Ei Climate Change

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6.1 INTRODUCTION

Climate is an average of the long-term weather patterns across a geographic area, which is a complicated metric controlled by factors within the lithosphere, atmosphere, cryosphere, hydrosphere, biosphere, and anthrosphere as well as factors beyond our own planet. It is helpful to separate out humans from other life (anthro-sphere verses biosphere) for several reasons, primarily because many of our activities are unique amongst life (industrialization) and it is helpful in understanding our role in climate change. Therefore, the science examining past, current, and future climate is extremely complex and interdisciplinary. You may not think of climate as a geological field of study, but the history of climate is recorded within rocks, the current climate is altered by geologic events, and future climate will be influenced by our use of geological resources such as fossil fuels. In addition to the complex nature of this subject, it is also one, if not the most, important scientific fields of study both in terms of understanding the dynamics and implications of future climate change as well as attempting to combat or mitigate the potential effects.

Though the basic science behind climate and climate change has been well studied to a point of near consensus within the scientific community, there is still significant debate amongst the broader population. This is likely related to many factors beyond science including economics, politics, the portrayal of the science by the media, and the overall public's scientific literacy. Gaining a better understanding of this issue is difficult given the enormous wealth of information and disparity in scientific literacy. This lab will explore this issue by examining climate data as well as how we, as scientists or scientific minded citizens, make interpretations and conclusions regarding data, how it is presented, and how it relates to our understanding of the world around us.

6.1.1 Learning Outcomes

After completing this chapter, you should be able to:

- Describe the climate system and how different variables are related

- Discuss how ancient climate patterns are reconstructed
- Plot, interpret, and explain the patterns in climate proxy data focusing on the sea ice extent in the North and South Poles
- Describe how heat is transported across the earth and how this can relate to local climate
- Describe the information needed to make conclusions regarding scientific patterns and how climate models should be constructed

6.1.2 Key Terms

- Albedo
- Climate Proxies
- Climate System
- Greenhouse Gases

- Ice Extent
- Negative Feedback
- Ocean Gyres
- Positive Feedback

6.2 THE CLIMATE SYSTEM

As was previously mentioned, climate is the long-term weather pattern across a region. It is important to emphasize the long-term portion of the definition to establish that climate is different from weather. Weather is the local and short-term patterns in temperature, humidity, precipitation, atmospheric pressure, wind, and other meteorological variables. As you well know, weather fluctuates throughout the day, week, month, and year such that it is difficult to see any trends beyond the random noise in the system. If you take a long-term view of weather we can begin to see patterns across time and geography that help to better understand and identify the factors that influence the climate system. **The climate system** is the interconnected network of variables that influence the earth's climate, which includes components from the lithosphere, atmosphere, hydrosphere, cryosphere, biosphere, anthrosphere, and solar system.

The heat that feeds this system comes from two primary sources. First, there is heat radiating from the Earth itself, which is coming from the decay of radioactive material and residual heat from the formation of the earth. This heat is not distributed equally, with more heat escaping in areas where the crust is thinner, such as divergent boundaries. More significantly, the earth receives heat from solar radiation. Again, this heat is not distributed equally across the earth's surface and the amount of energy received is related to the angle at which
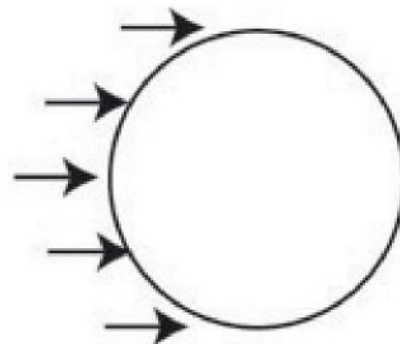

Figure 6.1 | The Earth's shape influences the angle at which the sun's rays hit the surface from perpendicular at the equator to parallel at the poles. This creates large climate differences across the Earth. **Author:** Bradley Deline
Source: Original Work
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the solar radiation hits the surface of the earth (Figure 6.1). If the solar radiation hits perpendicular to the surface more heat is absorbed than if it hits at an oblique angle, which is why the tropics are warmer than the poles.

The material on the Earth's surface is also important in that materials react differently to solar radiation. Some materials, normally dark in color, absorb and reradiate heat, most of which is retained at the surface of the planet. You are likely familiar with this if you have ever walked barefoot on dark concrete or asphalt in the summer. Other materials, that are shiny or light in color, reflect the solar radiation off the Earth's surface. Materials such as snow or ice are particularly effective at reflecting solar radiation. This is the reason Arctic explorers must use eye protection to avoid snow blindness. The proportion of solar radiation that is reflected off the Earth's surface is called **albedo**, which can vary depending on the type of ground cover. For instance the Earth's albedo is higher when it is covered with large expanses of glacial ice and thus the amount of sunlight absorbed and the temperature measured are lower.

Once heat is reradiated off of the Earth's surface it travels up into the atmosphere. Certain gases in Earth's atmosphere, called **greenhouse gases**, allow sunlight to pass but absorb terrestrial energy and radiate it in all directions including back to the surface of the Earth. These gases, such as water vapor, carbon dioxide, and methane represent a tiny, though important fraction of the material in the atmosphere. Different greenhouse gases vary both in how effectively they absorb and reradiate energy and their relative proportions in the atmosphere, such that a higher concentration of potent greenhouse gases can retain more thermal energy within the atmosphere. The rest of the reflected and radiated energy escapes from the atmosphere and dissipates into space.

Several factors can influence the simplified version of the climate system described above. The amount of radiation produced from the sun varies over time. In addition, the shape of our orbit around the sun varies over time from more circular to more elliptical because of the gravitational influences from other planets in our solar system. The angle at which solar radiation hits the planets' surface is influenced by the tilt and wobble of the Earth's axis. The distribution of water, ice, snow, vegetation, and other materials on the Earth's surface control the Earth's albedo and can change over time. The proportion of greenhouse gases can change dramatically depending on the rate of plate motion as well as the amount of volcanism, photosynthesis, weathering of rocks, burning of fossil fuels, and many other factors (to examine trends on climate and carbon dioxide levels see Figure 6.5 later in the lab).

The efficiency of the transportation of heat across the surface of the Earth also influences climate. Heat is transferred across the surface of the planet by wind, ocean currents, and storms. Therefore, the position of the continents as well as air and ocean currents affect climate and can change over time. The components in our atmosphere are also important, including water vapor and aerosols (dust). Water vapor in the atmosphere is a greenhouse gas, can reflect incoming solar radiation, and is the source of precipitation. Aerosols can come from the Earth's surface, ash

from volcanoes, and the burning of fossil fuels and can alter climate by reflecting incoming solar radiation before it reaches the Earth's surface. There are numerous additional factors that also have some level of effect on the climate system.

At this point you should be able to recognize the complexity of the climate system based on the number of variables and how those variables can change over time. It is also important to recognize that all of these variables are connected. For instance, if a volcano erupts it adds some thermal energy to the climate system; it produces aerosols that block solar radiation from hitting the Earth's surface, and produces greenhouse gases that retain heat. Notice that these factors do not all influence climate in a consistent way. The change of one variable as the result of another is called feedback, which can be either positive or negative (Figure 6.2). **Positive feedback** reinforces the initial change no matter the direction of that change. For instance, if the Earth warms, ice melts and reduces

Figure 6.2 | A simple diagram showing the relationship between two variables with either positive or negative feedback following a positive (A) or negative (B) initial change.
Author: Bradley Deline
Source: Original Work
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the albedo, which causes even more warming. This can also occur in the opposite direction, if the Earth cools, ice forms and increase the albedo, which causes more cooling. **Negative feedback** counteracts the initial change no matter the direction of the initial change. For instance, if the Earth warms, more area becomes arid resulting in an increase in the amount of dust in the atmosphere, which reflects solar radiation causing cooling. Again the opposite works, if the Earth cools, less area is arid resulting in a decrease in the amount of dust in the atmosphere, which causes warming. Therefore, an understanding of the climate system requires an identification of all of the important climate variables, how they are related to each other, the speed at which they can change, and the magnitude and direction of change of each feedback loop. The ideal way to gain a better understanding of the climate system is to study it through geologic history.

6.3 CLIMATE PROXIES AND THE CLIMATE RECORD

The first method most students think about when we talk about recording climate is using a thermometer to directly measure temperature. There are actually a
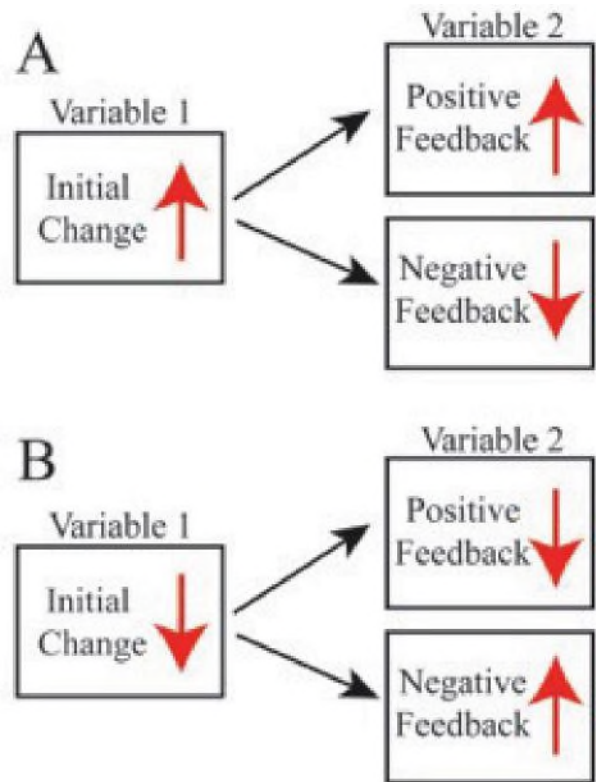
few problems reconstructing climate patterns this way, including that a thermometer gives a very local signal and more importantly, thermometers are a relatively recent invention. Given that direct observations do not give us the long-term trends needed to establish climate change or patterns, we must look at a natural recorder of climate called a **climate proxy**. As climate changes it affects the deposition of sedimentary rock, rock chemistry, and fossil organisms that scientists can detect in order to reconstruct ancient climate patterns, in a field called paleoclimatology. An individual climate proxy may not give a clear signal of global climate for a couple of reasons. First, proxies show a history of the area in which they were formed, not of an entire region. Second, an individual proxy, which may have a long or a short record, can record the short-term variability of weather events. And third, most climate proxies are influenced by multiple factors. For instance, the thickness of tree rings (dendrochronology) is a wonderful proxy for temperature. Trees grow more in warmer years (producing thicker rings) and less in colder years (producing thinner rings). However, a tree could also grow slowly because of a drought or because of an infestation of pests even if it was a warm year.

If all of the individual proxies show local patterns, with some degree of weather related noise, and possibly influenced by other factors, how do we then reconstruct long-term global temperature records? The answer lies in increasing the size of the dataset. If temperature is the most important variable influencing the proxies, and we combine hundreds to thousands of individual proxy records, an overarching pattern emerges from the noise. Again, an individual proxy record may be contrary to the overall trend, but that is expected since a local region can have a cold winter in the midst of an overall hot year for the planet. To illustrate this consider the following: say we want to reconstruct overall economic patterns over the past few hundred years in the United States of America. We could examine lots of proxies for economic growth, such as employment, the stock market, individual wealth, or rates of home ownership to name a few. If we only looked at one of these proxies we likely would not get a clear picture of change. Also, if we only looked at Macon, Georgia, for example, we would be unlikely to see a trend that mimics the entire country. For instance if a new factory opened outside of Macon, GA that would be a huge economic benefit for the city, but not for the country overall. Again, the more data we have, whether it is for economics, or climate, or any other complex system, the clearer the signal becomes over the local and random noise.

One of the most commonly used climate proxy is the measurement of oxygen isotopes. As you may remember from chapter one, isotopes are atoms of

Figure 6.3 | Short segment of an ice core that records ancient climate patterns.
Author: Ludovic Brucker, NASA
Source: Wikimedia Commons
License: Public Domain

the same element that differ in their weights because of differences in the number of neutrons in the nucleus of the atom. Multiple isotopes of oxygen are stable, meaning they do not radioactively decay over time. Oxygen has two stable isotopes that occur in a constant ratio on Earth. However, certain minerals (like calcite or ice) prefer one of the isotopes over the other within their crystal structure (a slightly larger or smaller atom fits better). This preference results in a ratio of oxygen isotopes that is different from the ratio found in other materials; this difference is called fractionation. The amount of fractionation in oxygen isotopes is temperature dependent, such that the mineral calcite has a different ratio of oxygen isotopes if it was formed in near freezing versus warm water temperatures. Using oxygen isotopes we can get climate records from many different sources, including coral, clams and other mollusks, the skeletons of single-celled organisms, and ice cores to name a few.

Ice cores (as shown in Figure 6.3) can contain a wealth of climate data in addition to temperature data from oxygen isotopes, such as air bubbles that record the levels of greenhouse gases, concentrations of windblown aerosols, and ash from volcanic eruptions.

Other proxies include the extent of glacial sediment, sea level curves, pollen (pal-ynology), and fossils. For instance, climatologists have used several features within fossil plants to reconstruct climate, largely because these organisms are sensitive to climate. These proxies include the thickness of tree rings, the shape of the leaves (toothier leaves are more common in colder climates), and the density of pores on leaf surfaces (more pores are needed with lower concentrations of carbon dioxide, which is necessary for photosynthesis).

As was mentioned before, by combining hundreds to thousands of individual climate records we can start to gain insight into overall climate trends. For instance, the Intergovernmental Panel on Climate Change (IPCC) and the National Oceanic and Atmospheric Administration (NOAA) regularly compile multiple types of proxy records from across the world (Figure 6.4) to reconstruct climate patterns (Figure 6.5). The accuracy of the climate records very much depends on the time frame being considered, with more certainty in the patterns of the recent past (Cenozoic) and less the further back in geologic time we are examining.
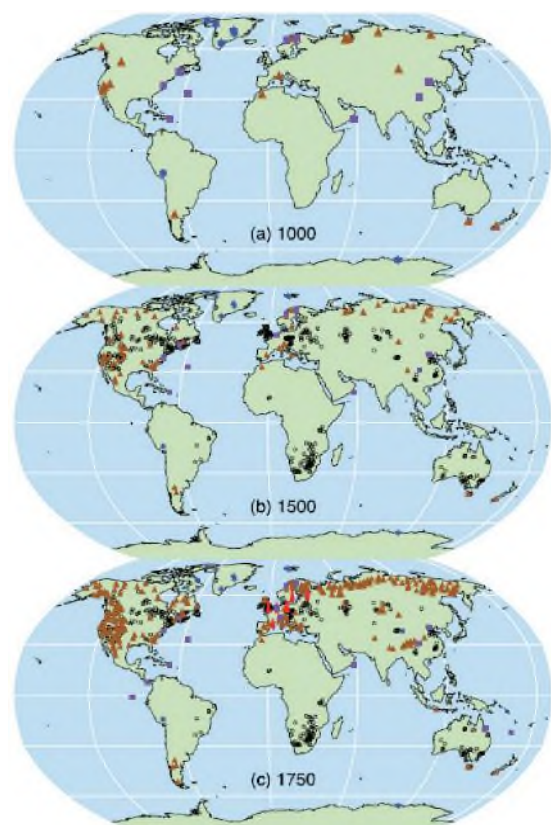

Figure 6.4 | Distribution of individual climate proxies used in the construction of Figure 5. Image from the National Ocean and Atmospheric Administration.
Author: NOAA
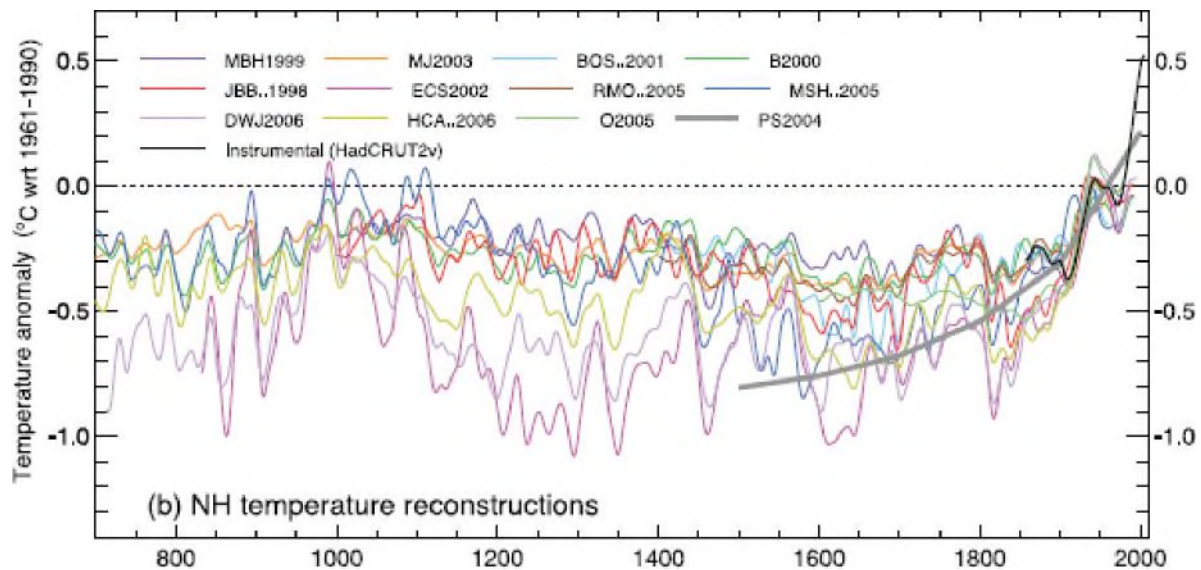**Source:** NOAA
License: Public Domain

Figure 6.5 | Climate reconstruction over the last 1300 years using multiple climate proxies (different colored lines) from "Climate change 2007: the physical science basis"; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Jansen, E. J. Overpeck, K. R. Briffa, J. C. Duplessy, F. Joss, V. Masson-Delmotte, D. Olago, B. Otto-Bliesner, W. R. Peltier, S. Rahmstorf, R. Ramesh, D. Raynaud, D. Rind, O. Solomina, R. Villalba, and D. Zhang.
Author: NOAA
Source: Wikimedia Commons
License: Public Domain

The climate proxy we will focus on for this lab is the extent of sea ice coverage on the North and South Polar ice sheets. This is an easy proxy to assess from satellite images and is measured as the size of the ice sheet in million square kilometers. This proxy isn't a perfect indicator of global climate change, but it is easy to understand that a warming of the Earth is likely to cause a decrease in the amount of ice at the poles and thus a decrease in the **ice extent**, while a cooling event will cause an increase in ice production. Ice extent is simply the amount of geographic area covered by a glacier as measured from satellites.

There is debate surrounding the interpretation of individual proxies and the resulting climate records, which largely stems from the economic and political aspects of climate change. This current lab was constructed following a discussion with a student regarding the information presented in several climate articles. The discussion focused on how scientific data is presented to the public and how we should make conclusions based on presented data. In considering information that we are presented with it is important to consider 1) the source of the data, 2) how the data was collected, 3) how the data is presented, and, most importantly 4) what are the reasonable conclusions you should make from the data independent of the opinions expressed alongside of the data.

6.4 LAB EXERCISE

As with Chapter 4, you will be expected to input your answers to this lab in several ways. There will be a couple of multiple-choice questions, but for the majority of the lab you will write your answers in the provided text box. This allows you to show your work in the questions requiring calculations as well as allowing you to answer open-ended questions thoroughly with multiple sentences. You will be expected to use correct grammar and complete sentences in your answers.

Materials

All of the data provided in the lab comes from the National Snow and Ice Data Center (NSIDC), housed at the University of Colorado. The data presented in this lab can be freely downloaded from them at nsidc.org. The original discussion was focused on a widely circulated though unattributed article entitled "Antarctic Sea Ice for March 2010 Significantly Greater Than 1980" published in April 2010 (climatechangehoax.com). For the dataset presented in this article as well as the following datasets, do the following before answering each set of questions: graph the data, connect the data points to better see the pattern through time, estimate the best fit line, and calculate the slope of the best fit line. Make sure to think about the data before you estimate the line of best fit so that your line falls within the data and is consistent with the trend in the data. An example of this process is shown in Figure 6.6.

Step 1. Plot the data.

Step 2. Connect the data points.

Step 3. Draw a best fit line that mimics the data through the entire time frame.

Step 4. Find two points on the best fit line that cross a grid line and record their values.
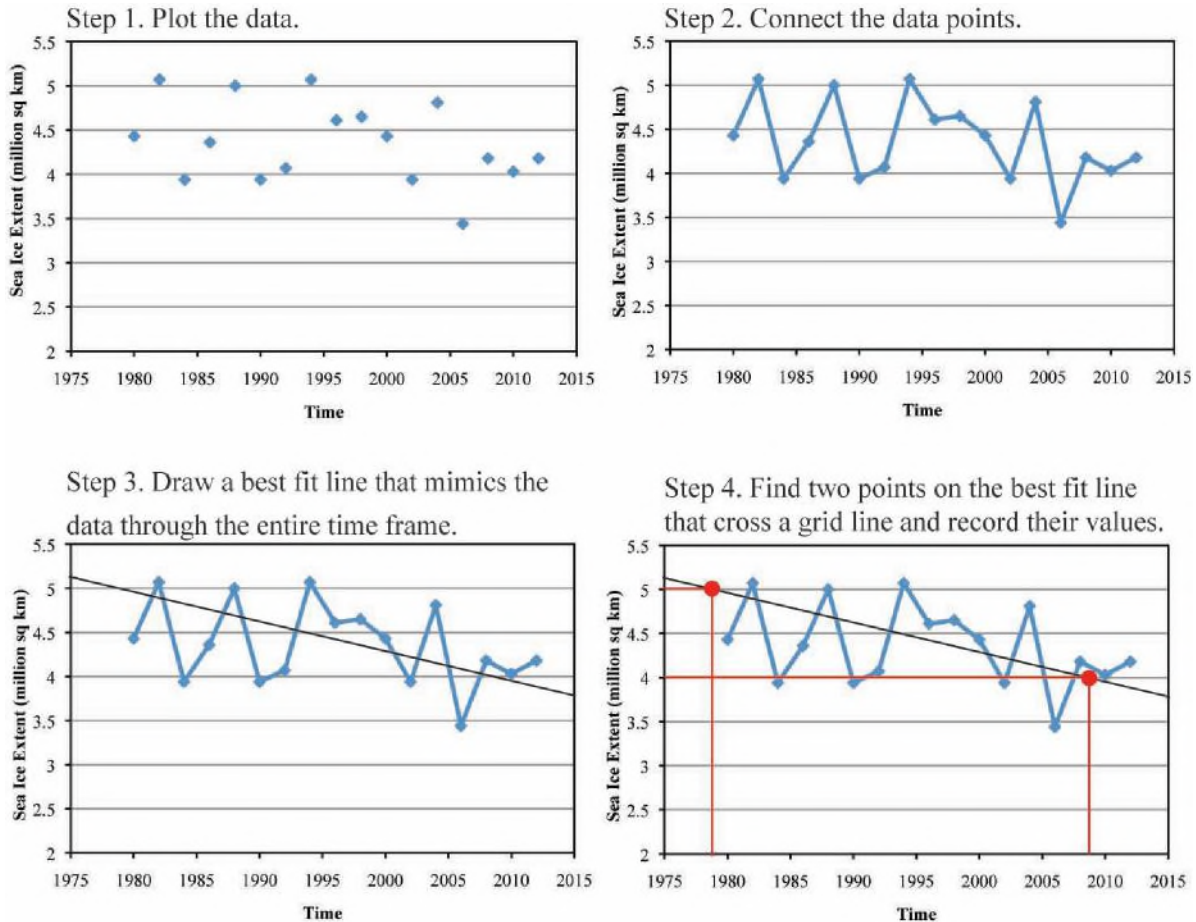
Step 5. Calculate the slope:

$$Slope = \frac{Rise}{Run}, which = \frac{y_2 - y_1}{x_2 - x_1}$$

$$Slope = \frac{4\,million\,sq\,km - 5\,million\,sq\,km}{2009 - 1979} = \frac{-1\,million\,sq\,km}{30\,years} = -0.033\frac{million\,sq\,km}{year}$$

Figure 6.6 | Steps needed to analyze the ice extent data to visualize patterns: place a line of best fit, and calculate the slope of that line.
Author: Bradley Deline
Source: Original Work
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Part A – Original Data

First, we want to take a closer look at the data presented in the original article ("Antarctic Sea Ice for March 2010 Significantly Greater Than 1980") and interpret the data. Feel free to read the article, but it isn't needed to complete the assignment or understand the patterns it is presenting. The data, which is included to the left of the graph below, is the extent of Antarctic sea ice in millions of square kilometers as measured in March of 1980 and 2010. This data is accurate and is consistent

with data that can be downloaded from NSIDC. To do this, follow the instructions in Figure 6.6. In this case, steps two and three are the same and you can easily calculate slope using the original data.

Sea Ice Extent

2010   4.0 million square km
1980   3.5 million square km.

1. Based exclusively on the data provided and your graph, what conclusion would you make regarding climate change?

    a.   Sea ice is expanding, which indicates an increase in temperature

    b.   Sea ice is expanding, which indicates a decrease in temperature

    c.   Sea ice is contracting, which indicates an increase in temperature

    d.   Sea ice is contracting, which indicates a decrease in temperature

2. What is slope of the line of best fit for this data?

    a.   0.008 million square kilometers per year

    b.   0.05 million square kilometers per year

    c.   -0.05 million square kilometers per year

    d.   0.017 million square kilometers per year

    e.   -0.17 million square kilometer per year

    f.   0.033 million square kilometer per year

3. Even though the above data is accurate, give and explain two reasons why this dataset might lead you to an incorrect conclusion regarding global climate change.

art B – South Pole Sea Ice Extent

Below is an expanded dataset showing Antarctic sea e (Figure 6.7) extent measured during March 1980 rough 2012 again downloaded from NSIDC. Only the ʻen numbered years are presented, but the addition of ld years does not alter the trend in the data. Following ιe instructions in Figure 6.6, graph the data, draw a ιe of best fit, and calculate the slope of the line.

gure 6.7 | Map of Antarctica showing e extent of the polar ice cap and the tent of the floating ice shelves. **Author:** GS

urce: Wikimedia Commons

:ense: Public Domain

year	Ice extent In million square km
1980	3.54
1982	4.8
1984	3.93
1986	4.08
1988	4.35
1990	4.36
1992	4.07
1994	5.07
1996	4.61
1998	4.65
2000	4.43
2002	3.94
2004	4.81
2006	3.44
2008	5.74
2010	4.03
2012	5.00
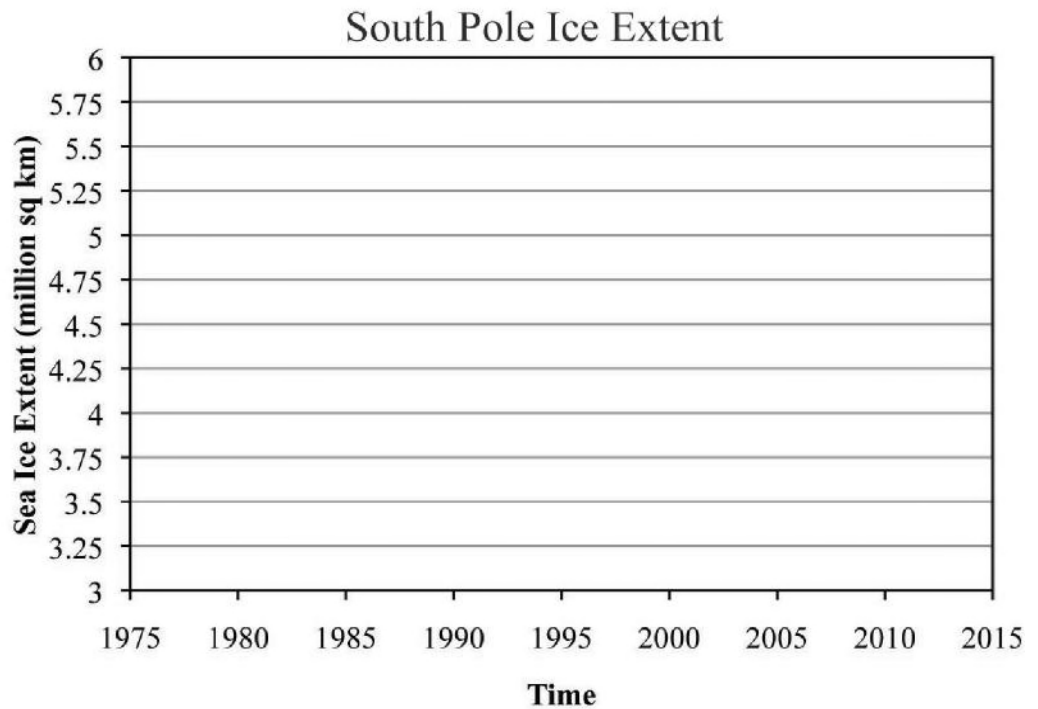
South Pole Ice Extent

4.   What is the slope of the line of best fit you estimated for this data set? Make sure to show your work.

5.   What conclusion about climate change could you make from this dataset? How does your result for the extended dataset compare to the results from the data presented in the article (Part A)?

Part C – North Pole Sea Ice Extent

Next, we will examine the ice extent patterns of the northern Arctic polar ice sheet that is located around Greenland (Figure 6.8). The ice extent data is from March 1980 through 2012, for even numbered years, again downloaded from NSIDC. Following the instructions in Figure 6.6, graph the data, draw a line of best fit, and calculate the slope of the line.
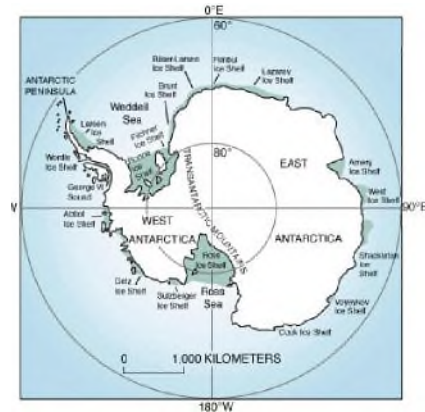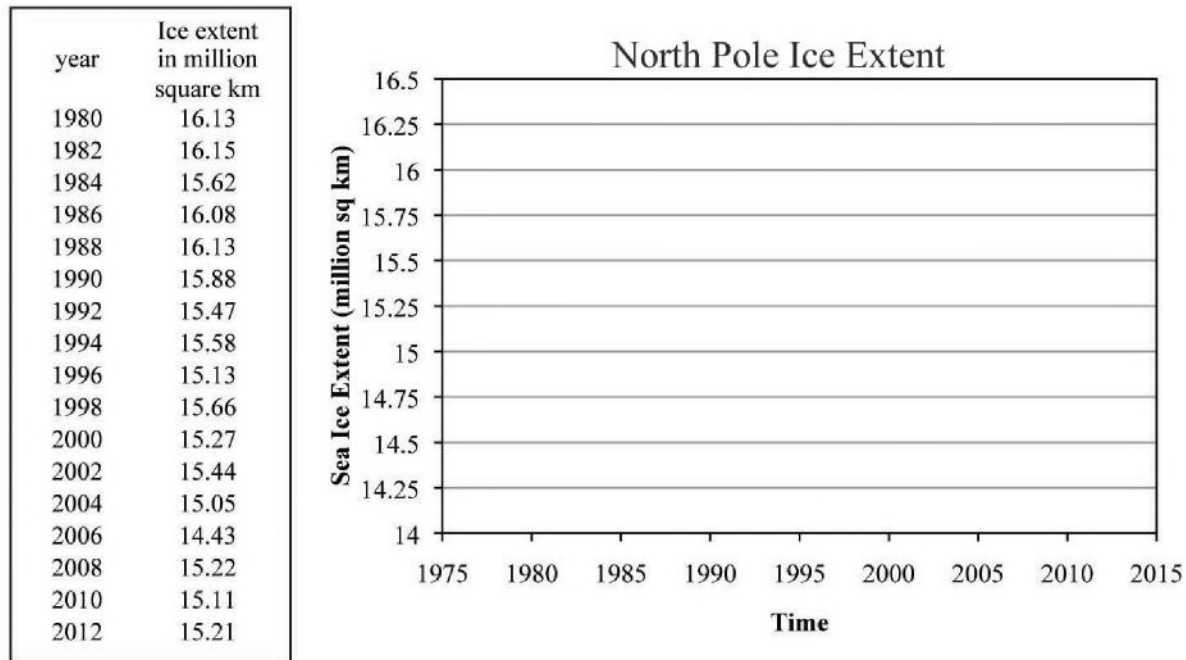

Figure 6.8 | Map of Greenland showing the extent of the polar ice cap.
Author: Eric Gaba
Source: Wikimedia Commons
License: CC BY-SA 3.0

year	Ice extent in million square km
1980	16.13
1982	16.15
1984	15.62
1986	16.08
1988	16.13
1990	15.88
1992	15.47
1994	15.58
1996	15.13
1998	15.66
2000	15.27
2002	15.44
2004	15.05
2006	14.43
2008	15.22
2010	15.11
2012	15.21

North Pole Ice Extent

6.   What is the slope of the line of best fit you estimated for this data set? Make sure to show your work.

7.   What conclusion on climate change could you make from this dataset? How does your result for the North Pole compare to that of the South Pole (Part B)?

6.5 HEAT TRANSPORT AND OCEAN CURRENTS

As was mentioned earlier in the lab, the tropics are warmer than the poles because of differences in the angle at which solar radiation impacts the Earth (Figure 6.1). Very little solar radiation reaches higher latitude areas because the solar radiation comes in almost parallel to the Earth's surface. Therefore, most of the thermal energy at higher latitudes comes from the movement of heat from the tropics. Heat is transported across the Earth's surface through wind currents, storms, and ocean currents. In particular, large circular ocean currents, called gyres, appear to have a significant impact on the geographic distribution of heat on Earth and large-scale climate change in Earth's history. These currents are particularly effec-

tive in melting polar ice in that they melt the sea ice from below. In addition, an examination of ocean current patterns will assist in explaining the patterns of sea ice extent you graphed earlier as the earth is warming (Part B and C).

6.6 LAB EXERCISE

Materials

A visualization of the ocean currents can be seen by downloading the file "ocean_currents.kml" either from your course's website or directly from the Science on a Sphere page from NOAA (sos.noaa.gov/kml/). Once you download the file you can open it within Google Earth. Once the file loads (which may take a few minutes), click on the wrench in the upper left corner of the screen to the left of the NOAA logo (Figure 6.9). Check the "loop animation" box and slide the cursor for animation speed to an intermediate position, then click OK. Then click the toggle animation icon (Figure 6.9) to start the animation. Watch the movement of the currents as they flow, making sure to examine the flow in different parts of the world and zoom out to get a broad prospective of the flow of the ocean currents around the world.
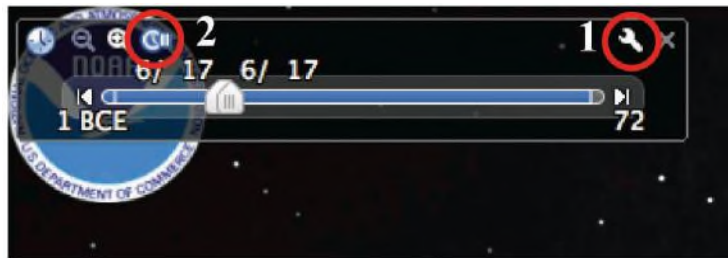
Figure 6.9 | Directions to visualize ocean currents in Google Earth. 1: Wrench icon to apply the correct settings. 2: Toggle animation icon to start the animation.
Author: Google
Source: Google Earth
License: Fair Use

If you have difficulty loading the file you can also access the visualization at: http://sos.noaa.gov/Datasets/dataset.php?id=130#. To access the visualization of the ocean currents click on "Interactive Sphere" and hit play, make sure to spin the globe to see the currents in the different oceans.

Part D – Ocean Currents and Heat Transport

8. Examine and describe the ocean currents flowing in the Atlantic Ocean from the equator to the North Pole starting from Brazil (6 08 54.55S 35 58 24.09W). Do these currents reach the northern polar ice sheet? If the tropics become warmer, how would this affect the northern ice sheet?

9.   Examine and describe the ocean currents flowing in the Pacific Ocean from the equator to the South Pole starting from Somalia (0 32 32.23N 44 09 15.47E). Do these currents reach the southern polar ice sheet? If the tropics become warmer, how would this affect the southern ice sheet?

10.   Based on your answer to questions eight and nine, explain why we see different trends in the sea ice extent in the south (Part B) and north poles (Part C).

11.   How might the changes you saw in the previous exercises relate to global albedo, sea level, ocean salinity, and temperature?

Part E – Conclusions

Making conclusions, let alone policy decisions, regarding any complex system such as climate and how it is changing is difficult. You can see how completely accurate data can be misrepresented as well as how accurate data out of context (ice extent without understanding ocean currents) may lead you to an incorrect conclusion. It is important to base any conclusion on rational, accurate, complete, and in context data, rather than data that has been poorly collected or misrepresented. Most importantly, it is important to come to your own conclusions regarding data rather than being swayed by the opinion of the author presenting the data, which is true both in science as well as many other aspects of your life.

12.   Do you think any conclusions (if any) regarding climate change should be made based on the data presented in this assignment?

12.   What data do you think are needed to make a conclusion regarding climate change?

6.7 ADDITIONAL RESOURCES

To learn more about the science behind climate change and the scientific communities position on anthropogenic climate change see the following:

National Aeronautics and Space Administration (NASA) climate Site:
http://climate.nasa.gov/

National Oceanic and Atmospheric Administration Climate Site:
http://www.noaa.gov/climate.html

Geological Society of America's Position Statement on Climate Change:
https://www.geosociety.org/gsa/positions/position10.aspx

American Metrological Society's Position Statement on Climate Change:
https://www.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/climate-change/

American Chemical Society's Position Statement on Climate Change:
https://www.acs.org/content/acs/en/policy/publicpolicies/sustainability/globalclimatechange.html?_ga=2.227911517.1368062825.1497897808-1921393895.1497558864

American Physical Society's Position Statement on Climate Change:
http://www.aps.org/policy/statements/climate/

American Association for the Advancement of Science's Position Statement on Climate Change:
http://www.aaas.org/sites/default/files/migrate/uploads/aaas_climate_statement.pdf

6.8 STUDENT RESPONSES

1.   Based exclusively on the data provided and your graph, what conclusion would you make regarding climate change?

a.   Sea ice is expanding, which indicates an increase in temperature

b.   Sea ice is expanding, which indicates a decrease in temperature

c.   Sea ice is contracting, which indicates an increase in temperature

d.   Sea ice is contracting, which indicates a decrease in temperature

2. What is slope of the line of best fit for this data?

a.   0.008 million square kilometers per year

b.   0.05 million square kilometers per year

c.   -0.05 million square kilometers per year

d.   0.017 million square kilometers per year

e.   -0.17 million square kilometer per year

f.   0.033 million square kilometer per year

3. Even though the above data is accurate, give and explain two reasons why this dataset might lead you to an incorrect conclusion regarding global climate change.

4. What is the slope of the line of best fit you estimated for this data set? Make sure to show your work.

5. What conclusion about climate change could you make from this dataset? How does your result for the extended dataset compare to the results from the data presented in the article (Part A)?

6.   What is the slope of the line of best fit you estimated for this data set? Make sure to show your work.

7.   What conclusion on climate change could you make from this dataset? How does your result for the North Pole compare to that of the South Pole (Part B)?

8.   Examine and describe the ocean currents flowing in the Atlantic Ocean from the equator to the North Pole starting from Brazil (6 08 54.55S 35 58 24.09W). Do these currents reach the northern polar ice sheet? If the tropics become warmer, how would this affect the northern ice sheet?

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10.   Based on your answer to questions eight and nine, explain why we see different trends in the sea ice extent in the south (Part B) and north poles (Part C).

11.   How might the changes you saw in the previous exercises relate to global albedo, sea level, ocean salinity, and temperature?

12.   Do you think any conclusions (if any) regarding climate change should be made based on the data presented in this assignment?

13.   What data do you think are needed to make a conclusion regarding climate change?