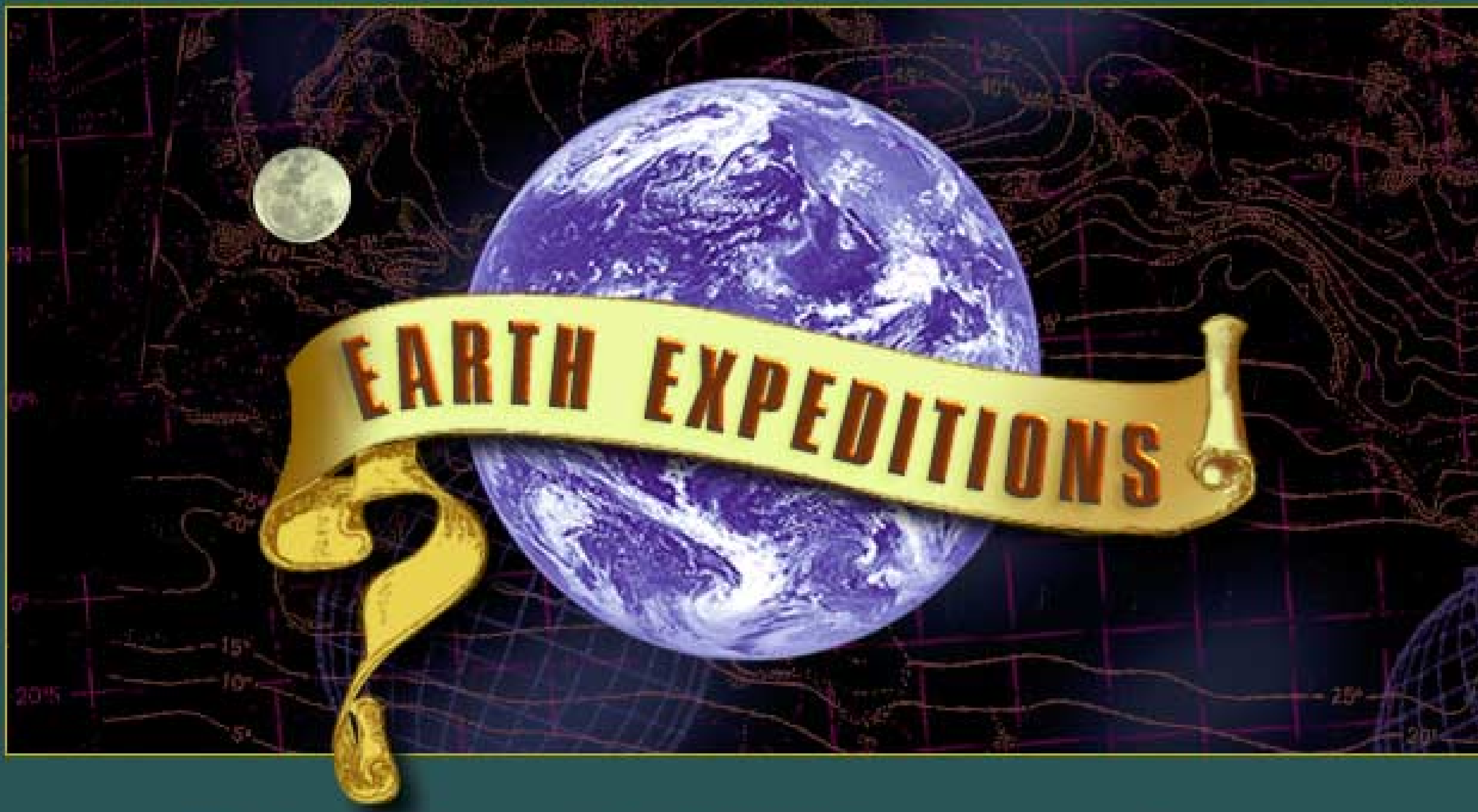


Global Warming

Developed by Planet Earth Science
with support from
the National Aeronautic and Space Administration

Contents

Overview

Earth Expeditions: Global Warming brings Earth System Science concepts to life in the classroom by challenging your students to conduct modern climate research as it really happens. This exciting multimedia learning tool places students in a scientific research lab where they run computer climate models to predict how climate in regions around the world may change as the concentration of carbon dioxide in the atmosphere continues to rise.

figure 1: R/V Glomar

The mission takes place early in the 21st century. Students are hired by Dr. X.S. Carbon, director of the fictitious Earth Monitoring Organization (EMO), to determine how climate in four regions of the world (Alaska, northern Canada and Greenland; Europe and western Russia; western tropical Pacific; and sub-Saharan Africa) may change over the next 100 years as human population continues to increase and non-industrialized nations become industrialized. Their conclusions will allow the EMO to advise nations around the world of the potential risks of increased carbon consumption. Students follow the scientific method by testing a given hypothesis on future climate patterns. Computer climate models, a data center and instructional movies are located within the research center to assist them.

A New Approach: Earth System Science

Earth Expeditions: Global Warming uses a new approach to studying Earth. This approach, known as Earth System Science (ESS), sees Earth as an evolving system of interacting components. It emphasizes the interconnections of the traditional scientific disciplines, such as biology, physics, chemistry, geography, oceanography, meteorology, and climate. The notion of considering Earth as an evolving, interactive system has emerged within the scientific community during the past few decades. It was led, to a large degree, by our ability to observe Earth from space, as well as by a need to better understand climate change and other global environment change phenomena.

The Planet Earth Science site at **www.PlanetEarthScience.com** provides access to many more ESS resources for teachers using this program.

Program Goals

Earth Expeditions: Global Warming supplements Earth and physical science courses by introducing a new systems approach to learning about Earth while giving students an exciting hands-on experience at conducting an interactive research investigation. By the time your students have completed *Earth Expeditions: Global Warming*, they should be able to:

- describe how Earth's temperature is determined.
- define the greenhouse effect.
- explain how human activities can alter the composition of Earth's atmosphere.
- identify increased carbon dioxide as contributing to the observed increase in Earth's global average temperature over the past century.
- explain possible climatic consequences that small changes in global average temperature could have in various regions of the world.
- explain that computer climate models are one tool that scientists use to help them understand how climate may change.
- explain that temperature changes are not uniform across the globe and that some places may cool even though the Earth's global average temperature may increase.

Earth Expeditions: Global Warming is one of several simulated research expeditions developed by Planet Earth Science. The mission of Planet Earth Science is to bring to your classroom a series of CD ROMs on various Earth System Science topics.

Broadly speaking, the goals of the Planet Earth Science CD ROMs are to give your students:

- a strong understanding of the process of scientific inquiry and confirmation.
- an excitement for learning about Earth science, the environment, and the active careers of scientists.
- a new, global vision of how the Earth operates as a system of interconnected processes.

- an appreciation for how science and technology play an important role in our civilization and our relationship to our ever-changing planet.

By actively participating in the scientific process, students gain a clearer picture of science as a career. *Earth Expeditions: Global Warming* is also aimed at developing the scientific literacy of students and preparing them to understand and make decisions about scientific, technological and environmental issues as informed citizens.

Using the Software

Launching the Program

After the guided tour of the ship, you will find yourself in the library, where you should open the cabinet and retrieve the videotape introduction. Play this introductory video on the TV. You will then receive further instructions.

Menu Buttons

The automatic ship/game tour shows the student how to use the pop-up menus. These menu shortcuts provide access to information that is also available within the virtual ship environment without needing to move about the ship to access it.

The "GO" menu button allows the student to transfer directly between instrument interfaces—for example, to go from the Com Terminal to the Data Center—without returning to the ship. The "GO" button also allows the student to return to the ship at any time.

The "DO" button provides a context-sensitive help system, and also a progress report.

The "FILE" button permits the student access to "save and quit" functions, volume control, and the game's glossary.

Double-click above to play the Quicktime Movie

Using QuickTime VR

The ships your students are crewing are the finest in the international Glomar fleet. Once on board, your students will enter a three-dimensional world that is much like the real world through a technology called QuickTime Virtual Reality (VR).

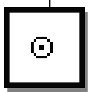
There are two ways to navigate around the ship. First, you can walk around the ship by moving your cursor with the mouse. Although you can open doors and walk up stairs, you cannot walk through objects — you must move around them. Second, you can click on the floor plan **hotspots** which bring you directly to a designated location.

Double-click above to play the Quicktime Movie

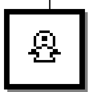
The ships in the Glomar fleet are also equipped with the latest research tools, such as the Data Center, the Instructional Terminals, and the Information Center. These devices, as well as many others like the television set and library books, are activated by clicking on them once.

As students move the cursor over the ship image, the cursor icon will change. The location of the cursor on the floor plan determines the icon at any given moment. The default cursor, for instance, looks like a circle, but as soon as it passes over an interactive instrument, like the Data Center or the television, it turns into a hand. Following is a list of cursor icons and what they do. Try them out yourself before you introduce *Earth Expeditions: Global Warming* to your students.

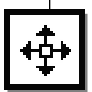
QuickTime VR Cursor Icons



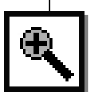
Move in any direction
When the cursor looks like this target, you can hold down the mouse button and drag it to move in any direction. This is the default cursor.



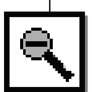
Step forward
When the cursor becomes this arrow, click the mouse button to move one step forward at a time.



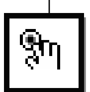
Turn around 360°
When you want to turn around, press and hold down the mouse button, until you see the cursor look like this. Then, drag the mouse in the direction you want to turn.



Zoom in
To zoom in, press and hold the option key. The cursor will change to look like this, and the image will enlarge.



Zoom out
To zoom out, press and hold the control key. The cursor will change to look like this, and the image will reduce in size.



Hotspots
When the cursor changes to this hand icon, the cursor is at a clickable hotspot, such as a terminal. Click once to access the object you are touching, for instance, to open a door, or to move up or down stairs.

Using Floor Plan Hotspots

Located directly below the QTVR screen is a floor plan. To move directly to a location on the ship, click that level (i.e., Level I Stern, Level I Lab, Level II Library, and Level III Bridge). To move around on that level, **click the color-coded circles on that floor plan itself.** The key to the color codes is directly above the floor plan. Your location is represented on the floor plan by the **bright green dot.**

Double-click above to play the Quicktime Movie

Understanding the *Earth Expeditions: Global Warming* Process

Earth Expeditions: Global Warming is an interactive, virtual research experiment designed to teach your students the fundamentals of the scientific method as they learn about the global climate and how it may change.

Keep in mind that your students can use *Earth Expeditions: Global Warming* on their own and at their own pace. Although your students make decisions while conducting their investigation, the mission itself is highly structured. Advice and direction are provided by a variety of video, audio, and text messages.

You will monitor your students' progress by reviewing and grading the message files they must complete during their mission investigation.

The Scenario

Earth Expeditions: Global Warming is a simulated research investigation that enables students to participate in scientific practices similar to those that real scientists participate in. The adventure takes place early in the 21st century. Dr. Carbon, director of the Earth Monitoring Organization (EMO), hires your students as visiting scientists at EMO Headquarters. Your students take on a critical mission to determine how the climate in regions around the world may change as the concentration of carbon dioxide in the atmosphere increases. Small changes in global average temperature could result in dramatic changes in regional climates including prolonged droughts and heat waves in sub-Saharan Africa, more intense and frequent hurricanes in the western tropical Pacific, the thawing of permafrost in the Arctic and bitter cold winters in Europe. The EMO needs to have an understanding of what changes are likely to occur so that nations of the world can take appropriate action.

The goal of your students, therefore, is to follow the scientific method to determine how temperature might change in regions around the world. As your students conduct the investigation, Dr. Carbon assists them by asking them to respond to a series of questions pertaining to their progress and findings.

The principal characters participating in the research investigation are:

- Your students, visiting scientists at the EMO.

- Dr. Carbon, director of the Earth Monitoring Organization, and chief scientist for this investigation.

- Other student scientists from the EMO.

Student Roles and Materials

There is a common role that all students have: Earth System Scientist. An Earth System Scientist is a member of a team of scientists who studies the interactions between the air, sea, land, snow, ice, and ecological systems.

Each student is given his/her own worksheet. The worksheet serves as an offline guide for students to follow along on their mission. The questions listed on the worksheet are identical to the questions posed by Dr. X.S. Carbon. The worksheet serves two purposes. First, as students work on obtaining answers at the computer, the worksheet acts as a reminder of the questions. Second, it provides enough room for students to write down their answers, avoiding the need for students to print out their answers from the computer.

Note: *Blackline masters are provided in the appendix of this document for easy duplication of the student worksheets.*

The Classroom Process

The simulation follows the process of scientific inquiry. Below are the specific steps your students will undertake. This program is designed to be completed in one or two 50 minute class periods.

Get Started

1. Meet student contacts at EMO Headquarters.

2. View a brief introduction on Global Warming using the VCR in the library.

3. Use the Help menu, when necessary, to learn how to use the various ship interfaces.

Discover the Mission

1. Proceed to any Com Terminal to meet Dr. Carbon who will explain the research mission. The mission is to determine how climate in different regions in the world may change as the concentration of carbon dioxide in the atmosphere increases.

Learn about Earth's Climate

1. View instructional movies on radiation from the sun and Earth, the Earth's energy balance, the greenhouse effect, atmospheric carbon dioxide and Earth's global average temperature.

2. Learn how gases in the atmosphere influence Earth's surface temperature.

Browse Information Center

1. Select region of world to investigate.

2. Browse Information Center to investigate present day climate and habitats in selected region.

Choose Hypothesis

1. Dr. Carbon provides students with a choice of four hypotheses to test:

   Hypothesis 1: The climate of the western tropical Pacific will change as carbon dioxide levels increase to 560 parts per million over the next 100 years.

   Hypothesis 2: The climate of Europe and western Russia will change as carbon dioxide levels increase to 560 parts per million over the next 100 years.

   Hypothesis 3: The climate of Alaska, northern Canada and Greenland will change as carbon dioxide levels increase to 560 parts per million over the next 100 years.

   Hypothesis 4: The climate of sub-Saharan Africa will change as carbon dioxide levels increase to 560 parts per million over the next 100 years.

Analyze Data

1. View instructional movie on computer climate models.

2. Run computer climate model calculations to estimate how surface temperature might change across the globe over the next 100 years.

3. Browse Information Center to determine how changes in surface temperature might alter climate in selected region of the globe.

Hypothesis Substantiation

1. Prepare report describing the results of data analysis, and submit findings to the EMO.

Managing the Classroom Experience

Earth System Science education is essential if we are to train and inspire a new generation of researchers capable of visualizing and solving the future global problems of our delicate and everchanging planet. Teaching Earth System Science, however, presents an instructional challenge because its goal is to provide students with not only a broad understanding of many traditional disciplines (e.g., geology, chemistry, physics) but also of their complex interconnections. This challenge can be met by training teachers in Earth System Science and by developing the appropriate instructional tools and materials, such as *Earth Expeditions: Global Warming* that illustrate and teach how the Earth operates as a system.

Preparing Yourself

Understand that no scientist is an expert in all areas of Earth System Science, so please do not expect to become one either. Rather, your role in class is primarily as a facilitator and role model in problem solving and information gathering, and to help students in the process of discovery.

Here are some ways to prepare for your role:

- Go through the program yourself.
- Review the rubric for assessing student responses described in this Teacher's Guide.
- Review **Overview of Earth System Science and Global Change** in this document.
- Explore Global Warming web sites by clicking the ESS Resources button on the Planet Earth Science web page at **http://www.PlanetEarthScience.com**.

Organizing Your Classroom

Earth Expeditions: Global Warming can be used by one or more students per machine, or by a classroom as a whole. We recommend two students per computer as it facilitates student interaction.

If you have many students and very few computers, here are a few special ideas. Project the screen of one computer so that all the students can see it, such as by using an LCD display, then use *Earth Expeditions: Global Warming* as a lecture tool. Run the program as you normally would for a single user, randomly asking your students for help. Because *Earth Expeditions: Global Warming* parallels the scientific process, you can take time to discuss how science research is done. Use all the tools that are available in the program to create a rich learning experience. For example, at the Instructional Terminal, play the movies on any given topic. Then, go to the Data Center and Information Center to show your students the most up-to-date, scientific data.

As an alternative, you could allow your students to use *Earth Expeditions: Global Warming* as an afterschool enrichment activity.

Assessing Student Performance

Content Objectives

In *Earth Expeditions: Global Warming,* your students' mission is to decide how climates around the world may change as the amount of carbon dioxide in the atmosphere increases. As they pursue the process of scientific inquiry, students will learn about how radiation from the sun and Earth together determine Earth's climate, how the composition of the atmosphere has changed since the Industrial Revolution and how to use computer climate models to help them predict temperature changes.

Earth's Energy Balance

- Students will be able to describe how both longwave and shortwave radiation influence the surface temperature of Earth.

Greenhouse Effect

- Students will be able to describe how carbon dioxide and water vapor interact with longwave radiation to create Earth's greenhouse effect.
- Students will be able to describe how the greenhouse effect raises the surface temperature of Earth.

Human Activities and CO_2 Levels Since the Industrial Revolution

- Students will be able to explain how human activities release previously stored carbon into the atmosphere.

Modern Atmospheric Concentration of CO_2

- Students will be able to describe how the concentration of carbon dioxide in the atmosphere has changed over the last 100 years.

Modern Global Temperature

- Students will be able to describe how the global average temperature has changed over the past century.

Computer Climate Models

- Students will be able to describe how computer climate models help scientists understand how climate may change in the future.

Assessment Rubric

As your students complete their mission in *Earth Expeditions: Global Warming* they must respond to a series of questions sent to them by Dr. Carbon at Earth Monitoring Organization (EMO) headquarters. These questions are sent for two reasons: (1) to direct your students in their investigation, and (2) to provide you, the instructor, with a means of monitoring your students' progress and evaluating their understanding of the scientific concepts in *Earth Expeditions: Global Warming.* These questions are included both in the Mission Status interface and in the Student Worksheet. Students can periodically save their game as well as their mission report using the save button which is accessible from the File menu.

Below we have listed the questions asked throughout the simulation, along with the correct answers. We have also given you a description of what constitutes an excellent, a good, and a poor response.

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Name three differences between radiation from the sun and radiation from the Earth.	1. Radiation from the sun is called solar radiation, or shortwave radiation. Radiation from the Earth is called terrestrial, or longwave radiation. 2. Radiation from the sun is higher energy radiation than radiation from the Earth. 3. Radiation from the sun has shorter wavelengths than radiation from the Earth. 4. Radiation from the sun includes visible light and ultraviolet light. Radiation from the Earth is not visible to human eyes, but is detected as heat.	At least three differences are described.	At least two differences are described.	Only one difference is described.
Why doesn't the Earth indefinitely heat up as it absorbs shortwave radiation from the sun?	Although the Earth continuously absorbs solar radiation, it does not heat up indefinitely because it releases heat energy to space via the emission of longwave radiation.	Student identifies the emission of longwave radiation and describes it as a process that releases heat energy to space.	Student identifies the emission of longwave radiation but does not describe it as a process that releases heat energy to space.	Student does not identify the emission of longwave radiation.

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
How do carbon dioxide and water vapor prevent longwave radiation emitted by the surface of the Earth from escaping to space?	Carbon dioxide and water vapor prevent longwave radiation emitted by the Earth's surface from escaping to space by absorbing it and re-emitting it back towards the surface of Earth.	Student identifies carbon dioxide and water vapor as both absorbing longwave radiation and emitting it back towards the surface of Earth.	Student identifies carbon dioxide and water vapor as either absorbing longwave radiation or emitting it back towards the surface of Earth, but not both.	Student does not identify carbon dioxide and water vapor as absorbers of longwave radiation and does not identify carbon dioxide and water vapor as emitters of longwave radiation.

Earth's Climate

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
If all the molecules of carbon dioxide and water vapor were removed from the atmosphere, what do you think would happen to Earth's surface temperature? Why?	If all the molecules of carbon dioxide and water vapor were removed from the atmosphere, the surface temperature of Earth would decrease, causing it to freeze. In the absence of carbon dioxide and water vapor, most of the longwave radiation that is emitted by Earth's surface would escape to space instead of being absorbed by these greenhouse gases and largely re-emitted back towards the surface.	The answer states that the temperature of Earth's surface would decrease because the absence of carbon dioxide and water vapor would prevent longwave radiation from being re-emitted back towards the surface.	The answer states that the temperature of Earth's surface would decrease but the reason is not given.	The answer does not state that the temperature of Earth's surface would decrease and no explanation of the role of carbon dioxide and water vapor in the warming Earth's surface is given.
If more molecules of carbon dioxide were added to the atmosphere, what do you think would happen to Earth's surface temperature? Why?	If more molecules of carbon dioxide were added to the atmosphere, the temperature of Earth would probably increase because more longwave radiation would enter the exchange of longwave radiation between the layer of greenhouse gases and the surface of the Earth.	Student provides a reasonable explanation for how he/she thinks the surface temperature might change.	Student provides a reasonable explanation for how he/she thinks the surface temperature might change.	Student does not provide an explanation for his/her answer.

Earth's Climate

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Explain why the amount of carbon dioxide in the atmosphere has increased since the late 1800s.	The amount of carbon dioxide in the atmosphere has increased as a result of the Industrial Revolution. The Industrial Revolution was a period of rapid industrialization which caused the consumption of fossil fuels to increase.	Student identifies the increase as caused by the Industrial Revolution and describes the Industrial Revolution as a period of increased consumption of fossil fuels.	Student identifies the increase as caused by the Industrial Revolution or describes the this time period as a period of increased consumption of fossil fuels.	Neither of these two reasons is mentioned.
Describe how the global average temperature of Earth's surface has changed over the past 100 years.	The temperature of Earth's surface has increased by approximately 1.0 degree Celsius over the past 100 years.	Student describes the temperature of the Earth as increasing by approximately 1.0 degree Celsius.	Student describes the temperature of the Earth as increasing but does not give an estimate of by how much.	Student does not describe the temperature of the Earth as increasing.

Regional Climate

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Name at least three of the important habitats that occur in Europe and western Russia, and list key features of climate in them	**Sea Ice:** •frozen ocean, much of which remains frozen year-round **Tundra:** •summers very short and cool •winters long and severe •very little precipitation (< 200 mm) **Boreal Forest:** •receives more precipitation than the tundra •precipitation spread throughout the year, with heavy snow during winter, and rain during the summer **Temperate Broadleaf Forest:** •both a warm and a cold season •30 to 60 inches of precipitation, evenly distributed throughout the year **Mediterranean vegetation:** •summers are warm and dry •winters are cool and rainy •summer temperatures moderated by cold ocean water and coastal fog •annual precipitation ranges between 15 and 40 inches per year **Short grass prairie (steppe):** •dry, cold, grassland •long droughts and violent winds •average rainfall is 10 to 30 inches per year •rain evaporates rapidly, due to strong winds **Desert:** •extreme daily temperature variation •very hot days and very cold nights •very little precipitation	student identifies three of the relevant habitats and lists at least two features of climate for each habitat	student identifies two of the relevant habitats and at least two features of climate for each habitat	student fails to identify relevant habitats and climate features

Regional Climate

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Name at least three of the important habitats that occur in Alaska, northern Canada and Greenland, and list key features of climate in them.	**Sea Ice:** • frozen ocean, much of which remains frozen year-round **Continental Ice:** • covered with snow and ice year-round •temperature does not rise above freezing **Tundra:** •summers very short and cool •winters are long and severe •very little precipitation (< 200 mm) **Boreal Forest (Taiga)** •receives more precipitation than the tundra •precipitation spread throughout the year, with heavy snow during winter, and rain during the summer	student identifies three of the relevant habitats and lists at least two features of climate for each habitat	student identifies two of the relevant habitats and at least two features of climate for each habitat	student fails to identify relevant habitats and climate features

Regional Climate

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Name at least three of the important habitats that occur in sub-Saharan Africa, and list key features of climate in them.	**Tropical Rain Forest:** •high temperatures year-round •very high precipitation •true droughts extremely rare **Tropical Woodland:** •temperatures are high all year •better-defined dry season than in the tropical rain forest **Savanna:** •6 to 8 month wet summer season •dry winter season •annual rain varies from 10 to 50 inches **Short Grass Prairie:** •too little precipitation for trees to grow, except near rivers **Desert:** •extreme daily temperature variation •very hot days and very cold nights •very little precipitation **Mediterranean Vegetation:** •summers are warm and dry •winters are cool and rainy •summer temperatures are moderated by the cold ocean water and coastal fog •between 15 and 40 inches of rain per year	student identifies three of the relevant habitats and lists at least two features of climate for each habitat	student identifies two of the relevant habitats and at least two features of climate for each habitat	student fails to identify relevant habitats and climate features

Regional Climate

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Name at least three of the important habitats that occur in the tropical western Pacific and list key features of climate in them.	**Rainforest:** •high temperatures year-round •very high precipitation •usually every month is very rainy **Tropical Woodland:** •temperatures are high all year •better-defined dry season than in the tropical rain forest **Savanna:** •6 to 8 month wet summer season •dry winter season with months of drought and frequent fire **Arid Interior:** •rainfall sparse and sporadic, falling mainly in winter in the south and in summer in the north **Temperate Eucalypt Forests:** •warm summer and cool winter •very cold temperatures only at high elevations	student identifies three of the relevant habitats and lists at least two features of climate for each habitat	student identifies two of the relevant habitats and at least two features of climate for each habitat	student fails to identify relevant habitats and climate features

Analyze Data

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Describe how computer climate models help scientists understand how climate may change in the future.	Scientists run the computer models with different values for carbon dioxide and see how this affects future values of other components of the models, such as rainfall or air temperature.	Student states that the models are run with different values for CO2 and that predictions are obtained for future values of other facets of climate.	Student states that running the models gives predictions about facets of climate.	Student does not make a connection between models and predictions.
Are computer models able to predict exact temperature values for the future? Why or why not?	Computer models cannot predict exact temperature values for the future, because some parts of the climate system, such as clouds and airborne particles, are difficult to represent using mathematical equations.	Student answers in the negative, and states that some parts of the climate system are difficult to represent using mathematical equations.	Student answers in the negative, but does not give an explanation.	Student gives the wrong answer.

Analyze Data

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Are parts of Europe and western Russia predicted to become warmer by 2100? According to the model, what is the greatest temperature increase expected?	Yes, parts of Europe and western Russia are predicted to become warmer. The greatest temperature increase expected is 4-5°C.	Student answers in the affirmative and identifies a temperature increase of the correct magnitude.	Student answers in the affirmative.	Student does not answer in the affirmative.
Which kinds of habitat occur in this region where temperature is predicted to increase the most?	Sea Ice Tundra Boreal Forest	Student identifies at least two of the correct habitats.	Student identifies at least one correct habitat.	None of the correct habitats are listed.
Is there a part of this region that is predicted to become cooler by 2100? If so, by up to how many degrees will it cool, and which habitats occur there?	Yes, part of this region is predicted to become cooler by up to 2°C. Tundra and Boreal forest occur in the area of predicted cooling.	Student answers in the affirmative, identifies the correct temperature decrease, and identifies at least one of the correct habitats.	Student answers in the affirmative, and identifies at least one of the correct habitats.	Student does not answer in the affirmative.

Analyze Data

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Are parts of Alaska, northern Canada and Greenland predicted to warm by 2100? According to the model, what is the greatest temperature increase expected?	Yes, parts of Alaska, northern Canada and Greenland are predicted to become warmer. The greatest temperature increase expected is 3-4°C.	Student answers in the affirmative and identifies a temperature increase of the correct magnitude.	Student answers in the affirmative.	Student does not answer in the affirmative.
Which kinds of habitat occur in this region where temperature is predicted to increase the most?	Sea Ice Continental Ice Tundra Boreal Forest	Student identifies at least two of the correct habitats.	Student identifies at least one correct habitat.	None of the correct habitats are listed.
Is part of this region expected to become cooler by 2100? If so, by up to how many degrees will it cool, and which habitats occur there?	Yes, part of this region is predicted to become cooler by up to 2°C. Ocean, Sea Ice, Tundra and Boreal Forest occur in the area of predicted cooling.	Student answers in the affirmative, identifies the correct temperature decrease, and identifies at least one of the correct habitats.	Student answers in the affirmative, and identifies at least one of the correct habitats.	Student does not answer in the affirmative.

Analyze Data

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
By how much is temperature predicted to increase over the tropical western Pacific ocean by 2100?	1-2°C	Student answers correctly.		Student answers incorrectly.
By how much is temperature predicted to increase over land in this region by 2100?	2-3°C	Student answers correctly.		Student answers incorrectly.
Name at least three kinds of habitat that occur where temperature is predicted to increase the most?	Arid Interior Tropical Savanna Short Grass Prairie Temperate Eucalypt Forest Wooded Savanna Rainforest	Student names at least three of the relevant habitats.	Students names only two habitats	Student names one or less of the relevant habitats.

Analyze Data

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Are parts of sub-Saharan Africa predicted to get warmer by 2100? According to the model, what is the greatest temperature increase expected?	Yes, part of sub-Saharan Africa are predicted to get warmer by 2100. The greatest temperature increase expected is 4-5° C.	Student answers in the affirmative and identifies a temperature increase of the correct magnitude.	Student answers in the affirmative.	Student does not answer in the affirmative.
Are parts of sub-Saharan Africa predicted to become cooler by 2100? If so, by how many degrees will they cool?	No	Student answers correctly		Student answers incorrectly
Which habitats occur in sub-Saharan Africa where temperature is predicted to change the most?	Short Grass Prairie Tropical Savanna Wooded Savanna	Student identifies at least two of the relevant habitats.	Student identifies at least one of the relevant habitats.	Student fails to list a relevant habitat.

Analyze Data

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Describe three possible ways in which the climate in your region of investigation may change over the next 100 years if global warming occurs.	**Alaska, northern Canada & Greenland:** Temperatures are expected to increase in the Arctic region over the next 100 years. As temperatures increase, sea ice and land ice may melt and permafrost may thaw. As land ice melts, sea level may rise. Increased temperatures may also cause boreal forests to move northward. **Europe and western Russia:** Temperature is expected to drop in Europe over the next 100 years if the Gulf Stream changes its course. If it does, air that reaches Europe from the Arctic region would not warm as it crosses the ocean causing the climate in Europe to become more severe. Winters would likely be longer and storms would likely become more severe. Temperatures are expected to increase in Siberia over the next 100 years. As temperatures increase, sea ice and land ice may melt and permafrost may thaw. As land ice melts, sea level may rise. Increased temperatures may also cause boreal forests to move northward. **Sub-Saharan Africa:** Climate in sub-Saharan Africa is expected to become warmer and drier over the next 100 years. Less rainfall is expected causing severe droughts and decreased availability of fresh water. **Western Tropical Pacific:** Over the next 100 years, ocean temperatures are expected to increase and sea level is expected to rise. As sea level rises, coastal areas will be destroyed and millions of people will be displaced from their homes.	Student identifies at least two possible changes.	Student identifies one possible change.	Student does not identify any possible changes in climate.

Hypothesis Substantiation

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Can you confirm your hypothesis that the climate in your region under investigation will change significantly as the amount of carbon dioxide in the atmosphere doubles over the next 100 years? Why or why not?	It is not possible to confirm what future climates will be like until the time comes. However, scientific evidence from climate models suggests the climate in each of the four regions will be significantly different than it is now. Climate models are only able to provide estimations and not exact predictions.	Student states that it is not possible to confirm the hypothesis and provides a reason.	Student states that it is not possible to confirm the hypothesis but does not provide any reasons.	Student does not attempt to answer the questions.
Based on these results, how urgent do you think it is to advise nations around the world to implement plans that will reduce the amount of carbon dioxide that is being released into the atmosphere?	Answer is subjective.	Subjective.	Subjective.	Subjective.
How did you come to this conclusion?	Answer is subjective.	Student provides reasons for the stated answer.	Student provides reasons for the stated answer.	Student does not provide any reasons for the stated answer.

Suggestions to Fit Your Curriculum

What kind of science classes do you teach? Earth science? Physical science? Chemistry? The content and approach of *Earth Expeditions: Global Warming* make it a valuable tool for students in these classes and many more. *Earth Expeditions: Global Warming* provides your students with a new approach to investigating the Earth system and how it operates. Below, we identify how *Earth Expeditions: Global Warming* fits into the National Science Education Standards and the 1998 California Science Content Standards.

National Standards

You can use *Earth Expeditions: Global Warming* to meet the National Science Education Standards set forth by the National Academy of Sciences.

Below is a list of National Science Education Standards for grades 5-8 that are addressed in *Earth Expeditions: Global Warming.* Thereafter, you will find a similar list for grades 9-12.

Science as Inquiry: Content Standard A

As a result of their activities in grades 5-8, all students should develop:

Abilities necessary to do Scientific Inquiry:

- Students can learn to formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.
- Use appropriate tools and techniques to gather, analyze, and interpret data. The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes.
- Develop descriptions, explanations, predictions, and models using evidence.

- Think critically and logically to make the relationships between evidence and explanations.

- Communicate scientific procedures and explanations. With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations.

Understandings about Scientific Inquiry:

- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.

Physical Science: Content Standard B

As a result of their activities in grades 5-8, all students should develop an understanding of:

Transfer of Energy:

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).

- The sun is a major source of energy for changes on earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Earth and Space Science: Content Standard D

As a result of their activities in grades 5-8, all students should develop an understanding of:

Structure of the Earth System:

- The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.

Earth in the Solar System:

- The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

Science and Technology: Content Standard E

As a result of their activities in grades 5-8, all students should develop:

Understandings about Science and Technology:

- Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs and aspirations.

- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size and speed. Technology also provides tools for investigations, inquiry and analysis.

Science in Personal and Social Perspectives: Content Standard F

As a result of their activities in grades 5-8, all students should develop an understanding of:

Natural Hazards:

- Internal and external processes of the earth system cause natural hazards, events that change or destroy human and wildlife habitats, damage property, and harm or kill humans. Natural hazards include earthquakes, landslides, wildfires, volcanic eruptions, floods, storms, and even possible impacts of asteroids.

- Human activities can also induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.

- Natural hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.

Science and Technology in Society:

- Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.
- Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact. Technological changes are often accompanied by social, political, and economic changes that can be beneficial or detrimental to individuals and society.
- Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. Students should understand the difference between scientific and other questions. They should appreciate what science and technology can reasonably contribute to society and what they cannot do.

History and Nature of Science: Content Standard G

As a result of their activities in grades 5-8, all students should develop an understanding of:

Nature of Science:

- Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.
- It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists.

Below is a list of National Science Education Standards for grades 9-12 that are addressed in *Earth Expeditions: Global Warming.*

Science as Inquiry: Content Standard A

As a result of their activities in grades 9-12, all students should develop:

Abilities necessary to do Scientific Inquiry:

- Students need to learn how to analyze evidence and data. The evidence they analyze may be from their investigations, other students' investigations, or databases.

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment.

- Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations.

- A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard.

- Student inquiries should culminate in formulating an explanation or model. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation.

- Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, constructing a reasoned argument.

Understandings about Scientific Inquiry:

- Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science.

- Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results.

- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.

Physical Science: Content Standard B

As a result of their activities in grades 9-12, all students should develop an understanding of:

Structure of Atoms:

- Matter is made of minute particles called atoms, and atoms are composed of even smaller components.

Each atom has a positively charged nucleus surrounded by negatively charged electrons.

- The atom's nucleus is composed of protons and neutrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.

Chemical Reactions:

- Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Interactions of Energy and Matter:

- Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.

- Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays.

Life Science: Content Standard C

As a result of their activities in grades 9-12, all students should develop an understanding of:

The Cell:

- Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment.

Interdependence of Organisms:

- The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere.

- Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.

Matter, Energy, and Organization in Living Systems:

- The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules.

Earth and Space Science: Content Standard D

As a result of their activities in grades 9-12, all students should develop an understanding of:

Energy In The Earth System:

- Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy.

- Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Geochemical Cycles:

- The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles.

- Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.

Science and Technology: Content Standard E

As a result of their activities in grades 9-12, all students should develop:

Understandings about Science and Technology:

- Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.

- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

Science in Personal and Social Perspectives: Content Standard F

As a result of their activities in grades 9-12, all students should develop an understanding of:

Natural Resources:

- Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations.

Environmental Quality:

- Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.

- Materials from human societies affect both physical and chemical cycles of the earth.

- Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth.

Natural and Human-Induced Hazards:

- Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.

- Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards--ranging from those with minor risk to a few people to major catastrophes with major risk to many people.

Science and Technology in Local, National, and Global Challenges:

- Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science- and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges.

- Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.

- Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use--which decreases space available to other species--and pollution--which changes the chemical composition of air, soil, and water.

History and Nature of Science: Content Standard G

As a result of their activities in grades 9-12, all students should develop an understanding of:

Nature of Scientific Knowledge:

- Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.

- Scientific explanations must meet certain criteria. They must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public.

- Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest.

State Frameworks

We designed *Earth Expeditions: Global Warming* to meet many of the major state science frameworks in addition to the National Science Education Standards. The California State Science Framework (1998) was chosen as a model for these standards based upon California's long-standing support for education reform. Your state's science framework is probably very similar. The main components of the 1998 California State Science Framework that relate to *Earth Expeditions: Global Warming* are identified below.

1998 California Science Standards

Grade 6 (Focus on Earth Science)

Shaping the Earth's Surface

Topography is reshaped by weathering of rock and soil and by the transportation and deposition of sediment. As the basis for understanding this concept, students know:

e. natural hazards, including earthquakes, volcanic eruptions, landslides, and floods, change or destroy human and wildlife habitats, damage property, and harm or kill humans.

Energy in the Earth System

Many phenomena on the Earth's surface are affected by the transfer of energy through radiation and convection currents. As a basis for understanding this concept, students know:

a. the sun is the major source of energy for phenomena on the Earth's surface, powering winds, ocean currents, and the water cycle.

b. solar energy reaches Earth through radiation, mostly in the form of visible light.

c. heat from Earth's interior reaches the surface primarily through convection.

d. convection currents distribute heat in the atmosphere and oceans.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept, students should develop their own questions and perform investigations. Students will:

a. develop a hypothesis

b. select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.

c. construct appropriate graphs from data and develop qualitative statements.

d. communicate the steps and results from an investigation in written reports and verbal presentations.

e. recognize whether evidence is consistent with a proposed explanation.

Grades 9-12

Energy in the Earth System (Earth Sciences)

Energy enters the Earth system primarily as solar radiation and eventually escapes as heat. As a basis for understanding this concept, students know:

a. the relative amount of incoming solar energy compared with Earth's internal energy and the energy used by society.

b. the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.

c. the different atmospheric gases that absorb the Earth's thermal radiation, and the mechanism and significance of the greenhouse effect.

d. the different greenhouse conditions on Earth, Mars, and Venus, their origins and climatic consequences.

Climate is the long term average of a region's weather and depends on many factors. As a basis for understanding this concept, students know:

a. weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere.

b. effects on climate of latitude, elevation, topography, as well as proximity to large bodies of water and cold or warm ocean currents.

c. how the Earth's climate has changed over time, corresponding to changes in the Earth's geography, atmospheric composition and/or other factors (solar radiation, plate movement, etc.).

d. use of computer models to predict the effects of increasing greenhouse gases on climate for the planet as a whole and for specific regions.

Investigation and Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept, students should develop their own questions and perform investigations. Students will:

a. select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.

d. formulate explanations using logic and evidence.

k. recognize the cumulative nature of scientific evidence.

l. analyze situations and solve problems that require combining and applying concepts from more than one area of science.

m. investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.

Detailed Scientific Background

Overview of Earth System Science and Global Change

The results of modern scientific research have changed the way we think about our planet Earth. For centuries, scientists had divided the study of Earth into specialized areas: biologists investigated life, meteorologists studied the atmosphere, oceanographers did research on the sea, and other specialists were concerned with ice and snow or land. Scientists working in each specialty often knew little about the others. Each field developed its own jargon, making communication across disciplines difficult.

The natural world, however, is not divided into separate and independent subjects like university departments. Instead, there are connections everywhere. Over the last few decades, scientists have developed new research methods and entirely new fields of study to understand these connections. Ecology, for example, is a science that deals with the relationships between living organisms and their environments. Ecology focuses on ecosystems, complexes of interdependent plants and animals, together with their physical environment. A pond is one example of a small ecosystem. The Earth, on the other hand, is the largest ecosystem.

Earth System Science is a field of science that deals with phenomena that involve interactions between components that make up Earth: the air, the sea, the land, snow and ice, and the world of living things. Viewing Earth as a system, a collection of interrelated elements that form a collective whole, is key to understanding many aspects of change on planet Earth. Systems are dynamic, changing in response to forces of many kinds, both inside and outside the system itself. Over billions of years, Earth has undergone enormous changes. Some were caused by external forces such as changes in the Sun and in Earth's orbit around it. Some involved events occurring within the Earth system itself, such as the movement of continents and the eruptions of volcanoes.

The Earth also changes from day to day and from month to month — changes on these time scales are apparent to all of us. Every child experiences the difference between night and day. People who live near the shore see the changes in sea level caused by tides. The mighty rhythm of the seasons governs the lives of farmers, as well as the migrations of birds. The climate is another aspect of the Earth system that affects us all. Floods and droughts, summer heat waves and frigid winter blizzards, dust storms in the desert and hurricanes in the tropics are all powerful examples of how climate affects people, as well as animals and plants. More subtle changes in the Earth system also affect life:

- **The loss of ozone in the stratosphere,** dramatized by the Antarctic ozone hole, allows harmful ultraviolet radiation from the sun to reach Earth's surface, causing skin cancers and other damage such as an increased incidence of cataracts and a weakening of the immune system in humans; reductions in leaf area, shoot length, and photosynthesis rates in many plants; and damage to plankton at the base of the marine food chain.

- **An increase in the natural greenhouse effect,** caused by people adding carbon dioxide and other gases to the atmosphere, gradually warms Earth, resulting in rising sea levels and changes in storm patterns.

- **El Niño,** a phenomenon arising from the interplay between the atmosphere and ocean in the tropical Pacific, causes severe droughts in Australia and Indonesia and heavy losses in the fishing industry in Peru.

These changes in Earth involve interactions between the air, sea, land, snow and ice, and the world of living things, including ourselves. The key to understanding, and eventually to predicting all these phenomena, is Earth System Science.

World Wide Web Resources

Visit our web page at **www.PlanetEarthScience.com** to gain access to the most current resources available on earth system science topics covered by our products including the Amazon River, El Niño, ozone depletion, and global climate change.

Appendix: Worksheet Masters

Sign In

Your Name: ______________________________

Your Teammates: ______________________________

Earth's Climate

1. Name three differences between radiation from the sun and radiation from the Earth. ______________________________

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2. Why doesn't the Earth indefinitely heat up as it absorbs shortwave radiation from the sun? ______________________________

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Earth's Climate (cont.)

3. How do carbon dioxide and water vapor prevent longwave radiation emitted by the surface of the Earth from escaping directly to space? __________

4. If all the molecules of carbon dioxide and water vapor were removed from the atmosphere, what do you think would happen to Earth's surface temperature? Why? __________

5. If more molecules of carbon dioxide were added to the atmosphere, what do you think would happen to Earth's surface temperature? Why? __________

Earth's Climate (cont.)

6. Explain why the amount of carbon dioxide in the atmosphere has increased since the late 1800s. ______________________________

7. Describe how the global average temperature of Earth's surface has changed over the past 100 years. ______________________________

Regional Climate

Answer the question that applies to your region of investigation.

- Name at least three of the important habitats that occur in Europe and western Russia, and list key features of climate in them.

- Name at least three of the important habitats that occur in Alaska, northern Canada and Greenland, and list key features of climate in them.

Regional Climate (cont.)

- Name at least three of the important habitats that occur in sub-Saharan Africa, and list key features of climate in them.

- Name at least three of the important habitats that occur in the tropical western Pacific and list key features of climate in them.

Analyze Data

1. Describe how computer climate models help scientists understand how climate may change in the future. ______________________________

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2. Are computer models able to predict exact temperature values for the future? Why or why not?______________________________

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Analyze Data (cont.)

Answer the 3 questions that apply to your region of investigation.

Europe and Western Russia

1. Are parts of Europe and western Russia predicted to become warmer by 2100? According to the model, what is the greatest temperature increase expected?

2. Which kinds of habitat occur in this region where temperature is predicted to increase the most?

Analyze Data (cont.)

3. Is there a part of this region that is predicted to become cooler by 2100? If so, by up to how many degrees will it cool, and which habitats occur there? ______________________________

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Alaska, northern Canada and Greenland

1. Are parts of Alaska, northern Canada and Greenland predicted to warm by 2100? According to the model, what is the greatest temperature increase expected? ______________________________

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Analyze Data (cont.)

2. Which kinds of habitat occur in this region where temperature is predicted to increase the most? ______________________________

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3. Is part of this region expected to become cooler by 2100? If so, by up to how many degrees will it cool, and which habitats occur there? ________

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Analyze Data (cont.)

Tropical Western Pacific

1. By how much is temperature predicted to increase over the tropical western Pacific ocean by 2100? ______________________

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2. By how much is temperature predicted to increase over land in this region by 2100? ______________________

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Analyze Data (cont.)

3. Name at least three kinds of habitat that occur where temperature is predicted to increase the most?____________________________________

Sub-Saharan Africa

1. Are parts of sub-Saharan Africa predicted to get warmer by 2100? According to the model, what is the greatest temperature increase expected?__

Analyze Data (cont.)

2. Are parts of sub-Saharan Africa predicted to become cooler by 2100? If so, by how many degrees will they cool?____________________________

3. Which habitats occur in sub-Saharan Africa where temperature is predicted to change the most? ____

Analyze Data (cont.)

Answer this question as it applies to your region of investigation.

1. Describe three possible ways in which the climate in your region of investigation may change over the next 100 years if global warming occurs.

Hypothesis Substantiation

1. Can you confirm your hypothesis that the climate in your region under investigation will change significantly as the amount of carbon dioxide in the atmosphere doubles over the next 100 years? Why or why not? ______________________________

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2. Based on these results, how urgent do you think it is to advise nations around the world to implement plans that will reduce the amount of carbon dioxide that is being released into the atmosphere? ______________________________

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Hypothesis Substantiation

3. How did you come to this conclusion? ______