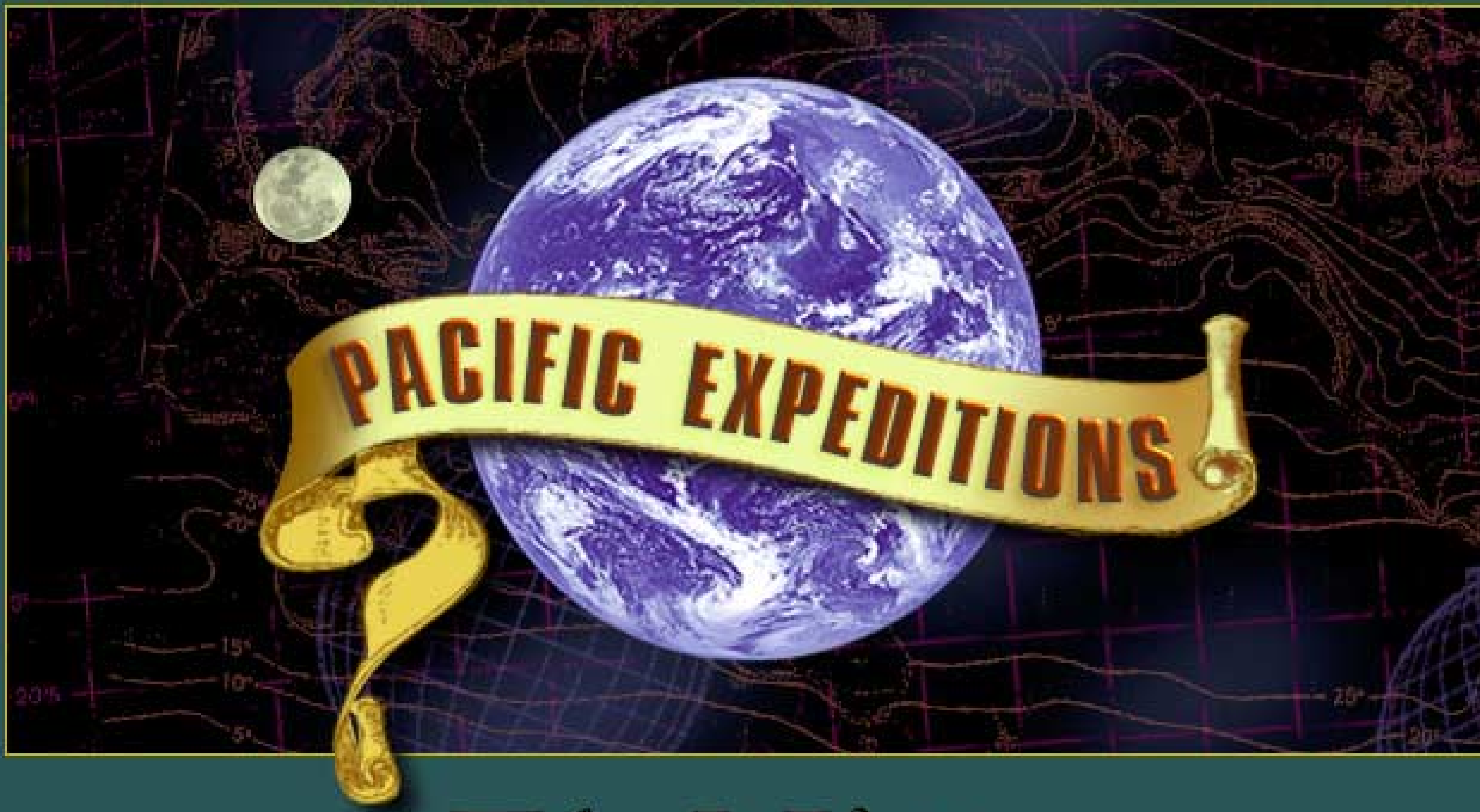


El Niño

Developed by Planet Earth Science

with support from

the National Aeronautic and Space Administration

Overview

Pacific Expeditions: El Niño 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 engages students in a journey where they operate modern research tools and manipulate satellite and climate model data to investigate and help predict El Niño — one of our planet's largest global climatic disruptions.

figure 1: R/V Glomar

The adventure takes place early in the 21st century. Students are hired by Dr. Enso, director of the fictitious Earth Monitoring Organization (EMO), to verify conflicting reports about a predicted El Niño event that poses disastrous consequences for life and economies around the world. Crew members set sail on the Research Vessel Glomar to embark on their own investigation. They follow the scientific method by testing a given hypothesis. To assist them, satellite images of sea surface temperature and instructional movies are located onboard the ship.

A New Approach: Earth System Science

Pacific Expeditions: El Niño 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

Pacific Expeditions: El Niño 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 *Pacific Expeditions: El Niño*, they should be able to:

- identify El Niño as an alteration of climate which originates in the tropical Pacific but has global climatic consequences.
- describe potential climatic consequences of El Niño across the globe.
- describe El Niño as a continuously occurring phenomenon which occurs at irregular intervals.
- describe sea surface temperature patterns in the tropical Pacific for El Niño, La Niña, and typical conditions.
- describe the process of scientific inquiry and confirmation.

Pacific Expeditions: El Niño 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. *Pacific Expeditions: El Niño* 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 adults.

Using the Software

Launching the Program

After choosing to start a new simulation and receiving a welcome message from student scientists, your students will find themselves in the library, where they should open the cabinet and retrieve the videotaped introduction. After they play this introductory video on the TV, they will receive further instructions.

Using QuickTime VR

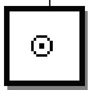
The ships your students are aboard are the finest in the international Glomar fleet. Once on board, your students will enter a three-dimensional world that is much like the real world through a technology called QuickTime Virtual Reality (VR).

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.

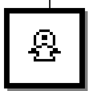
The ships in the Glomar fleet are also equipped with the latest research tools, such as the Data Center, the Instructional Terminals, and the Information Center. These devices, as well as many others like the television set and library books, are activated by clicking on them once.

As students move the cursor over the ship image, the cursor icon will change. The location of the cursor on each ship image 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, such as the Data Center or a television, it turns into a hand. Following is a list of cursor icons and what they do. Try them out yourself before you introduce *Pacific Expeditions: El Niño* to your students.

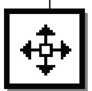
QuickTime VR Cursor Icons



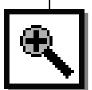
Move in any direction
When the cursor looks like this target, you can hold down the mouse button and drag it to move in any direction. This is the default cursor.



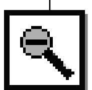
Step forward
When the cursor becomes this arrow, click the mouse button to move one step forward at a time.



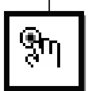
Turn around 360°
When you want to turn around, press and hold down the mouse button, until you see the cursor look like this. Then, drag the mouse in the direction you want to turn.



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.**

Menu Buttons

The menu buttons at the top of the screen provide shortcut 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, to the game's glossary and to the volume control.

The Help menu provides access to movies explaining various game interfaces.

Understanding the *Pacific Expeditions: El Niño* Process

Pacific Expeditions: El Niño is an interactive, virtual research experiment designed to teach your students the fundamentals of the scientific method, as they learn about Earth and its dynamic climate system.

Keep in mind that your students can use *Pacific Expeditions: El Niño* 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 that they must complete during their mission investigation.

The Scenario

Pacific Expeditions: El Niño is a simulated research mission that resembles a real scientific investigation. The adventure takes place early in the 21st century. Dr. Enso, director of the Earth Monitoring Organization (EMO), hires your students as crew members of the Research Vessel Glomar. The crew undertakes a critical mission about a predicted El Niño event that may have disastrous effects on life and economies around the world.

The goal of your students, therefore, is to follow the scientific method to accurately confirm or refute the existence of an El Niño or La Niña event. As your students conduct the investigation, Dr. Enso asks them to respond to a series of questions pertaining to their progress and findings. You should note, however, that each time your students start a new *Pacific Expeditions: El Niño* simulation, there is an equal chance that typical conditions, an El Niño event or a La Nina event will be in existence. Consequently, their responses will change on each new run of the simulation and not all computers in your classroom will illustrate the same condition.

Your students launch *Pacific Expeditions: El Niño* to enter their new, virtual world and undertake their investigation. Along the journey, your students follow the process of scientific inquiry outlined in this section.

The principal characters participating in the mission investigation are:

- Your students, the crew of scientists.
- Dr. Enso, contact scientist from the Earth Monitoring Organization, and scientific director of the expedition.
- 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. Enso. 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 of the student worksheets are provided in the appendix of this document for easy duplication.*

The Classroom Process

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

Get Started

1. Meet student contacts from the EMO on the ship's deck.
2. View a brief introduction on El Niño using the VCR in the library.
3. Use the Help menu, when necessary, to learn how to use the various ship interfaces.
4. Use the "What am I supposed to do?" menu, when necessary, to obtain guidance on what to do next.

Obtain Hypothesis

1. Proceed to any Com Terminal to meet Dr. Enso. Dr. Enso will explain your mission to determine if an El Niño is developing in the tropical Pacific.

Learn about Sea Surface Temperature and its Relevance to El Niño

1. View instructional movies on sea surface temperature and its importance to climate.

2. Learn about how the wind and current patterns of the tropical atmosphere and ocean change as El Niño conditions develop.

Analyze Data

1. Analyze the current sea surface temperature pattern to identify its main features.

2. Compare the present sea surface temperature map to historical maps using the Data Center.

Hypothesis Substantiation

1. Submit results of data analysis.

Browse Information Center

1. View other El Niño resources using simulated access to the internet.

Conclude

1. Learn about the importance of your research to societies across the globe.

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 knowledge 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 *Pacific Expeditions: El Niño* 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 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 El Niño web sites by clicking the ESS Resources button on the Planet Earth Science web page at **http://www.planetearthscience.com**.

Organizing Your Classroom

Pacific Expeditions: El Niño 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 *Pacific Expeditions: El Niño* as a lecture tool. Run the program as you normally would for a single user, randomly asking your students for help. Because *Pacific Expeditions: El Niño* 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 *Pacific Expeditions: El Niño* as an afterschool enrichment activity.

Assessing Student Performance

Content Objectives

In *Pacific Expeditions: El Niño,* your students' mission is to verify a predicted El Niño event by analyzing sea surface temperature patterns. As they pursue the process of scientific inquiry, students must learn about the importance of sea surface temperature to climate. By the time students have verified their hypothesis, they will have gained a broad understanding of the climate system and will have met the following objectives:

Introduction to Sea Surface Temperature

- Students will be able to describe climate disruptions which may occur as sea surface temperatures in the eastern and central Pacific rise.

Sea Surface Temperature Maps

- Students will be able to interpret maps of sea surface temperature derived from satellite data.

Warm Pool and Cold Tongue

- Students will be able to identify the two main sea surface temperature features in the tropical Pacific.

Factors Affecting Sea Surface Temperature

- Students will be able to describe the two main factors affecting SST patterns.

Sea Surface Temperature Patterns

- Students will be able to identify the three climate phases of the tropical Pacific.

- Students will be able to describe how SST patterns change for each of these climate phases.

Ocean Atmosphere Circulation

- Students will be able to describe how the atmosphere and ocean together shape wind, current and rainfall patterns in the tropical Pacific.

Ocean Atmosphere Circulation During El Niño

- Students will be able to describe how El Niño changes the wind, current and rainfall patterns in the tropical Pacific.

Sea Surface Height

- Students will be able to describe why changes in sea surface height are an early warning sign of El Niño.

Satellite Images of Sea Surface Height

- Students will be able to identify typical, El Niño, and La Niña conditions on satellite images of sea surface height.

Assessment Rubric

As your students complete their mission in *Pacific Expeditions: El Niño*, they must respond to a series of questions sent to them by Dr. Enso 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 *Pacific Expeditions: El Niño*. 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. Keep in mind, however, that many of the questions have three answers depending on which condition (data set) of *Pacific Expeditions: El Niño* is activated at start-up, namely El Niño, La Niña, or typical conditions.

The condition presented to your student will be one of the three sea surface temperature phases, El Niño, Typical, or La Niña. To determine which condition your student is analyzing you can look at the last digit of the report number found in either the Mission Status window or their saved report. The digit will be 1, 2, or 3 for El Niño, Typical, or La Niña respectively.

Impacts of El Niño

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Identify three impacts of El Niño, including the location where they occur.	**Economic:** Flooding in Peru, Cuba, Bolivia, Ecuador, the western coast of the U.S., and U.S. Gulf States Hurricanes in Tahiti and Hawaii Reduced agricultural production in Northeastern Brazil Decreased rainfall in Australia and Indonesia **Biological:** Coral bleaching in the equatorial Pacific Destruction to sea lion and other populations of marine life along coast of Peru Fish, from Chile to British Columbia, become displaced Anchovy and sardine populations decline along coast of Peru and Ecuador Malaria and cholera cases increase in Peru and Ecuador	Three impacts and the locations where they occur are identified.	Three impacts are identified but not the locations where they occur.	Less than two impacts are identified.

Sea Surface Temperature

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Identify the two main sea surface temperature features in the tropical Pacific.	The two main sea surface temperature features are the cold tongue and the warm pool.	Both SST features are identified.	One feature is identified.	Both SST features are not identified
Describe how each of these SST features evolves.	**The cold tongue evolves as a result of two processes:** 1) the transport of cold water from the deep ocean towards the surface 2) the transport of cold water towards the equator by the Peru Current **The warm pool forms as:** 1) surface waters in the western Pacific absorb solar energy 2) surface waters warmed by solar energy are transported westward by equatorial currents into the warm pool region.	Two mechanisms for the formation of the cold tongue and one mechanism for the formation of the warm pool are described.	One mechanism for the formation of the cold tongue and one mechanism for the formation of the warm pool are identified.	No mechanisms are described.

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Describe the shape of the warm pool and cold tongue in your SST image.	**El Niño conditions:** Present sea surface temperature patterns show a weak cold tongue that is confined to the eastern equatorial Pacific. The warm pool remains close to the equator and extends from the western Pacific well into the central Pacific. **Typical conditions:** Present sea surface temperature patterns show a moderate cold tongue that extends close to the central Pacific. The warm pool extends partially into the central Pacific. **La Niña conditions:** Present sea surface temperature patterns show a strong cold tongue that extends from the coast of South America along the equator well into the central Pacific. The warm pool region remains confined to the western equatorial Pacific.	The sea surface temperature variation across the Pacific is correctly described using the terms “warm pool” and “cold tongue.”	The sea surface temperature variation across the Pacific is described without using the terms “warm pool” and “cold tongue.”	The temperature variation across the equatorial Pacific is not described.
Do the present conditions more closely resemble El Niño, typical, or La Niña conditions?	The condition presented to your student will be one of the three sea surface temperature phases, El Niño, Typical, or La Niña. To determine which condition your student is analyzing you can look at the last digit of the report number found in either the Mission Status window or their saved report. The digit will be 1, 2, or 3 for El Niño, Typical, or La Niña respectively.	The present climate condition is correctly identified.		The present climate condition is not correctly identified.

Ocean Atmosphere Circulation

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Describe the wind and current patterns in the tropical Pacific during typical climate conditions.	During typical climate conditions, the trade winds blow from east to west across the equatorial Pacific. In the western Pacific, the air rises and then travels from west to east in the upper atmosphere where it sinks. Ocean surface currents also travel from east to west. As water moves away from the coast of South America, vertical currents bring water from the deep ocean towards the surface.	Both the ascending and descending circulation system in the atmosphere and the surface and vertical current system in the ocean are described.	Either the ascending and descending circulation system in the atmosphere or the surface and vertical current system in the ocean is described.	Neither the ascending and descending circulation system in the atmosphere nor the surface and vertical current system in the ocean is described.
Describe the changes that occur to the wind and current patterns in the tropical Pacific during El Niño conditions.	During El Niño conditions, westerly winds appear in the western Pacific and the strong upward motions usually found in the atmosphere in the western Pacific are located further east. In the ocean, surface currents weaken and the amount of cold water which is brought up to the surface decreases.	The westerly winds, eastward shift in the atmospheric circulation cell and the weakening of the entire oceanic circulation system are described.	The changes to either the atmospheric or ocean circulation system are described.	Changes to neither the atmospheric nor the ocean circulation system are described.

	QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Sea Surface Height	Describe sea surface height patterns across the tropical Pacific during typical conditions.	During typical conditions, the sea surface slopes upward across the tropical Pacific from the eastern to the western Pacific.	The variation in sea surface height across the Pacific is correctly described.		The variation in sea surface height across the Pacific is incorrectly described.
	Describe sea surface height patterns across the tropical Pacific during El Niño conditions.	During El Niño conditions, the sea surface flattens out across the tropical Pacific.	The variation in sea surface height across the Pacific is correctly described.		The variation in sea surface height across the Pacific is incorrectly described.
Confirm Hypothesis	Is it possible to confirm the hypothesis: “Sea surface temperature patterns indicate El Niño conditions are developing in the tropical Pacific?” Why or why not?	It is possible to confirm the hypothesis for either El Niño, Typical or La Niña conditions.	The present climate conditions are correctly identified and an explanation is given describing the shape and extent of the warm pool.	The present climate conditions are correctly identified but an explanation is not provided.	The present climate conditions are incorrectly identified.
	What other climate variables could you investigate to help support your findings?	Surface pressure, surface wind, surface current, rainfall and sea surface height patterns.	Three other climate variables are identified.	One or two climate variables are identified.	No other climate variables are identified.

Browse Information Center

QUESTION	ANSWER	EXCELLENT	GOOD	POOR
Describe one impact of the 1997-98 El Niño. Be sure to include the location in which it occurred.	There are numerous possibilities identified in the Information Center including: Decreased hurricane activity in the Atlantic Increased hurricane activity in the Pacific Coral bleaching off the coast of Panama and the Galapagos Islands Drought in Indonesia Decreased rainfall in northeastern Brazil through Central America	One impact and its location are described.	One impact is described, but its location is not identified.	No impact is identified.

Suggestions to Fit Your Curriculum

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

National Standards

You can use *Pacific Expeditions: El Niño* 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 *Pacific Expeditions: El Niño.* 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.

- 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:

- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the “water cycle”. Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil and in rocks underground.

- Clouds, formed by the condensation of water vapor, affect weather and climate.

- Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.

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.

- Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics.

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.

- 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 *Pacific Expeditions: El Niño.*

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:

- Use technology and mathematics to improve investigations and communications.
- Communicate and defend a scientific argument.

Understandings about Scientific Inquiry:

- Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific principles.
- Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recent phenomena, or test the conclusions of prior investigations or the predictions of current theories.
- 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. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

Physical Science: Content Standard B

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

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.

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.
- Heating of the earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

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:

- 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.

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 Hazards and Human-Induced Hazards:

- Normal adjustments of earth may be hazardous for humans. Humans live at the interface between the atmosphere driven by solar energy and the upper mantle where convection creates changes in the earth's solid crust. As societies have grown, become stable, and come to value aspects of the environment, vulnerability to natural processes of change has increased.

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:

- Scientific explanations must meet certain criteria. First and foremost, 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. Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific.

State Frameworks

We designed *Pacific Expeditions: El Niño* 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 *Pacific Expeditions: El Niño* are identified below.

1998 California Science Standards

Investigation and Experimentation

Grade 6

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept, and to address the content of the other three strands, students should develop their own questions and perform investigations, recognize whether evidence is consistent with a proposed explanation, and interpret events by sequence and time from a natural phenomena (e.g. relative ages of rocks and intrusions). Students will:

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.

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.

g. interpret events by sequence and time from natural phenomena (e.g. relative ages of rocks and intrusions).

Grade 7

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept, and to address the content of the other three strands, 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.

b. utilize a variety of print and electronic resources (including the World Wide Web) to collect information as evidence as part of a research project.

d. communicate the logical connection among hypothesis, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

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

Grade 8

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept, and to address the content of the other three strands, students should develop their own questions and perform investigations. Students will:

a. plan and conduct a scientific investigation to test a hypothesis.

b. evaluate the accuracy and reproducibility of data.

Structure and Composition of the Atmosphere

Grades 9-12

Life has changed Earth's atmosphere and changes in the atmosphere affect conditions for life. As a basis for understanding this concept, students know:

c. the location of the ozone layer in the upper atmosphere, its role in absorbing ultraviolet radiation and how it varies both naturally and in response to human activities.

Investigation and Experimentation

Grades 9-12

Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept, and to address the content of the other three strands, students should develop their own questions and perform investigations. Students will:

a. select and use appropriate tools and technology (such as computer linked probes, spread sheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

d. formulate and revise explanations using logic and evidence.

i. observe natural phenomena and analyze their location, sequence, or time intervals (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).

k. recognize the cumulative nature of scientific evidence.

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

m. investigate a science-based societal issue by researching the literature, analyzing data where appropriate and communicating their findings. Examples include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions (including 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 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 El Niño and ozone depletion.

Tropical Ocean-Atmosphere System

We live on the surface of Earth where, to us, the atmosphere appears to extend to enormous heights above our heads. Likewise, the ocean appears very deep. But these impressions are due entirely to our own tiny size, compared with the size of Earth itself. In fact, the atmosphere and the ocean are thin outer layers on the spherical Earth, rather like the skin on an apple. One astronaut, contemplating Earth's planetary wrapping of atmosphere from the viewpoint of an orbiting space capsule, described the atmosphere as "a fragile seam of dark blue light."

Since about 70 percent of the Earth surface is covered by ocean, most of the atmosphere lies over water, not land. Scientists call the boundary between the atmosphere and ocean the "air-sea interface." This is not a static interface, but an active one, continuously changing. The air and the sea are each in constant motion. These motions range from the great current systems of the sea, such as the Gulf Stream, to the powerful global atmospheric wind systems, such as the jet stream. The motions also include waves on the ocean surface driven by wind and gigantic tropical storms and hurricanes fueled by energy from the warm oceans, which in turn have been heated by the strong rays of the sun. As the moving ocean and the moving atmosphere rub up against one another, these two mighty elements of the Earth system influence each other continually through the exchange of water, heat, and momentum:

- The sea gives up water to the air through evaporation. The atmosphere returns it to the ocean through precipitation.

- Heat exchange occurs just as a warm bowl of soup heats the air above it while the air gradually cools the soup. Whenever two substances such as the atmosphere and the ocean are in contact, heat flows from the warmer one to the colder one, tending over time to equalize their temperatures.

- The exchange of momentum is illustrated by the whitecaps which occur when strong winds whip the sea surface into a frenzy of wild waves.

The continual dialogue between air and sea, this exchange of water, heat, and momentum across the air-sea interface, makes the air and the sea two components of a system. Scientists have learned that they cannot understand the system by studying only the air without considering the sea, or vice versa. Instead, they must direct their research at the combined system of ocean, atmosphere, and the interactions between them. Scientists have a name for this system: the coupled ocean-atmosphere system.

El Niño

In the tropical Pacific, from Southeast Asia to the west coast of South America, the interactions between the atmosphere and ocean are particularly strong. The ocean is especially sensitive to the wind, with currents quickly responding to changes in wind speed and direction, while the atmosphere is powerfully affected by sea surface temperature. The results are often dramatic. Fishermen of Ecuador and Peru have long known that every few years, ocean surface waters warm, while along the coast there are unusually strong thunderstorms, heavy clouds, and rain. These events are synchronized not only with each other, but with the seasons — typically occurring around Christmas time. The conditions last for a few months and temporarily reduce the abundance of fish in the region. The fishermen call the event "El Niño" ("The Child") referring to Jesus Christ and symbolizing the association of the phenomenon with Christmas. Scientists distinguish between typical conditions, El Niño conditions (commonly called "warm events"), and La Niña conditions (commonly called "cool events"). Under typical conditions very warm ocean surface waters occur only in the western Pacific, just off Southeast Asia and north of Australia, giving rise to abundant rainfall in that area. The thermocline is shallow in the eastern Pacific and slopes downward to the west, becoming relatively deep in the western Pacific. Trade Winds blow steadily from east to west, causing cool, nutrient-rich waters to rise to the surface off western South America. These waters sustain the fishing industry in Ecuador and Peru.

During warm El Niño events, all this changes. The warm surface waters are now found in the central and sometimes eastern Pacific off the coasts of Ecuador and Peru, and are accompanied by thunderstorms, heavy clouds, and rain. The east-west slope of the thermocline becomes less steep. Trade Winds weaken and occasionally cease altogether. When they cease, they are replaced by winds blowing from the west. The fisheries off South America can collapse, since warm water depleted of nutrients is unable to sustain the abundant marine life found during typical conditions.

La Niña conditions are the opposite of El Niño. These cool events are typified by cold waters extending from the South American coast into the Central Pacific. The thermocline has an exaggerated tilt where the warm pool piles up in the western Pacific. The impacts of La Niña can be just as devastating as El Niño bringing drought to the southern U.S. and Peru and extensive flooding to Indonesia.

El Niño and La Niña also affect countries far from the tropical Pacific. It causes changes in the jet stream, as well as in global pressure and wind patterns, leading to unusual weather in many parts of the world. For example, western Canadian winters may be less severe during some El Niños, heavy rains may occur over the southern United States, and severe droughts can devastate Australia.

Nowadays, scientists use the term El Niño to refer to the strong warm events in which the regular seasonal cycle appears to be powerfully amplified, with ocean warming typically persisting into May or June. Yet no two El Niños are alike. For example, there were seven distinct El Niño events between 1961 and 1989, each with a different pattern of unusual ocean temperatures, rainfall, and other climate parameters. Thus, scientists speak of "interannual variability," referring to the sequence of El Niños alternating with typical conditions over the course of many years. This interannual variability is superimposed on the ordinary seasonal cycle, or "annual variability." Scientists use the term "phases of the climate system" to denote the fact that at any one time, the tropical Pacific may be either experiencing a warm event, cool event, be in typical conditions, or be in transition between them.

Methodology of Science

The story of El Niño is an especially successful example of Earth System Science. It is also typical in many ways of how any science makes progress. Science is a process, carried out by people who agree on a few fundamental principles. For example, they agree that research results should be reproducible so that one scientist's laboratory experiment or theoretical calculation can be checked by another. In the scientific process, there is a need for several types of scientists, including the lone investigator doing "small science" and the team member involved in "big science."

What led to the research that provides our current ability to understand and predict El Niño events? The story of this research offers a fascinating look at how science works. One of the early pioneers in the field was a British scientist, Sir Gilbert Walker, who worked in India during the 1920s. Walker noticed, by carefully studying weather records, that atmospheric pressures on the eastern and western sides of the Pacific are related. When the barometer is high in the east, it is low in the west, and vice versa. Walker called this seesaw in pressure the "Southern Oscillation." The term "southern" comes from the fact that Walker used measurements from stations in the Pacific Ocean south of the equator, so the phenomenon was occurring in the southern tropics.

Predicting El Niño

Part of the difficulty in understanding and predicting El Niño is simply the task of adequately observing a phenomenon which extends over such a large region: the entire tropical Pacific Ocean and the atmosphere above it. Today, however, an expensive array of instrumentation is in place, ranging from buoys in the ocean to satellites orbiting above the atmosphere. These instruments continuously monitor key parameters such as sea surface temperature and sea level, together with patterns of atmospheric surface pressure and surface winds. These instruments were not in place in 1982–83. They are in place today because we recognize their value in allowing scientists to observe and predict El Niño events.

Peru, for example, experienced a 14% decrease in the gross value of its agricultural sector as a result of El Niño's effect on the rainy season of 1982–83. Rainfall was far above normal. By the 1986–87 El Niño, scientists were able to predict the event, and agricultural planners planned crops based on the forecast. They knew to increase production of rice, which thrives in wet weather, over cotton which does better in dry weather. As a result, Peru increased the value of its agricultural sector by 3%, in spite of El Niño. Brazil and other countries have also benefited from El Niño predictions.

Forecasts need not be perfect to be useful. Just as a gambling casino can become wealthy by having the odds only slightly in its favor, so a nation's agriculture can profit by relying on climate forecasts that are only a little better than chance. Today, research is underway in many countries to improve the observations and computer models which make these forecasts possible. The 1991–95 El Niño, an exceptionally long-lived event, and the 1997-98 El Niño, provided a real-time laboratory for researchers to test their most recent theories, and to predict many aspects of this El Niño.

Appendix: Worksheet Masters

Ocean Expeditions: El Niño Worksheet

Sign In

Your Name: ____________________

Your Teammates: ____________________

Impacts of El Niño

1. Identify three impacts of El Niño, including the location where they occur. ____________________

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Hypothesis

1. Test the hypothesis: Sea surface temperature patterns show that El Niño conditions are developing in the tropical Pacific.

Sea Surface Temperature

1. Identify the two main sea surface temperature features in the tropical Pacific.

2. Describe how each of these SST features evolves.

Collect & Analyze Data

1. Describe the shape of the warm pool and cold tongue in your SST image. ______________________________

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2. Do the present conditions more closely resemble El Niño, typical, or La Niña conditions? ______________________________

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Ocean Atmosphere Circulation

1. Describe the wind and current patterns in the tropical Pacific during typical climate conditions. ______________________________

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2. Describe the changes that occur to the wind and current patterns in the tropical Pacific during El Niño conditions. ______________________

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Sea Surface Height

1. Describe sea surface height patterns across the tropical Pacific during typical conditions. ____________________

2. Describe sea surface height patterns across the tropical Pacific during El Niño conditions. ____________________

Confirm Hypothesis

1. Is it possible to confirm the hypothesis: "Sea surface temperature patterns indicate that El Niño conditions are developing in the tropical Pacific?"

Why or why not?____

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2. What other climate variables could you investigate to help support your findings? ____

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Browse Information Center

1. Describe one impact of the 1997-98 El Niño. Be sure to include the location in which it occurred.____

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