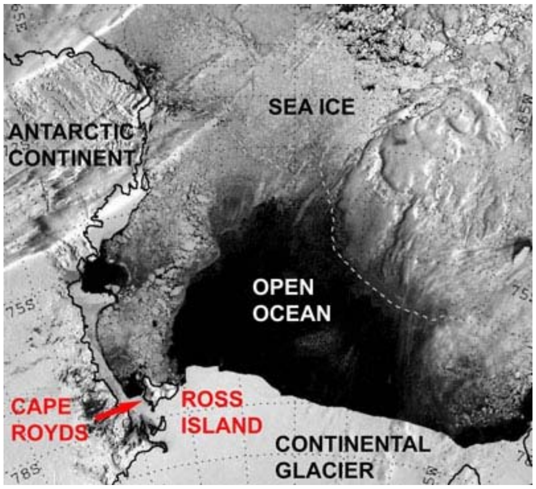
Here researchers are pulling a core of ice that they extracted from a glacier in the Andes Mountains of South America. In the right picture, you can see the hollow drill that was screwed downward into the glacier. The ice core came out of the pipe. Photos courtesy Lonnie Thompson, Ohio State University.

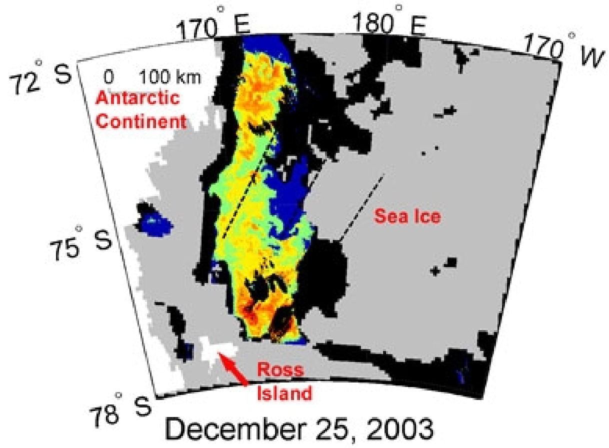
Penguins here are nesting near a receding ice cap. During the existence of this glacier there were windy periods when a lot of dust was blown into the atmosphere. These periods are 'recorded' as dark bands in this glacier's ice.



The series of graphs, above, show 5 climate and/or sea-ice proxies, along with direct measurements of temperature, with the time scale reading up-down. In the right-most column (1) is the temperature record, with the time span being just 50 years. As you read each column to the left from temperature, the time scale of each record gets longer from the present: 2) sand in sediment core goes back 100 years; 3) penguin occupation back 500 years (from bones at colony sites); 4) O8-O16 ratio back 500 years also from a glacier core; 5) magnetic susceptibility in a sediment core (something we'll not go into) goes back 4000 years; and 6) amount of carbon from diatoms in a sediment core, going back 8000 years. Look at the sand record (2) and the temperature record (1). As temperature has been rising so has the amount of sand deposited in coastal bays, where the sediment core came from. The warmer temperature creates more runoff from glacier melt, with silt having been from the glacier. Similarly, you can see the warming temperature record during the last 50 years as pink at upper end of scale #4 (oxygen ratio). Warmer temperatures, means that the sea ice melts sooner in this area, and that's why there is more organic carbon now in the sediment (scale #6) —sea ice used to 'shade' the sea surface, but this shade has been pulled back allowing more sunlight and therefore more microscopic plant growth in the water. In any case, these are all climate proxies. The appearance of G (Gentoo) and Chinstrap (C) penguins during the last 30 years in the penguin record (#3) confirms that sea ice is disappearing (G and C are open-water species). This graph is from BioScience, with permission from the authors (Smith et al.).

Finally, we now have direct measurements of sea ice as well as the amount of phytoplankton (small ocean plants) as a result of satellites that can take direct images of Earth's surface. The sea ice and ocean phytoplankton records from satellites during the past 30 years (there were no Earth sensing satellites until 1973) help to confirm the climate proxies from glacier and sediment cores.





A satellite image of the Ross Sea sector of Antarctica. Major geographical features can be seen, as well as some of the locations mentioned in this section. Courtesy of NASA.

Here is the same Ross Sea sector of Antarctica showing the intensity of plant pigments in waters not covered by sea ice at the time this image was taken. The intensity of phytoplankton, as 'seen' by a satellite, can be used to confirm records of diatom abundance in sediment cores. The blue means low concentration. From yellow to red means higher concentration. Courtesy of Kevin Arrigo, Stanford University.

Taken together, the record of penguin presence or absence, and the climate proxies from glacier and sediment cores, we can see how penguins have responded to changes in climate for thousands of years. Penguins are living creatures on Earth just like us. Knowing how penguins responded will give us a clue as to how we might have to be responding to climate change.