E

Earth Science Standard E.4.c.

Student Workbook

California Education and the Environment Initiative

The Greenhouse Effect on Natural Systems

California Education and the Environment Initiative

Approved by the California State Board of Education, 2010

The Education and the Environment Curriculum is a cooperative endeavor of the following entities:

California Environmental Protection Agency
California Natural Resources Agency
Office of the Secretary of Education
California State Board of Education
California Department of Education
California Integrated Waste Management Board

Key Leadership for the Education and Environment Initiative:

Linda Adams, Secretary, California Environmental Protection Agency
Patty Zwarts, Deputy Secretary for Policy and Legislation, California Environmental Protection Agency
Andrea Lewis, Assistant Secretary for Education and Quality Programs, California Environmental Protection Agency
Mark Leary, Executive Director, California Integrated Waste Management Board
Mindy Fox, Director, Office of Education and the Environment, California Integrated Waste Management Board

Key Partners:

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Contents

Lesson 1 Climate, A Changing Environment

Key Unit Vocabulary 2

Considering Climate Change 3

Lesson 2 Earth's Greenhouse

Describing Earth's Greenhouse Effect 5

Lesson 3 Sources and Sinks of Greenhouse Gases

Sources and Sinks of Greenhouse Gases 8

Lesson 4 GHGs and Climate Change

Reading the Ice 11

Lesson 5 Too Much of a Good Thing?

Predicting a Warming Trend 13

Lesson 6 Deciding About the Atmosphere

Reconsidering Climate Change 15

Absorption: The process of taking in and not reflecting something, such as a light ray or radiation.

California Air Resources Board (ARB): The state agency that works with the public, the business sector, and local governments to protect the public's health, the economy, and the state's ecological resources through the most cost-effective reduction of air pollution.

Carbon footprint: The total amount of carbon gases produced directly and indirectly through human activities that use carbon-based fuels.

Climate: The prevailing, average weather conditions influenced by temperature, precipitation, humidity, and other meteorological factors in a given region over a long period of time.

GHG sink: Any process, activity, or reservoir that absorbs a greenhouse gas (GHG) from the atmosphere and stores it.

GHG source: Any process, activity, or reservoir that releases a greenhouse gas (GHG) into the atmosphere.

Global climate change: A long-term significant change in the Earth's climatic patterns.

Global warming: The gradual increase of average surface temperatures of Earth caused in part by high levels of atmospheric carbon dioxide.

Greenhouse effect: The combined effect of certain gases in the atmosphere absorbing infrared and thermal radiation, affecting the overall temperature of Earth.

Greenhouse gas (GHG): Any gas, such as water vapor, carbon dioxide, chlorine, or methane, that absorbs infrared radiation in the atmosphere and contributes to the greenhouse effect.

Infrared radiation: Electromagnetic radiation not visible to the eye ("below red" in the visible portion of the spectrum), measured as heat or thermal energy.

Paleoclimatology: The study of past climate and its causes and effects.

Proxy data: Information used "in place of" direct evidence to draw conclusions. Proxy data can include data from fossils, sediments, ice sheets, and tree rings.

Reflection: The process of scattering or bouncing back something, such as a light ray or radiation.

Thermal radiation: Electromagnetic radiation emitted as heat.

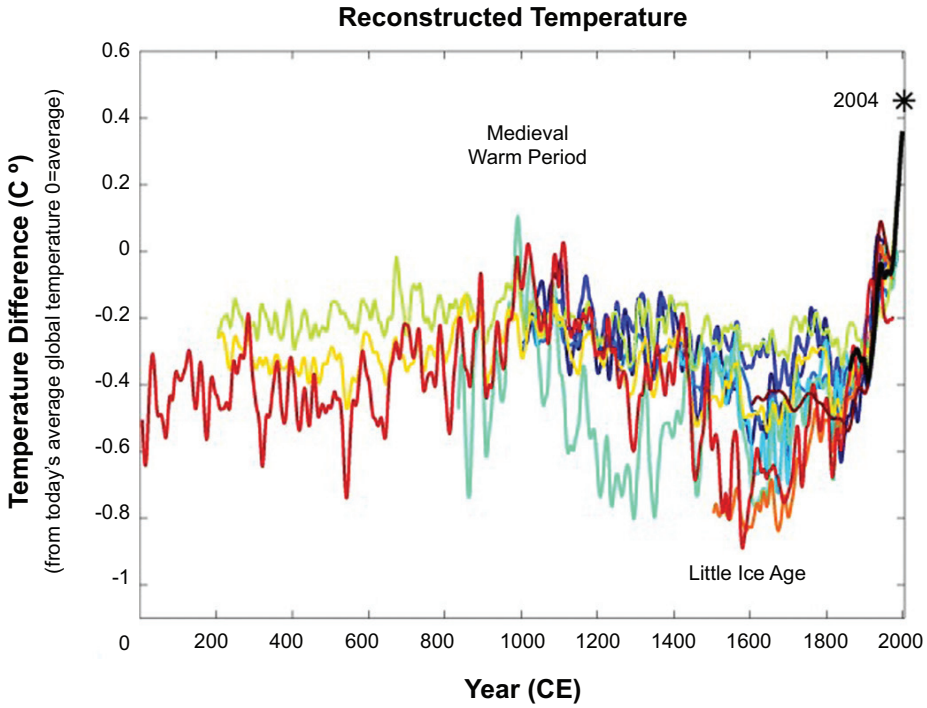
Weather: The conditions in the atmosphere (temperature, moisture, wind, and other atmospheric conditions) at a given time and location.

Name: _____

Instructions: Review the graph below and consider the information as you write an essay on the next page.

Temperature is one of the components of climate. As temperatures change, climate changes. Climatologists record the global temperature as a way to describe and predict how climate is changing.

The graph below shows a collection of temperature changes that have been reconstructed by various scientific teams from around the world. Each team looked at a different time period and used a variety of evidence to determine how Earth's temperature had changed during that time. The lines on the graph are showing how Earth's global temperature changed, not the actual temperature at that time.



Data	Time period studied	Scientific team
	1000–1991	*P. D. Jones, K.R. Briffa, T. P. Barnett, and S. F. B. Tett (1998)*
	1000–1980	*M. E. Mann, R. S. Bradley, and M. K. Hughes (1999)*
	1000–1960	*Crowley and Lowery (2000)*
	1402–1960	*K. R. Briffa, T. J. Osborn, F. H. Schweingruber, I. C. Harris, P. D. Jones, S. G. Shiyatov, S. G. and E. A. Vaganov (2001)*
	831–1922	*J. Esper, E. R. Cook, and F. H. Schweingruber (2002)*
	200–1980	*M. E. Mann and P. D. Jones (2003)*
	200–1995	*P. D. Jones and M. E. Mann (2004)*
	1500–1980	*S. Huang (2004)*
	1–1979	*A. Moberg, D. M. Sonechkin, K. Holmgren, N. M. Datsenko and W. Karlén (2005)*
	1600–1990	*J. H. Oerlemans (2005)*
	1856–2004	*Climatic Research Unit and the UK Meteorological Office Hadley Centre (2005)*

Name: _____

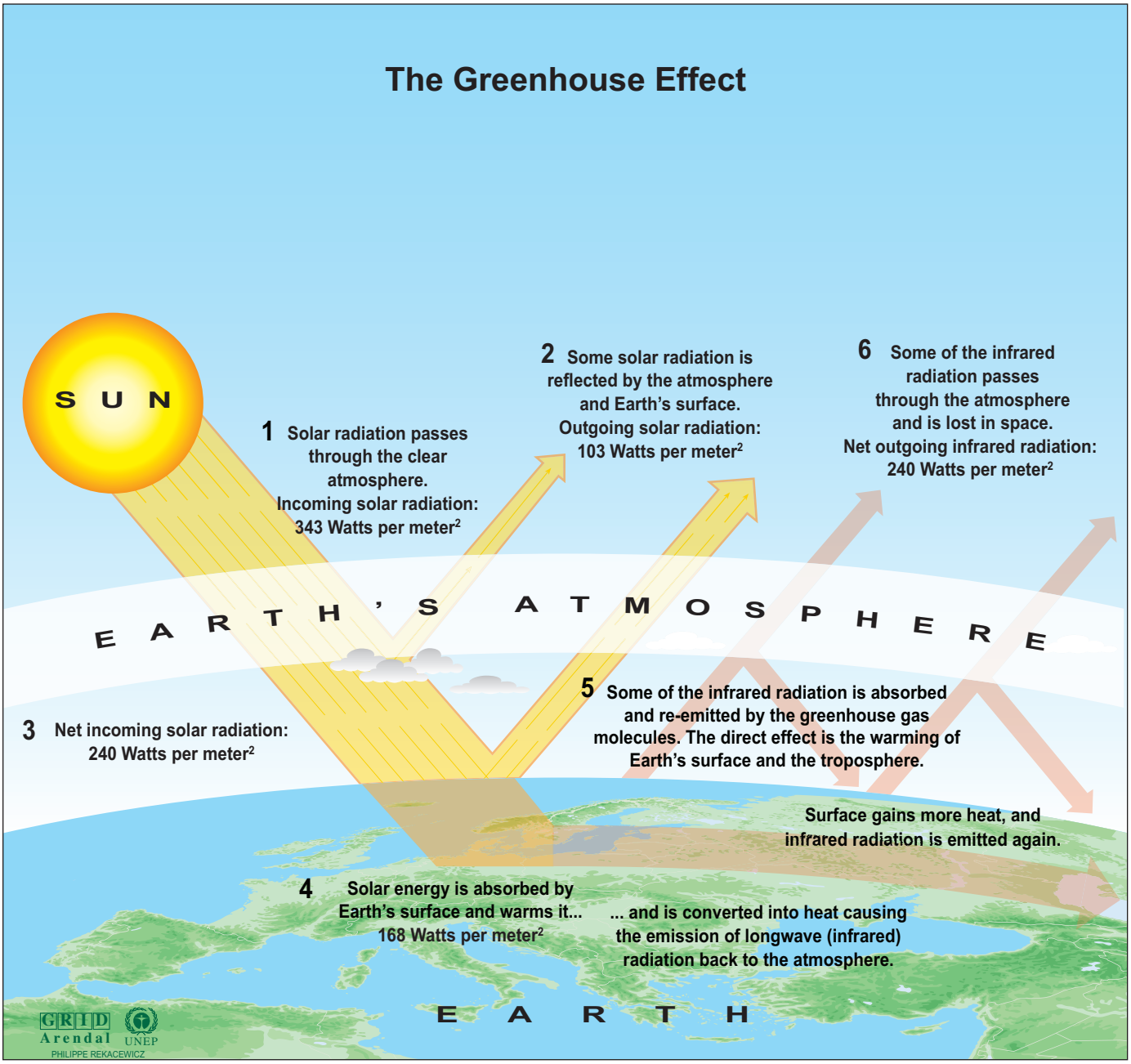
Think and Write

Consider how climate has changed in the past and the fact that climate is continuing to change. How could life be different in the future? What are some of the issues people need to consider when examining climate change?

Instructions: Use information from ***California Connections: Climate Change in the Golden State*** (Student Edition, pages 2–6) and the graph on the previous page to develop your answer. Write your essay in the space provided.

Name: _____

Instructions: Use the illustration below to complete the following tasks in the spaces provided on page 2. (5 points each)



Name: _____

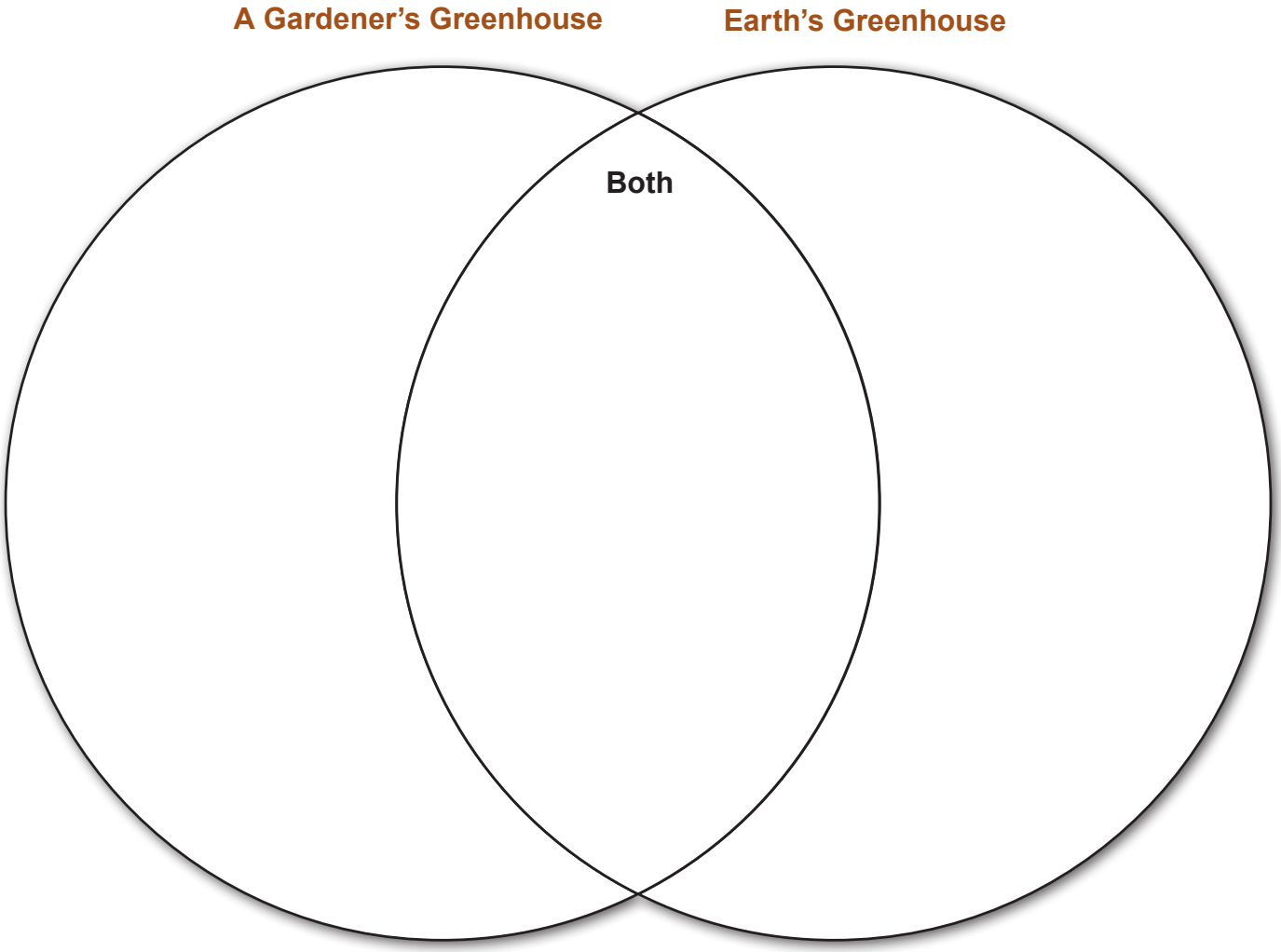
1. Describe how certain gases in the atmosphere (carbon dioxide, methane, water vapor, and nitrous oxide) influence Earth's thermal radiation, and how these gases affect Earth's atmosphere.

2. Explain what the "greenhouse effect" is and how it affects temperatures on Earth.

Name: _____

Instructions: Complete the Venn diagram below. (10 points)

3. Complete the Venn diagram below by comparing a gardener's greenhouse to Earth's "greenhouse." How are they similar? How are they different?



Name: _____

Instructions: Complete the following chart using information from the class discussion. (6 points each GHG)

GHG	Sources and Sinks
Water vapor	**Sources:** _____ _____ _____ **Sinks:** _____ _____ _____ **Human influences:** _____ _____ _____ _____ _____
Carbon dioxide	**Sources:** _____ _____ _____ **Sinks:** _____ _____ _____ **Human influences:** _____ _____ _____ _____ _____

Name: _____

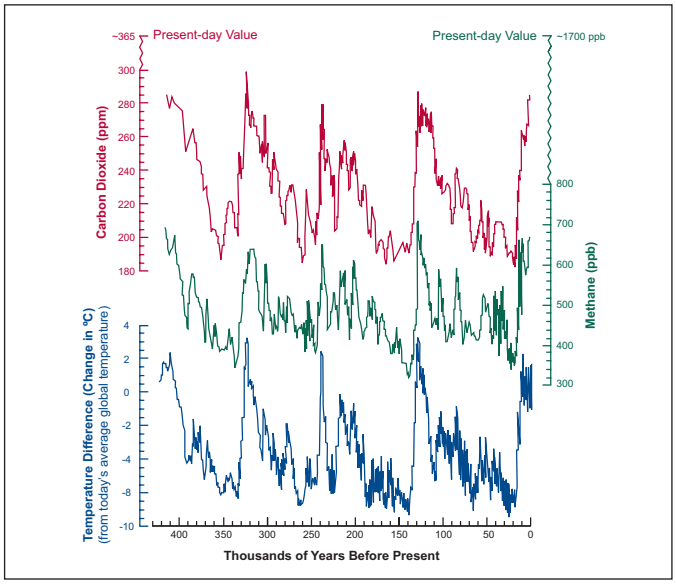
GHG	Sources and Sinks
Methane	**Sources:** _____ _____ _____ **Sinks:** _____ _____ _____ **Human influences:** _____ _____ _____ _____ _____
Nitrous oxide	**Sources:** _____ _____ _____ **Sinks:** _____ _____ _____ **Human influences:** _____ _____ _____ _____ _____

Name: _____

GHG	Sources and Sinks
Other	**GHG:** _____ _____ **Sources:** _____ _____ _____ **Sinks:** _____ _____ _____ **Human influences:** _____ _____ _____ _____ _____

Name: _____

Studying proxy data shows us that throughout much of Earth's geologic past, changes in climate occurred over long periods. The scale of these changes was generally large whether the transition was from periods of cold to cool to warm, or the opposite. Respond to the questions using the information from the ice core graph below.



The data to the left is from an ice core drilled at Vostok, Antarctica. The red line (top) shows the concentration of carbon dioxide there. The green line (center) shows the concentration of methane at the site. The blue line (bottom) shows the average temperature, plotted as the difference from today's average temperature (represented by the 0° C line).

Notes: These are the values measured in the ice cores.

0 on the Y-axis indicates the average temperature over time, not the actual temperature. Other numbers on the Y-axis indicate the difference from the average temperature.

Instructions: Use what you learned in **What Can Ice Tell Us About Past Climate?** (Student Edition, page 15) and the graphs above to answer the following questions in the spaces provided.

1. Describe what happens to carbon dioxide and methane over time. How does temperature data compare to changes in these greenhouse gases? Explain your answer. (3 points)

_____

_____

_____

_____

2. What is the overall pattern we can draw from this data? How would you describe this pattern? (3 points)

_____

_____

_____

_____

Name: _____

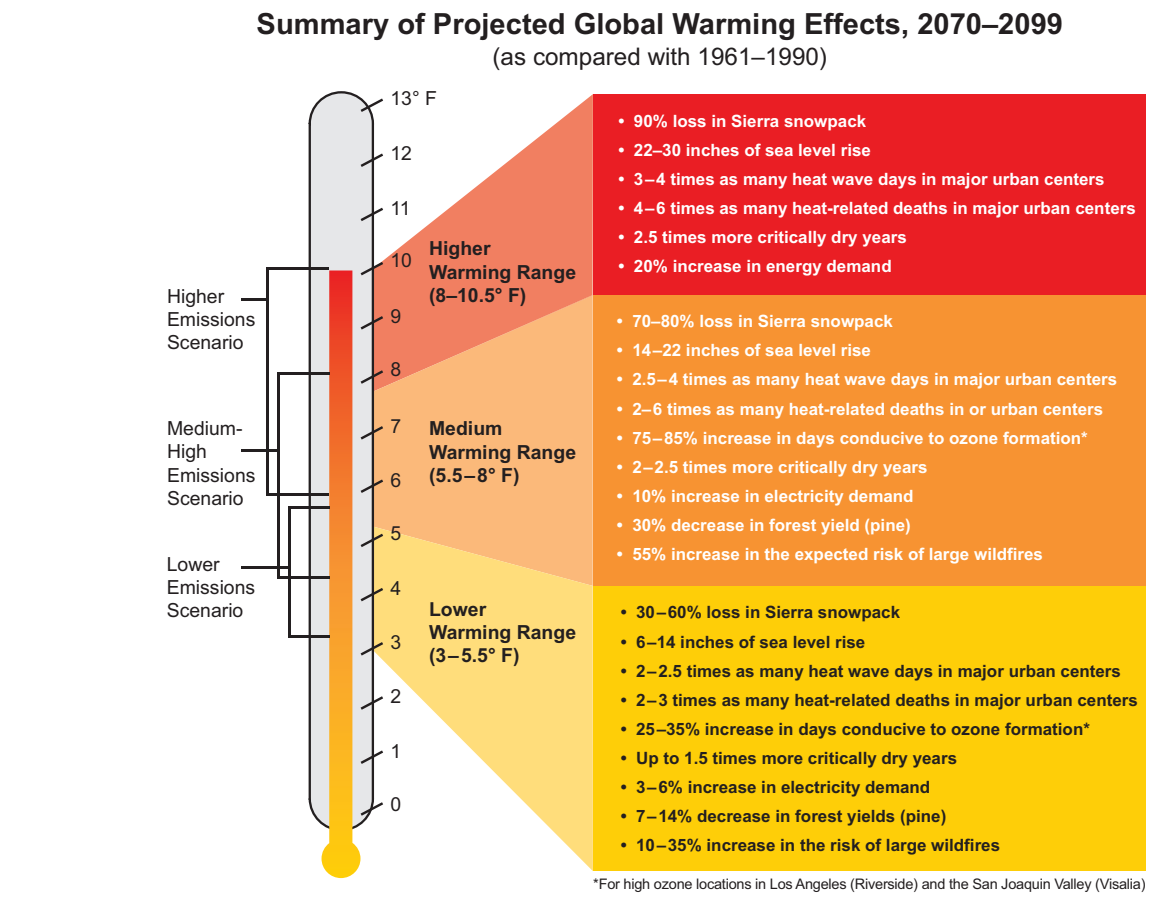
3. How does the concentration of methane and carbon dioxide from 320,000 years ago compare with current concentrations of these gases? (3 points)

4. Were the concentrations of methane and carbon dioxide ever higher than they are today? (3 points)

5. Based on this data, would you conclude that temperatures are warming or cooling? (3 points)

6. Given ancient ice core data and your understanding of the greenhouse effect, what conclusions can you draw about climate change? (10 points)

Name: _____



Source: Union of Concerned Scientists http://www.climatechoices.org/impacts_overview/

This image is based on computer climate model projections using three different emission scenarios.

Lower Emissions Scenario

This scenario predicts that global population growth will slow, and people will switch from using fossil fuels to technologies that are cleaner and greener. In this scenario, greenhouse gas emissions will peak by 2050 and then decline, with carbon dioxide emissions doubling from preindustrial levels by 2100.

Medium-High Emissions Scenario

This scenario projects continuous population growth and the introduction of some new technologies to replace fossil fuels. In this scenario, greenhouse gas emissions increase throughout the century, and CO_2 emissions triple by 2100 from preindustrial levels.

High Emissions Scenario

This scenario predicts a world in which fossil fuels are a main source of energy. In this scenario, new fossil-fuel-free technologies are not introduced until the end of the century. By 2100, greenhouse gas emissions will more than triple from preindustrial levels.

Name: _____

Instructions: Write an essay below that covers each of the following topics and is supported with a logical argument. (10 points for each of these four topics)

1. What is global climate change?
2. What do scientists think is the likely cause of it?
3. How could global climate change affect our human communities?
4. What actions could be taken to avoid the projected results that would arise with the "High Emissions Scenario"?

Name: _____

Instructions: Review the graph below and consider the information as you write an essay on the next page.

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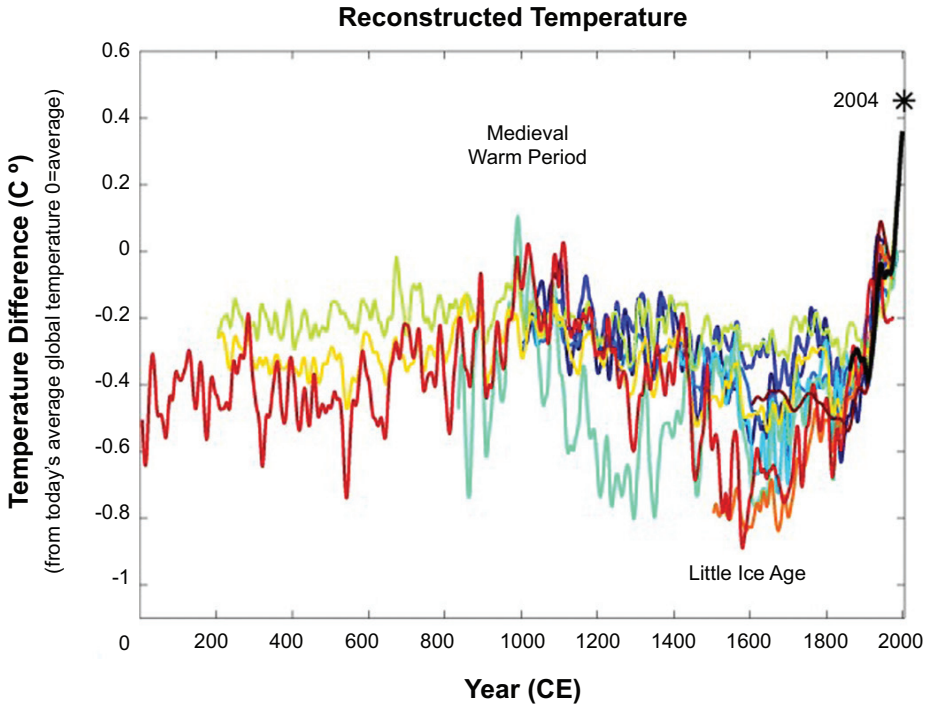

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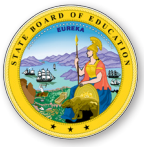
Think and Write

Consider how climate has changed in the past and the fact that climate is continuing to change. How could life be different in the future? What are some of the issues people need to consider when examining climate change?

Instructions: Based on the answers to these questions, write a new essay or revise the one you wrote at the end of Lesson 1 on **Considering Climate Change** (pages 3–4). Write your essay in the space provided. (40 points)



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