

Introduction

It has been proposed that increases in carbon dioxide (CO₂) emissions resulting from human activity are responsible for climate change. We know that CO₂, together with water vapor, ozone, methane, and other molecules in the atmosphere, helps to regulate temperatures on earth. We also know that the climate is always changing and that, regardless of human activity, it has undergone both abrupt and gradual swings in temperatures and atmospheric conditions. Within the past decade, our understanding of the climate has improved. However, there is still much that remains uncertain within the scientific community. A closer look at some of the factors that influence climate will put into perspective how difficult it is to model and understand past, current, and future changes in climate.

Over the past 100 years, the climate has undergone periods of both warming and cooling. During the late nineteenth century and early twentieth century, there were warnings of an impending ice age. In 1923, *Time* magazine stated, “[T]he discoveries of changes in the sun’s heat and the southward advance of glaciers in recent years have given rise to conjectures of the possible advent of a new ice age.” A decade later, the *New York Times* warned that the nation had entered its longest warming spell since 1776. [1]

Considering the complexity of our climate system, it is not surprising that forecasts change. As new information surfaces, we change the way we think about the natural world—including climate. In fact, many scientists who once thought human activities caused climate change are no longer certain that that is the case. On April 6, 2006, for example, 60 scientists signed a

letter to Canadian Prime Minister Stephen Harper asserting that climate alarmism is unsupported by science. They wrote:

Observational evidence does not support today’s computer climate models, so there is little reason to trust model predictions of the future ... Significant [scientific] advances have been made since the [Kyoto] Protocol was created, many of which are taking us away from a concern about increasing greenhouse gases. If, back in the mid-1990s, we knew what we know today about climate, Kyoto would almost certainly not exist, because we would have concluded it was not necessary. [2]

Even scientists who have worked with the United Nations Intergovernmental Panel on Climate Change (IPCC) are raising doubts about a climate crisis. In a January 2007 TV interview, scientist Richard Linden of the Massachusetts Institute of Technology said that fears of human-made climate change are “silly.” [3]

In a 2007 *Wall Street Journal* article, atmospheric scientist John Christy, who declined his share of the Nobel Peace Prize awarded to the IPCC, noted that the climate system is so “extraordinarily complex” that it is “beyond the mastery of mere mortals.” [4] He reminds us that the conditions we observe in today’s climate have also existed in the past.

Historic climate change

The earth has warmed and cooled many times throughout history. (These cyclical patterns can be seen in Lesson 2, Figure 2.1.) Indeed, tem-

temperatures have been much higher in the past than they are today—as much as 10° C higher than temperatures have been at any time during the last century.

Past climate change is often discussed in the context of geologic time scales, as shifts have occurred over thousands or even tens of thousands of years. However, scientists have discovered that climate change is not always gradual. In fact, there is strong evidence that temperature changes can occur over the course of a few decades.

For example, it is estimated that temperatures in Greenland increased by 8° C to 16° C within a span of several decades about 15,000 years ago. Two decades after this rise in temperature, atmospheric levels of methane increased rapidly for about 50 years. Scientists believe that this was the result of an expansion of wetlands in tropical regions. [5]

During the last Glacial Maximum (about 21,000 years ago), ice covered all of Northern Europe and Canada, extending as far south as the Missouri River and as far east as New York. Since that time, temperatures have increased by an estimated 4° C to 7° C. [6] Only about 0.65° C of that warming has occurred during the last century. [7]

It is estimated that the earth is about 4.6 billion years old, but temperature records do not extend back that far. Consequently, scientists apply “proxies” (surrogate data) to estimate prehistoric temperatures. Proxies are constructed using fossils, sediment samples, and tree rings, as well as data from air bubbles found in ice cores in Antarctica and Greenland.

Based on such data, researchers have determined that rapid warming events typically have been followed by periods of gradual cooling that were triggered by accelerated glacial melt and the breakup of sea ice. The massive influx of fresh water into the north Atlantic Ocean is

believed to have altered the patterns of ocean circulation, causing a cooling shift in the climate. Atmospheric CO₂ concentrations varied only slightly during these events—probably by less than 10 parts per million (ppm) during the warming periods and by 20 ppm during the cooling periods. [8] By comparison, CO₂ levels have increased by about 100 ppm during the last century, while temperatures have increased by only about 0.6° C. This evidence suggests that the correlation between rising temperatures and levels of CO₂ in the atmosphere is not causative.

During the Medieval Warm Period (c. 800-1300 CE), the earth was at least as warm as it is today. The warm temperatures of the time could not have been caused by the use of fossil fuels or by other human activities since people did not have cars or coal-burning power plants back then. After the Medieval Warm Period, temperatures dropped significantly, and the Little Ice Age, which lasted until the mid-nineteenth century, began.

When the earth began to warm again following the Little Ice Age, scientists began to track surface temperatures in the United States and elsewhere. [9] This data revealed a gradual warming trend that became more pronounced between 1900 and the 1940s, while carbon dioxide emissions resulting from human activity were low. Between the 1940s and the 1970s, temperatures actually declined slightly while carbon dioxide emissions caused by industrialization increased. This evidence suggests that CO₂ levels in the atmosphere cannot explain changes in climate.

Earth is not the only planet where temperatures are increasing. Mars, which is not affected by carbon dioxide emissions caused by human activity, has been warming, as well. [10] Scientists also believe that Jupiter, Neptune’s moon, and even Pluto are warming, and that these warmer temperatures are probably the result of increases in the amount of energy given off by the sun. [11]

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Introduction

Drivers of climate change

The sun exerts the most significant influence on earth's climate. Thus, when we study climate change, it is important to consider the various factors that affect the amount of solar radiation that reaches the earth.

Incoming solar radiation

Changes in earth's orbit or orientation toward the sun alter the amount of energy the earth receives. Such a change can have a significant impact on earth's climate. In addition, the amount of energy the sun produces also changes, thereby altering the amount of energy that reaches earth. The surface and atmosphere of earth absorb an average of 240 watts of solar energy for every square meter of earth's surface area.

Variations in earth's orientation to the sun and its orbit around the sun are collectively known as the Milankovitch Cycles. There are three Milankovitch Cycles: eccentricity, obliquity, and precession (see Figures 4.1 and 4.2).

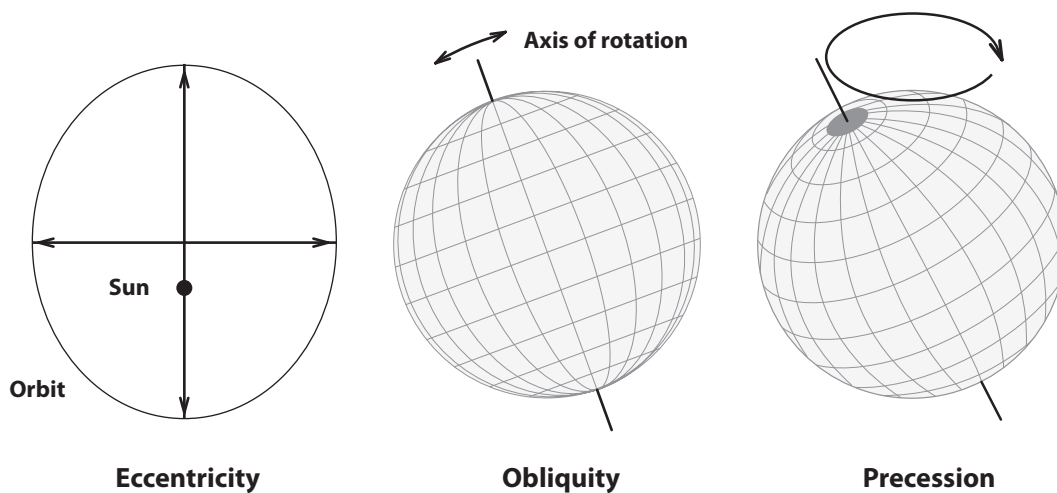
1 Eccentricity

Eccentricity is the shape of earth's orbit around the sun. This shape oscillates between less elliptical (nearly circular) and more elliptical (oval-shaped) over a cycle of about 100,000 years. We are currently in a period of low eccentricity, meaning that our orbit around the sun is more circular.

2 Obliquity

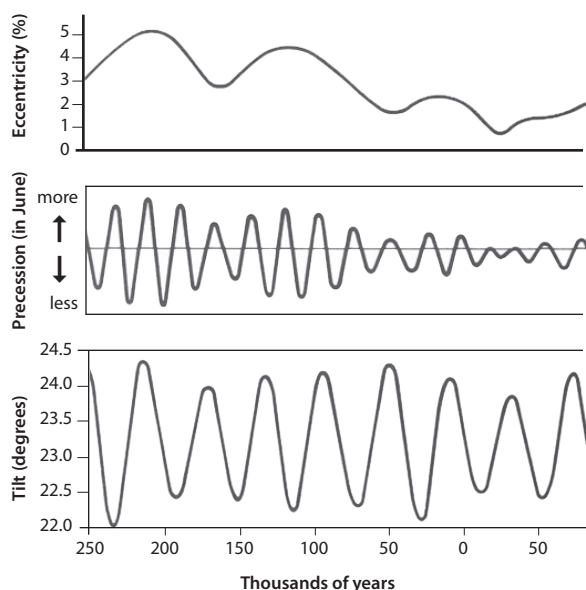
Obliquity refers to the tilt of earth's axis in relation to its plane of orbit around the sun. This tilt oscillates between about 22.1° and 24.5° over a cycle of 41,000 years. While obliquity does not change the total amount of solar energy the earth receives over time, it does alter the intensity of the summer and winter seasons at higher latitudes. As obliquity increases, the amount of solar radiation reaching higher latitudes intensifies during summer and lessens in intensity during winter months, thereby making summers warmer and winters colder. Currently, earth's axis of rotation is 23.5° and is declining, causing milder summers and winters at higher latitudes.

Figure 4.1: Milankovitch Cycles



Source: Riebeek, Holli (2006). *Paleoclimatology: Explaining the Evidence*. NASA. <http://earthobservatory.nasa.gov/Features/Paleoclimatology_Evidence/>.

Figure 4.2: Milankovitch Cycles over the past 250,000 years, with projections for the next 100,000 years



Source: Bagenal, Fran (2005). *Atmospheric Evolution*. University of Colorado. <<http://lasp.colorado.edu/~bagenal/3720/CLASS20/20AtmosEvol1.html>>.

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Introduction

3 Precession

Precession refers to changes in the orientation of earth's axis in space, a cycle that occurs over 19,000 to 23,000 years. Precession affects the time of year at which the earth is closest to or farthest away from the sun. Currently, we are closest to the sun in January and farthest away in July. As a result, our winters are relatively mild compared to winters during past ice ages.

Though we have discussed these three cycles in isolation, each cycle can have an impact on the effects of the other cycles. For example, earth's current obliquity may result in milder summers and winters, but changes in precession or eccentricity may lessen or intensify this effect.

There is widespread agreement among scientists that the Milankovitch Cycles have a significant

impact on climate, one that is far greater than the impact of any human activity.

Reflected solar radiation

Albedo refers to the percentage of solar energy that is reflected by earth's atmosphere back into space. Albedo depends on a variety of factors, including the amount of water vapor (and other particles) in the atmosphere and the type of cloud cover. For example, warmer temperatures can increase atmospheric water vapor, which in turn can increase cloud cover. Denser cloud cover can increase the amount of solar radiation that is reflected back into space, causing a cooling effect. Alternatively, denser cloud cover can also lead to warmer temperatures by trapping heat closer to earth's surface.

About 30% of incoming solar radiation is reflected back into space, and two thirds of that amount is reflected by cloud cover and particles in the atmosphere, while the rest is reflected by earth's surface. Thus, particles in the atmosphere are partly responsible for keeping temperatures on earth lower. For example, the 1991 eruption of Mt. Pinatubo in the Philippines spewed an estimated 17 million tons of sulfur dioxide and ash particles into the atmosphere. By altering the amount of energy reaching earth's surface, the eruption had a profound impact on earth's climate, temporarily decreasing global average temperatures by about 0.5° C. [12]

Cosmic rays from other galaxies or other parts of our galaxy can also influence earth's climate. These cosmic rays collide with other molecules when they enter the atmosphere, creating ultra-small particles that can facilitate cloud formation. Over the past 100 years, scientists have recorded fewer cosmic rays and less cloud cover, meaning that more solar radiation has been able to reach the earth's surface.

Absorbed solar radiation

About 70% of solar radiation is absorbed by earth's surface and atmosphere and by clouds. Greenhouse gases can reduce the amount of infrared (heat) energy that is radiated by earth's surface, allowing more energy to remain in the lower atmosphere and at the surface. Without these gases, average global temperatures would be about -19° C instead of 14° C.

The amount of CO₂ in the atmosphere has varied widely over time. Current estimates suggest that CO₂ levels fluctuated between 180 ppm and 280 ppm throughout the 650,000 years leading up to the Industrial Revolution. Significant fluctuations in temperatures also occurred during that period.

Since 1850, atmospheric CO₂ levels have increased from about 265 ppm to 383 ppm (by volume). It is expected that CO₂ levels will continue to increase as developing nations such as China and India move through their own industrial revolutions.

Changes in land use affect the amount of energy absorbed by earth's surface and thus the amount of energy it radiates as heat. On a global scale, this effect is estimated to have increased surface temperatures by about 0.06° C over the last century. [13] On a local scale, the effects of land use changes can be much more significant. For example, densely populated urban areas absorb more heat energy than grassy fields or forests do, creating what is known as the "heat island effect." Annual mean temperatures in urban and suburban areas can be 1° C to 3° C greater than those in neighboring rural locations. [14]

Over the past few million years, earth's climate has fluctuated widely, along with temperatures and atmospheric compositions of greenhouse gases. These changes are the result of a multitude of factors, the complexity of which frustrates our ability to predict future climate conditions with accuracy.

References

- 1 Anderson, R. Warren, and Dan Gainor (2006). *Fire and Ice*. Business and Media Institute. <<http://www.businessandmedia.org/specialreports/2006/fireandice/fireandice.asp>>.
- 2 *Financial Post* (2006, April 6). Open Kyoto to Debate. <<http://tinyurl.com/fpApr606>>.
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- 5 Intergovernmental Panel on Climate Change [IPCC] (2007). *Climate Change 2007: The Physical Science Basis*. Intergovernmental Panel on Climate Change. <<http://www.ipcc.ch/ipccreports/ar4-wg1.htm>>.
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- 12 Self, Stephen, Jing-Xia Zhao, Rick E. Holasek, Ronnie C. Torres, and Alan J. King (1996). The Atmospheric Impact of the 1991 Mount Pinatubo Eruption. In *Fire and Mud: Eruptions and Lahars of Mount Pinatubo, Philippines* (United States Geological Survey). <<http://pubs.usgs.gov/pinatubo/self/index.html>>.
- 13 IPCC (2007).
- 14 US Environmental Protection Agency (2009). *What Is an Urban Heat Island?* <<http://www.epa.gov/heatisland/about/index.htm>>.

Lesson 4-A

Climate drivers

Theme

This lesson examines the primary drivers of climate change, including the absorption and reflection of solar radiation. It demonstrates that our climate is always changing.

Purpose

This lesson emphasizes that, even with advanced technology, there is still much that is uncertain about climate change. This lesson shows that there are natural forces that inevitably cause glacial periods as well as warming periods, irrespective of human activities.

Description

Students will read about the main drivers of climate change and examine a graph showing temperature changes in the United States between 1880 and 2005. Using this information, they will create hypotheses to explain those changes.

Procedure

1 Remind the class of the climate change hypotheses they constructed in *Lesson 1-B: Climate change hypothesis*. Ask students whether they think their hypotheses could be supported by our current understanding of climate change.

2 Let students know that beliefs about climate have changed over time. Some of these changes are illustrated in *Visual 4.1: News timelines*.

In the early 1900s, some people were concerned that the world was entering an ice age. By the 1930s and 1940s, the media reported that the world was warming, but by the 1970s, the focus was again on cooling. There have been cooling and warming trends throughout history. Over

time, technology will improve, new data will become available, and better models will be designed to help us understand climate.

3 Have students use the scientific method to test their hypotheses. You may wish to refer back to *Visual 1.2: The scientific method*.

4 Hand out *Student Reading 4.1: Drivers of climate change* and *Worksheet 4.1: Temperature change*. Have students complete the reading and the worksheet.

5 Display *Visual 4.2: Correlation does not imply causation* and *Visual 4.3: US temperature change*. Ask students what evidence these graphs provide and what ideas are implied, but not supported, by the data. For example:

- How often has the climate changed?
- Does *Visual 4.3: US temperature change* show correlation and/or causation between CO₂ and temperature?

Point out that temperatures rose between 1900 and 1940, when CO₂ emissions were relatively low. Between 1940 and 1975, CO₂ emissions rose while temperatures declined.

6 Ask students to share their answers to question 4 from *Worksheet 4.1: Temperature change*. What factors are likely to cause climate change?

7 Note some factors that influence global temperatures:

- Incoming solar radiation is the amount of radiation that reaches earth. This is illustrated in *Visual 4.4: Incoming solar radiation*.
- Albedo is the percentage of solar radiation that is reflected by earth back into space. This is illustrated in *Visual 4.5: Albedo*.
- Absorbed solar radiation is defined in *Visual 4.6: Radiation absorbed*. Energy absorption is affected by chemical concentrations in the atmosphere and by land use changes (e.g., the “heat island effect”).

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Lesson 4-A

Visual 4.1**News timelines**

A *Time* magazine timeline

"The discoveries of changes in the sun's heat and the southward advance of glaciers in recent years have given rise to conjectures of the possible advent of a new ice age."

September 10, 1923

"Gaffers who claim that winters were harder when they were boys and girls are quite right ... weathermen have no doubt that the world, at least for the time being, is growing warmer."

January 2, 1939

"Climatological Cassandras are becoming increasingly apprehensive, for the weather aberrations they are studying may be the harbinger of another ice age."

June 24, 1974

"[S]cientists no longer doubt that global warming is happening, and almost nobody questions the fact that humans are at least partly responsible."

April 9, 2001

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**Visual
4.1**

A *New York Times* timeline

"MacMillan Reports Signs of New Ice Age"

September 18, 1924

"America in Longest Warm Spell Since 1776; Temperature Line Records a 25-Year Rise"

March 27, 1933

"Scientists Ponder Why World's Climate is Changing; A Major Cooling Widely Considered to be Inevitable"

May 21, 1975

"Past Hot Times Hold Few Reasons to Relax About New Warming"

December 27, 2005

Source: Anderson, R. Warren, and Dan Gainor (2006). *Fire and Ice*. Business and Media Institute. <<http://www.businessand-media.org/specialreports/2006/fireandice/fireandice.asp>>.

Student Reading 4

Drivers of climate change

The sun has the most significant influence on earth's climate. Thus, when we study climate change, it is important to consider the various factors that affect the amount of solar radiation that reaches the earth.

Incoming solar radiation

Changes in earth's orbit or orientation toward the sun alter the amount of energy the earth receives. Such a change can have a significant impact on earth's climate. In addition, the amount of energy the sun produces also changes, thereby altering the amount of energy that reaches earth. The surface and atmosphere of earth absorb an average of 240 watts of solar energy for every square meter of earth's surface area.

Variations in earth's orientation to the sun and its orbit around the sun are collectively known as the Milankovitch Cycles. There are three

Milankovitch Cycles: eccentricity, obliquity, and precession (see Figures 4.1 and 4.2).

1 Eccentricity

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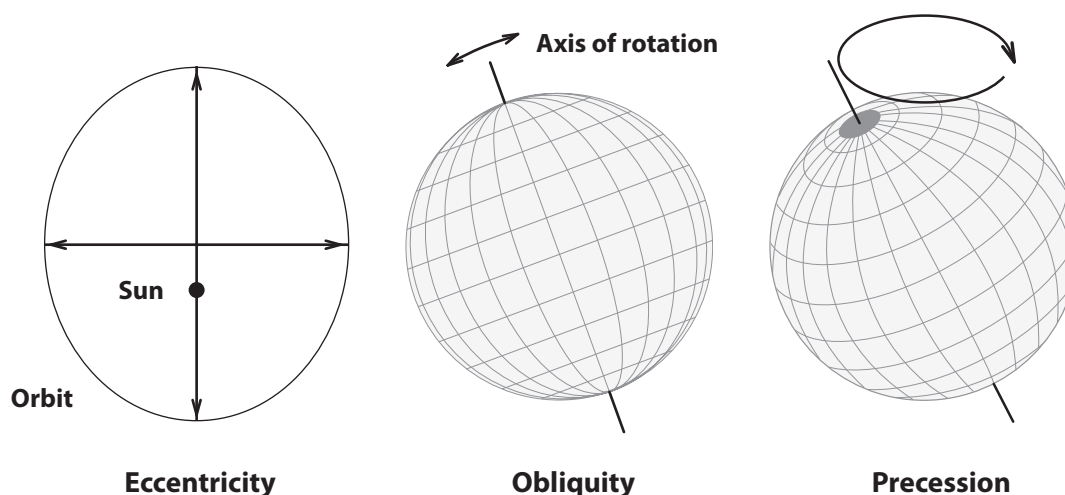
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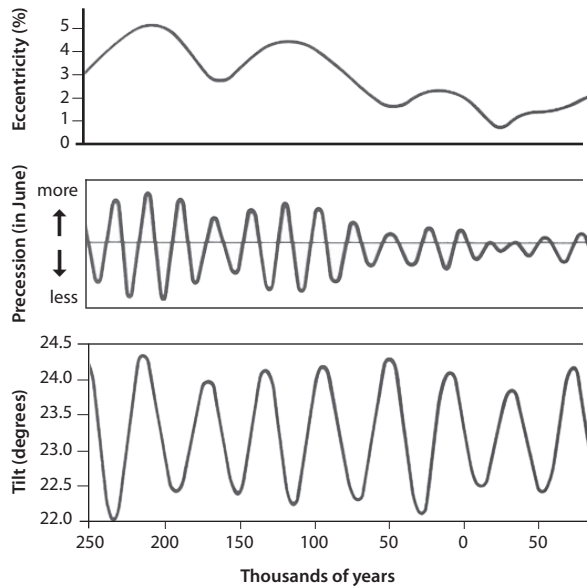
Student Reading

Figure 4.1: Milankovitch Cycles



Source: Riebeek, Holli (2006). *Paleoclimatology: Explaining the Evidence*. NASA. <http://earthobservatory.nasa.gov/Features/Paleoclimatology_Evidence/>.

Figure 4.2: Milankovitch Cycles over the past 250,000 years, with projections for the next 100,000 years



Source: Bagenal, Fran (2005). *Atmospheric Evolution*. University of Colorado. <<http://lasp.colorado.edu/~bagenal/3720/CLASS20/20AtmosEvol1.html>>.

warmer and winters colder. Currently, earth's axis of rotation is 23.5° and is declining, causing milder summers and winters at higher latitudes.

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Reflected solar radiation

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About 30% of incoming solar radiation is reflected back into space, and two thirds of that amount is reflected by cloud cover and particles in the atmosphere, while the rest is reflected by earth's surface. Thus, particles in the atmosphere are partly responsible for keeping temperatures on earth lower. For example, the 1991 eruption of Mt. Pinatubo in the Philippines spewed an estimated 17 million tons of sulfur dioxide and ash particles into the atmosphere. By altering the amount of energy reaching earth's surface, the eruption had a profound impact on earth's climate, temporarily decreasing global average temperatures by about 0.5°C . [1]

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Absorbed solar radiation

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Student Reading

Changes in land use affect the amount of energy absorbed by earth's surface and thus the amount of energy it radiates as heat. On a global scale, this effect is estimated to have increased surface temperatures by about 0.06° C over the last century. [2] On a local scale, the effects of land use changes can be much more significant. For example, densely populated urban areas absorb more heat energy than grassy fields or forests do, creating what is known as the "heat island effect." Annual mean temperatures in urban and suburban areas can be 1° C to 3° C greater than those in neighboring rural locations. [3]

Over the past few million years, earth's climate has fluctuated widely, along with temperatures and atmospheric compositions of greenhouse gases. These changes are the result of a multitude of factors, the complexity of which frustrates our ability to predict future climate conditions with accuracy.

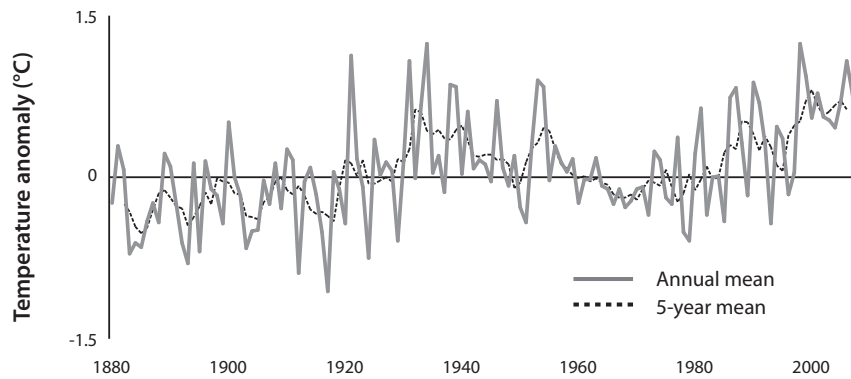
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Worksheet 4.1

Temperature change

Annual mean temperature change in the United States, 1880-2008



Source: NASA Goddard Institute for Space Studies (2009). *GISS Surface Temperature Analysis*.
<http://data.giss.nasa.gov/gistemp/graphs/>.

Examine the graph above and answer the following questions:

- 1 What is the overall trend in temperatures indicated by the graph?
- 2 Is there any time period that diverges from the general trend in the graph?
- 3 Create two hypotheses to explain why temperatures have generally increased since 1880.
- 4 Create a hypothesis to explain why temperatures were cooler between 1940 and 1970.

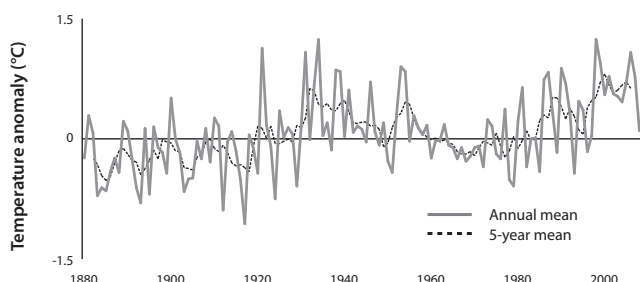
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Worksheet
4.1

Worksheet 4.1 Answer Key

Temperature change

Annual mean temperature change in the United States, 1880-2008



Examine the graph above and answer the following questions:

- 1 What is the overall trend in temperatures indicated by the graph?

The general trend is that temperatures are increasing, but there are other smaller warming/cooling cycles within the larger trend.

- 2 Is there any time period that diverges from the general trend in the graph?

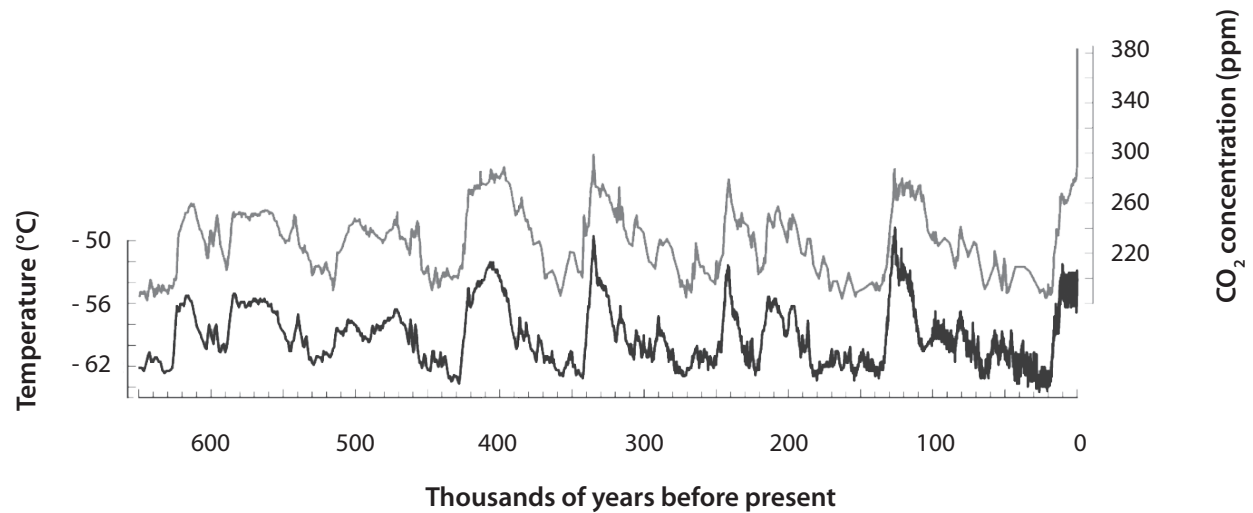
Between 1940 to 1970, temperatures declined.

- 3 Create two hypotheses to explain why temperatures have generally increased since 1880.

- A. Energy from the sun has increased, resulting in warmer temperatures on earth.
- B. It is part of a natural cycle—the climate is always changing.
- C. There are fewer global pollutants in the air than there were 50 or 100 years ago, which means that more direct sunlight is reaching earth's surface.
- D. Increased emissions from industrial development have amplified the greenhouse effect.
- E. Milankovitch Cycles have created conditions for temperatures to increase.
- F. Albedo has decreased, meaning less heat is reflected back into space.

- 4 Create a hypothesis to explain why temperatures were cooler between 1940 and 1970.

- A. Economies grew rapidly following the Great Depression and industrial emissions increased. The particulate matter emitted into the air reflected the incoming solar radiation and cooled the earth.
- B. It is part of a natural cycle—the climate is always changing.

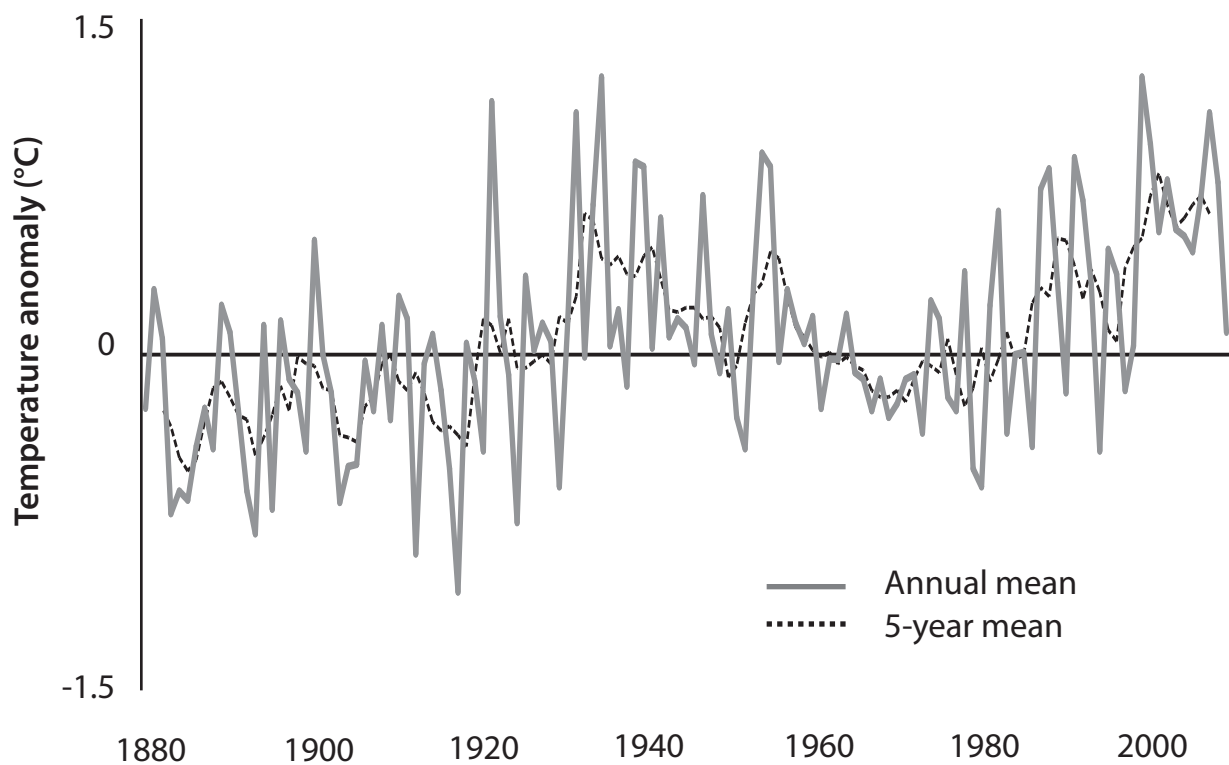
Visual 4.2**Correlation does not imply causation****Estimated temperature and carbon dioxide levels in Antarctica over the past 650,000 years****4****Visual
4.2**

Source: Physics Institute, University of Bern, Switzerland. Adapted from Fretwell, Holly (2007). *The Sky's Not Falling: Why It's OK to Chill about Global Warming*. World Ahead Media.

Visual 4.3

US temperature change

Annual mean temperature change in the United States, 1880-2008



Source: NASA Goddard Institute for Space Studies (2009). *GISS Surface Temperature Analysis*. <<http://data.giss.nasa.gov/gistemp/graphs/>>.

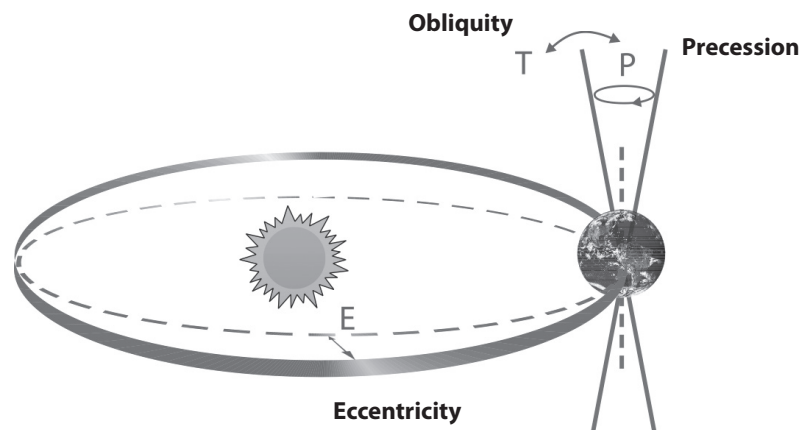
Visual 4.4

Incoming solar radiation

The solar energy received on earth changes when the relationship between earth and the sun changes. Variations in earth's orientation to the sun and its orbit around the sun are collectively known as the **Milankovitch Cycles**, which are:

- **Eccentricity**: the shape of earth's orbit around the sun
- **Obliquity**: changes in the angle of earth's axis (tilt)
- **Precession**: the wobble of earth's tilt

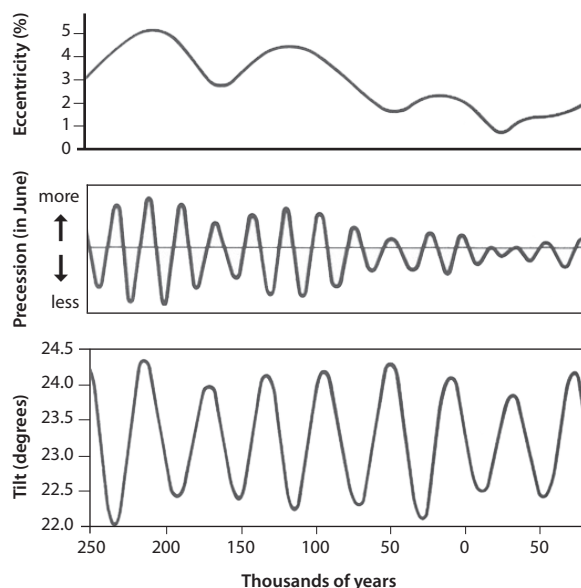
Figure 1:
Milankovitch Cycles



4

Visual
4.4

Figure 2:
Milankovitch Cycles over
the past 250,000 years,
with projections for the
next 100,000 years



Source: Bagenal, Fran (2005). *Atmospheric Evolution*. University of Colorado. <<http://lasp.colorado.edu/~bagenal/3720/CLASS20/20AtmosEvol1.html>>.

Visual 4.5

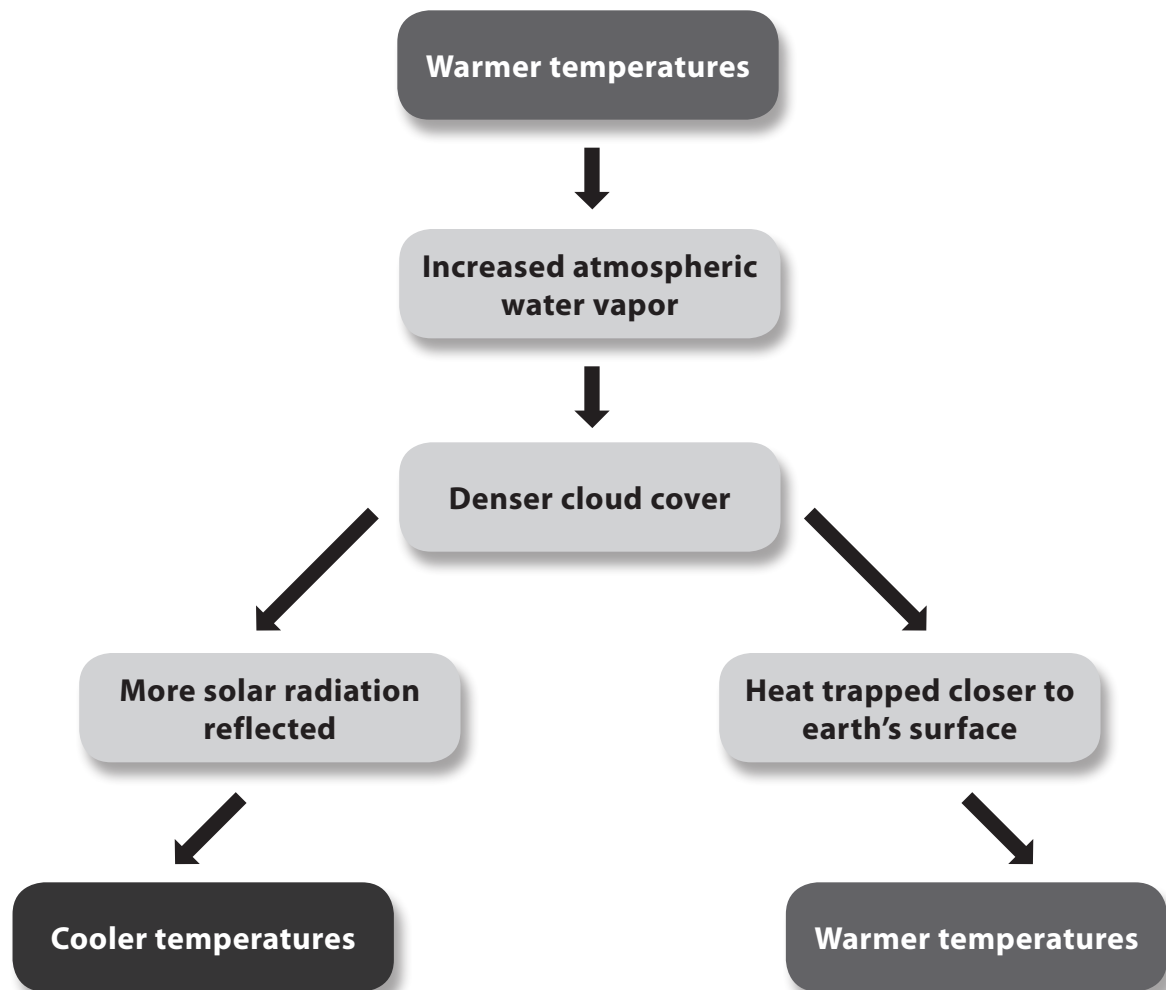
Albedo

Albedo is the fraction of solar radiation reflected from earth back into space. Albedo depends upon a number of factors including:

- Water vapor
- Aerosols (particles in the air)
- Changes in cloud cover

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Visual
4.5



Visual 4.6

Radiation absorbed

Land absorbs energy

- Changes in land use change the amount of energy absorbed by land

The “heat island effect”

- Annual mean temperatures in urban and suburban areas can be 1° C to 3° C higher than those in neighboring rural locations
- Displacing trees minimizes cooling from shade
- Buildings and streets can trap air and reduce air flow
- Vehicles, factories, and machines emit heat

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Visual
4.6

Lesson 4-B

Climate forces

Theme

The complexity of climate change stems from the innumerable forces that can impact local and global temperatures and climate over time. Some factors may have a warming effect while others may have a cooling effect. Researchers examine these factors for evidence to support or refute different hypotheses.

Purpose

This lesson emphasizes the importance of looking at a number of factors related to climate change, instead of narrowly focusing on CO₂. It will help students recognize that there is still much uncertainty regarding the role each factor plays in climate change.

Description

Students will complete a writing assignment to improve their understanding of the many variables that affect climate. In class, students will break off into groups and then analyze hypotheses about climate change. Two groups will be assigned to each hypothesis; one group will find evidence to support the hypothesis and the other group will find evidence to refute it.

Procedure

1 Talk with students about the different factors that impact global temperatures. Have students give examples of factors that may warm or cool temperatures. Organize their ideas into categories, e.g., incoming solar radiation, albedo, and radiated or absorbed heat energy.

2 Hand out *Worksheet 4.2: Climate forces*. This is a writing assignment that will help students learn how temperature responds to a variety of

natural forces. Each student will write a paper discussing a variety of factors that impact climate and how each factor may affect global temperatures in the future. Discuss the various factors students wrote about in class.

3 Split the class into small groups (or students may work individually). Hand out *Worksheet 4.3: Hypothesis testing*. This is a group assignment that will help students learn how temperature and climate respond to a variety of factors, and increase their understanding of the difficulties surrounding climate analyses.

Choosing from the list below (or a list of your own), assign two groups to each hypothesis. One group will examine evidence that supports the hypothesis; the other group will gather evidence to refute it.

- CO₂ emissions from human activities are the main driver of climate change.
- Solar radiation is the most important driver of climate change.
- Cloud cover is likely to increase global temperatures.
- Cloud cover is likely to decrease global temperatures.

4 Have each group present their findings and answer the following questions.

- What was their goal?
- What data did they find to support their hypothesis?
- What data did they ignore?
- Given their findings, do they expect global temperatures to increase, decrease, or remain constant in the future?

Final Thought

It is important to consider many perspectives when analyzing an issue. People may get a biased view of an issue if they hear only one group's hypothesis. The information provided by a variety of sources is much more enlightening.

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Lesson 4-B

Worksheet 4.2

Climate forces

- 1 On a separate page, write a one-page paper discussing a variety of factors that may impact climate. You must discuss at least four factors, including each of the following:
 - Solar radiation
 - Cloud cover
 - At least one of the Milankovitch Cycles
- 2 Provide global temperature forecasts for the next 5, 10, and 100 years, and justify your forecasts by citing various climate factors. How confident are you in your predictions?

4

**Worksheet
4.2**

Worksheet 4.3

Hypothesis testing

Working as a group, find evidence to support or reject the hypothesis highlighted below.

Be prepared to explain your findings to the class. Use the presentation summary below to organize your findings.

4

Hypothesis:

- 1 CO₂ emissions from human activities are the main driver of climate change.
- 2 Solar radiation is the most important driver of climate change.
- 3 Cloud cover is likely to increase global temperatures.
- 4 Cloud cover is likely to decrease global temperatures.

Presentation summary:

- 1 What was your goal?
- 2 What data supports your hypothesis?
- 3 What data contradicts your hypothesis?
- 4 According to your findings, what role, if any, does human activity play in climate change?
- 5 Given your findings, do you expect global temperatures to increase, decrease, or remain constant in the future?