Coral Paleoclimate Slide Set

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Reef flat, Palau Archipelago (Micronesia).*** | |
| What was the [weather](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=weather&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) like in the Incan land of Tuyantunsuyu (present-day Peru, Bolivia, and Ecuador) in the year 1503 A. D.? Did moderate rains bring harvests of plenty, filling the ruler's granaries and the people's stomachs, or did the skies open up with fury, flooding the countryside and destroying the crops upon which this vast empire depended? Since the dawn of human existence, the rhythms of human societies like Tuyantunsuyu have been intimately linked to the rhythms of nature. Aside from the daily cycle of light and dark and the seasonal change from summer to winter, the most important natural rhythm is [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). Climate (the statistical or average expression of daily weather events) dictates when the first killing frost arrives, how long the growing season will last, the quantity and location of game animals, the severity of winter livestock kills, the productivity of coastal fisheries. In short, climate throughout most of history has determined when every group of human beings from farmers to fishermen to hunters would suffer and when they would prosper. As we approach the 21st century, human societies are once again realizing the vital role that climate plays in our daily lives.  Turn your attention (and your imagination) to Australia in 1807 A. D. Both the aboriginal inhabitants of the continent and the newly arrived European settlers worry and wonder whether this will be a year marked by drought and fire, or one blessed by life-giving rains. Their fate, like that of the Incas thousands of miles and hundreds of years from them, was tied to the variations of a climatic system whose mysteries scientists are only beginning to understand, the El Niño/[Southern Oscillation](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=Southern+Oscillation&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (ENSO for short).  Many scientists believe that studying the past behavior of ENSO is the key to understanding how it will act in the future. These people call themselves paleoclimatologists and their goal is to gather as much information as possible about past climates. You are about to learn how paleoclimatologists use innovative techniques to unlock the door to new understandings of the ways in which the tropical climate system works. Surprisingly enough, their most powerful tools, tools that can potentially tell us what the climate was like in Peru in 1503 or Australia in 1837, are the beautiful coral reefs like this that dot Earth's tropical oceans.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_225_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_225_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_225_bslide.html)  [Download 2027 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral01.zip) |

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| ***Global effects ("teleconnections") of ENSO warm events.*** | |
| The term El Niño (Spanish for the Christ Child) was originally used by South American fisherman to refer to especially warm ocean conditions that typically appear around Christmas and occasionally last well into the summer. Catches decline markedly during these warm periods, producing economic hardships not only for individual fisherman, but also for entire nations such as Chile and Peru who depend on fish for crucial export earnings. But the impacts of El Niño extend far beyond the South American coast. As this map shows, El Niño events produce ripples throughout the world's climate system. Ripples that occur far away but seem to be related are known as [teleconnection](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=teleconnection&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). These teleconnections stretch across the globe, from flooding in the Peruvian Andes and the southeastern United States, to severe drought in Indonesia and central India, to voracious wildfires that hurtle across the forests and brush of eastern Australia.   Photo Credits: Thomas.G. Andrews  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_226_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_226_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_226_bslide.html)  [Download 1990 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral02.zip) |

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| ***Pacific climate system during ENSO's two modes, cold or "normal," and warm.*** | |
| What is an El Niño? In the strictest sense, an El Niño is the appearance of unusually warm waters (named for the Christ-Child) in the eastern Pacific around Christmas-time. In a broader sense, however, an El Niño is the radical alteration of the entire Pacific [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) system. Climatologists speak of El Niño as having two phases: a cool (or normal) phase and a warm phase (what a South American fisherman would consider an El Niño event). In a cool phase, strong southeasterly trade winds push eastern Pacific surface waters westward, allowing cool nutrient-rich bottom waters to upwell or come to the surface. These waters are some of the most productive in the world, supporting enormous [plankton](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=plankton&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and fish populations. The central Pacific is extremely dry during cool phases; Kiritimati (Christmas) Island and its neighbors receive less than 20 cm (8 inches) of rain most years and are truly desert islands. The western Pacific during cool phases is typified by two features: a pool of extremely warm water stretching eastward to about 170 degrees W, and an accompanying belt of low pressure and high precipitation known as the [Indonesian Low](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=Indonesian+Low&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) that covers portions of Asia, Oceania and Australia. Another belt of high precipitation known as the [Intertropical Convergence Zone](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=Intertropical+Convergence+Zone&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) or ITCZ lies several degrees north of the Equator and east of the International Date Line.  In the warm phase, the trade winds weaken or even reverse, and less eastern Pacific surface water is pushed westward. Nutrient pumping in the eastern Pacific is curtailed as less nutrient-rich bottom water reaches the surface, causing fish populations to decline precipitously. Warm waters spread across the Pacific, pushing [sea surface temperatures](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=sea+surface+temperatures&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (SST's) up by 3-5 degrees C in the Galapagos Islands. The Intertropical Convergence Zone moves south and west, while the Indonesian Low follows the warmer waters east. Kiritimati Island, once dry as a bone, is deluged with 50-125 cm (20-50 inches) of rain a year during warm events. Barometric pressure in Darwin, Australia rises as higher pressure replaces the Indonesian Low. During particularly severe warm events, winds in the western Pacific actually reverse from their usual easterly direction to become mild westerlies. In short, the differences between warm and cool phases of ENSO are often as clear as night and day.   Photo Credits: Thomas.G. Andrews  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_227_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_227_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_227_bslide.html)  [Download 2041 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral03.zip) |

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| ***Annual average Sea Surface Temperature (SST) and anomalies during cool and warm years.*** | |
| Satellite imagery allows us to measure and map Pacific [sea surface temperatures](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=sea+surface+temperatures&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (SST's). The top image depicts annual average SST and shows key features of the Pacific [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) system. A pool of very warm water dominates the western Pacific, while a tongue of cool water stretches along the Equator to 160 degrees W. Cool waters prevail off the South American coast, indicating strong [upwelling](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=upwelling&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and high productivity. Also shown are the limits of coral growth; as you can see, corals can only grow in areas with mean annual SST's higher than 22-23 degrees C. White circles show the locations of sites where long coral records have been analyzed and the results published.  The next two images show sea surface temperature anomalies for the months of December through February. An anomaly is the arithmetic deviation from the mean. For example, if Shaquille O'Neal averages 30 points a game but scores 40 against the Knicks, he would have a positive scoring anomaly of 40 minus 30, which equals 10. Likewise, if the SST anomaly in the central Pacific during a warm phase is positive 2, that means that temperatures are 2 degrees C above average. Notice the negative anomaly in the central Pacific during a cool phase such as 1988-1989 created when strong southeasterly winds push cold surface waters away from the South American coast and into the mid-ocean. In warm modes like 1991-1992, weaker southeasterlies are unable to push as much cool water into the central ocean. Large SST anomalies of 2 degrees C or more occur near the equator during ENSO warm mode events but the strength and location of each anomaly is different. While all ENSO events are similar, it is important to remember that no two warm events are exactly alike; the high SST anomaly during the 1982-1983 event shifted 40 degrees further east and 5 degrees further south compared with warm events in 1986-1987 and 1991-1992.  Photo Credits: Rob Dunbar  Department of Geology and Geophysics, Rice University | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_228_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_228_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_228_bslide.html)  [Download 2168 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral04.zip) |

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| ***Caribbean star coral [Montastraea annularis]*** | |
| So what do corals like this one have to do with [El Niño](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=El+Ni%EF%BF%BDo&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2)? Before we can answer that question, we must first look at the wonderful world of coral biology to learn exactly what these organisms called corals are really like. From a distance, corals like this massive Caribbean star coral look like single organisms. When we take a closer look, however, . . .   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_229_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_229_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_229_bslide.html)  [Download 2019 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral05.zip) |

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| ***Branching coral Pocillopora damicornis from the Gulf of Panama (8N, 79W).*** | |
| We see that corals are in fact colonies composed of hundreds of thousands of tiny animals called coral [polyp](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=polyp&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). The polyps in this photo of the branching coral *Pocillopora damicornis* look like tiny bushes. To simplify things, think of a polyp as a hollow fleshy column sitting in a hard cup. On the side of the column that comes into contact with water, a ring of tentacles capture tiny organisms called [plankton](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=plankton&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and direct them down the column and into the [pharynx](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=pharynx&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) to be digested. Most reef-building corals also have an alternate source of food: a type of [algae](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=algae&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) called [zooxanthellae](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=zooxanthellae&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) live within the fleshy parts of coral polyps. These algae give living corals their brownish color. Zooxanthellae photosynthesize light and carbon dioxide to supply both themselves and the coral with food and oxygen. In turn, the food caught by the coral supplies both organisms with the crucial nutrients phosphorous and nitrogen, which are then cycled back and forth between the two. Algae also help corals with [calcium carbonate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=calcium+carbonate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) deposition and without algal populations corals are unable to produce substantial reef structures. This interdependent relationship between corals and the algae they contain is an example of [symbiosis](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=symbiosis&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2), a biological term describing a relationship where two organisms work together to survive.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_230_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_230_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_230_bslide.html)  [Download 2028 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral06.zip) |

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| ***Positive x-radiograph collage of Galapagos Pavona clavus coral.*** | |
| The [polyp](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=polyp&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) is seated in a pit in the coral skeleton composed of [calcium carbonate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=calcium+carbonate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (CaCO3) crystals secreted by the [epidermis](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=epidermis&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) or skin of the lower half of the column. As long as the colony is alive, calcium carbonate is deposited beneath its living tissues. The colony lies entirely above the skeleton and, with its network of interconnected polyps, completely covers it. Many corals periodically lift their bases and produce a new floor to their cup, encapsulating a tiny portion of their skeleton and entirely sealing it off from any contact with sea water or living tissues. Over the course of many years, each polyp lifts itself hundreds of times, each time leaving even more skeleton behind. The [density](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=Density&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) of the capsule left behind depends on the timing of its creation. Coral skeleton formed in winter has a different density than that formed in summer because of variations in growth rates related to temperature and cloud cover conditions. Thus corals exhibit seasonal [growth bands](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=growth+band&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) very much like those in trees. Sometimes these bands are visible to the naked eye; usually, however, they are more visible in an x-ray like this. When paleoclimatologists drill a coral core, they can count the growth bands and date samples exactly. Long cores can cover several hundred years; this portion of a core from Urvina Bay in the Gal�pagos Islands covers the period from 1716 to 1735 A. D. To best understand past [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2), scientists need to be able to date their samples as accurately as possible. They need to know exactly when climatic changes occurred so that they can create realistic computer models of the global climate system.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_231_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_231_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_231_bslide.html)  [Download 2266 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral07.zip) |

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| ***5-meter high colony of massive coral (Pavona clavus), Urvina Bay, Galapagos Islands.*** | |
| The earth's surface is a dynamic place shaped and reshaped by incredibly powerful processes. This 5-meter high colony of massive coral (*Pavona clavus*) from the Galapagos was lifted high and dry during a turbulent period of rapid tectonic uplift in 1954. Cataclysmic transformations such as this underscore the fact that our planet is always changing. Most of these changes, however, are much subtler than the sudden rise of the ocean floor or the dramatic explosion of a volcano.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_232_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_232_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_232_bslide.html)  [Download 2065 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral08.zip) |

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| ***Bird's eye view of Cariaco Basin, Venezuela (11N, 65W).*** | |
| One of the most exciting new fields of science is global change. Global change refers to transformations in any aspect of the earth system and it is a discipline that brings together biologists, chemists, geologists, physicists, and social scientists. One of the most pressing issues in global change is the impact of human activities on the environment.  What do corals have to do with global change? A central principle of geology is called uniformitarianism; this doctrine states past geologic events can be explained by processes observable today, that, in effect, The present is the key to the past. Paleoclimatologists, however, believe that the converse of this statement is also true, that the past is the key to the present and even the future. Coral records give us important clues about how the tropical climate system operates, which, in turn, will make it possible for scientists to predict future global change. Long paleoclimatic records also supply information about the natural range of climatic variation and provide a baseline against which [anthropogenic](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=anthropogenic&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (man-made) climate change can be detected. Paleoclimatologists come here, to warm shallow waters perfect for coral growth, to unlock the earth's >climate history.   Photo Credits: Julie Cole  INSTAAR, University of Colorado at Boulder | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_233_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_233_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_233_bslide.html)  [Download 2011 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral09.zip) |

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| ***Ecuadorean ship Wahoo off Bartholeme, Galapagos Islands (1S, 89W).*** | |
| The first and most obvious ingredient in coral research is the corals themselves. But coral alone does not attract the paleoclimatologist's eye. The location of a site is also extremely important. Paleoclimatologists are interested only in those sites where a clear, identifiable climatic signal can be detected. In earlier slides, we discussed how El Niño activity affected different areas of the Pacific. It is these places where El Niño leaves a clear signature to which scientists take the time, effort, and expense to travel. The Galapagos Islands in the eastern Pacific exhibit wide ENSO-linked variations in [sea surface temperatures](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=sea+surface+temperatures&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and thus make an ideal site for research. In this slide, the Ecuadorian ship Wahoo prepares to take a group of paleoclimatologists to the reefs off of Bartholome.  Photo Credits: Glen Shen  School of Oceanography, University of Washington | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_234_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_234_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_234_bslide.html)  [Download 1992 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral10.zip) |

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| ***Colonies of Pavona clavus and branching coral Pocillopora robusta, Baja California*** | |
| Once they've sailed to their desired destination, scientists anchor their boat. Now, after months of preparation, comes the fun part. Donning wet suits and scuba tanks, they dive into the shallow reef waters. Once they've descended a few feet, their eyes meet with wonderful scenes such as this. Corals stretch as far as the eye can see. Some, like the branching coral *Pocillopora robusta* that you see in the sides of this photo, are beautiful but not particularly useful for paleoclimatic research. Others, like the massive coral *Pavona clavus* that dominates this picture, are perfect: big, easily cored, and sometimes hundreds of years old, ancient enough to produce a long and interesting climatic record.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_235_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_235_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_235_bslide.html)  [Download 2002 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral11.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Extracting core with hydraulic drill on a Porites lobata colony, Clipperton Atoll*** | |
| The scientists have found an ideal candidate. Armed with a hydraulic drill connected to a compressor on ship, they begin to take their core. The most important part of the drilling process is trying to get a core that follows the coral's plane of maximum growth. Think of the coral's structure as being very similar to an onion sliced in half, with a new ring added each year. If you wanted to drill into an onion to sample as many rings as possible, you would core from the surface directly towards the center. This is exactly how scientists go about getting as long a sample as possible from each coral.   Photo Credits: Maris Kazmers  SharkSong Photography, Okemos, Michigan | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_236_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_236_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_236_bslide.html)  [Download 2107 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral12.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Extracting core with hydraulic drill on a Porites lobata colony, Clipperton Atoll*** | |
| While drilling does kill the few [polyp](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=polyp&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2)s living on the core surface, the process does not damage the colony as a whole. In fact, polyps often grow over the holes left by drilling within a couple of years. As we discussed earlier, only the surface of a colony is alive; all of the rest is the [calcium carbonate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=calcium+carbonate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) skeleton deposited by the polyps. This skeleton is created from the calcium, carbon, and oxygen available to the coral in the water and organisms that surround it. When a polyp lifts itself and encapsulates a piece of skeleton, the chemistry of that portion of skeleton is locked in forever. In other words, every time a piece of skeleton is created, it leaves an indelible record of the conditions under which it was created. It is this record that paleoclimatologists are trying to unlock by drilling long cores into the coral skeleton.   Photo Credits: Maris Kazmers  SharkSong Photography, Okemos, Michigan | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_237_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_237_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_237_bslide.html)  [Download 2014 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral13.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Extracting core with hydraulic drill on a Porites lobata colony, Clipperton Atoll*** | |
| The drilling is completed and the core segment is removed from the hole. Paleoclimatologists travel the world, from the stark whiteness of the Greenland Ice Sheet to the scrub forests of the American Southwest to the lush underwater jungles of the tropics. Most of them spend a few months a year doing field work. The rest of the year, they analyze samples like this core segment that they have gathered in the field, teach courses to college students, and write articles and books about their research. If you asked just about any paleoclimatologist what they liked most about their job, they would say moments like the one pictured, creative moments when they get to apply years of training to the environments they are so interested in.  The drill goes all the way into the coral. Next, the scientists carefully extract the core pieces, label them, and box them for safe shipment home. Back in the laboratory, the excitement of the field work will be followed by new discoveries and new insights into our planet's past.   Photo Credits: Maris Kazmers  SharkSong Photography, Okemos, Michigan | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_238_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_238_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_238_bslide.html)  [Download 1987 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral14.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Two sections of a core of Pavona clavus from Urvina Bay, Galapagos (0, 91W).*** | |
| First the cores are x-rayed so that scientists can see the [growth bands](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=growth+band&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). Next, segments like the one on the right from Urvina Bay, Galapagos are marked for sampling: black lines represent annual bands, while blue and red lines further subdivide the year into quarters. The core is then cut along the lines and the individual segments analyzed in a laboratory for stable [isotope](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=isotope&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and geochemical signals.   Photo Credits: Rob Dunbar  Department of Geology and Geophysics, Rice University | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_239_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_239_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_239_bslide.html)  [Download 1991 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral15.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Comparison of coral cores and sea surface temperatures (SST).*** | |
| Paleoclimatologists do not have the luxury of measuring past climates directly; instead, they use [proxy signals](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=proxy+signals&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) that follow climatic signals closely yet indirectly. 18O, the ratio of heavy oxygen (18O) to light oxygen (16O), is a crucial proxy signal and the most important result of laboratory analysis. This ratio is determined by the ambient water conditions (i.e. sea surface temperature and, in some locations, fresh water influx and precipitation) at the time when a given portion of coral skeleton was formed.  This graph illustrates the close correspondence between the record of 18O obtained from coral cores from Punta Pitt, Galapagos and instrumental measurements of [sea surface temperatures](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=sea+surface+temperatures&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (SST) from Puerto Chicama, Peru (8S, 79W). Notice that red spikes in the 18O record match up with red spikes in the SST record and with the yellow zones that indicate ENSO warm phases. These red areas indicate periods when water temperatures were above the average. Remember that in the Galapagos, high water temperatures indicate the eastward movement of the Pacific warm pool and the reduction of upwelling activity in the eastern Pacific. As this graph shows, coral 18O data is nearly as accurate as instrumental data; moreover, coral records can cover the past 500-800 years of [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) change, while instrumental records are only available for the last 50-100 years in many tropical areas.   Photo Credits: Thomas.G. Andrews  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_240_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_240_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_240_bslide.html)  [Download 1998 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral16.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Long Delta 18O record from Urvina Bay, Galapagos.*** | |
| The last figure demonstrated the accuracy of coral 18O as a proxy measurement of [sea surface temperatures](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=sea+surface+temperatures&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). 18O can also serve as a proxy measurement for precipitation, particularly in areas like the central Pacific where large ENSO-related oscillations in annual rainfall occur. Now that scientists have established the reliability of coral 18O as a proxy signal, they are beginning to take deeper cores that provide increasingly long climatic records. Think of coral 18O as a paleothermometer that enables us to answer important questions about climatic variability in the world's oceans. This core from the Galapagos Islands gives us a 350-year record of sea surface temperatures and, by extension, El Niño activity in the eastern Pacific.   Photo Credits: Thomas.G. Andrews  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_241_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_241_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_241_bslide.html)  [Download 1981 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral17.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***Records of coral Cd/Ca and Ba/Ca and East Pacific sea surface temperature (SST) anomalies.*** | |
| This graph compares coral cadmium/calcium and barium/calcium anomalies from a coral core from Punta Pitt with East Pacific sea surface temperature anomalies from Puerto Chicama for the period 1950-1980. Because of their nutrient-like distribution, cadmium and barium act as sensitive indicators of vertical mixing in the water column. Note the strong correlation between negative Cd/Ca and Ba/Ca anomalies (e.g. a relative decrease in nutrient availability because of reduced [upwelling](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=upwelling&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2)) and positive SST anomalies during ENSO events. In the coming years, paleoclimatologists will be coming to the tropics, drilling more cores, and creating even longer records of tropical climatic variability. Coral paleoclimatology is a new and promising field because of the annual-resolution dating which [growth bands](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=growth+band&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) allow and because of the strong [proxy signals](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=proxy+signals&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) contained in the coral skeleton.   Photo Credits: Thomas.G. Andrews  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_242_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_242_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_242_bslide.html)  [Download 1993 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral18.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| **Erosion of (Pavona), Saboga Island, Panama** | |
| The 1982-83 El Niño killed many corals in the eastern Pacific. All or part of the coral colonies bleached and therefore died. In the year following the El Niño, conditions were favorable for the growth and survival of young sea urchins. Unfortunately, sea urchins scrape away the coral skeleton of a reef as they graze on algae. Due to the increase in the sea urchin population, the death of the corals was followed by increased erosion, destroying the reef structure. These two events occurring in succession destroyed corals that might be used to obtain a record of past climate. This slide from Saboga Island, Panama shows the erosion by sea urchins of a coral partially killed in the 1982-83 El Niño. Fifteen years after these events, many reefs in the eastern Pacific are still eroding faster than corals are depositing skeletons.  Photo Credits: Mark Eakin  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_243_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_243_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_243_bslide.html)  [Download 1989 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral19.zip) |

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| ***Paleo Slide Set: Coral Paleoclimatology*** |

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| ***A school of goatfish (Mulloidicthys dentatus) at Clipperton Atoll.*** | |
| The modern age, an era where human beings have attained an uneasy control over the natural world, is a direct threat to many of the species with which we share this planet. If in coming years, pollution or [anthropogenic](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=anthropogenic&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) climate change erases scenes such as this, a school of goatfish serenely swimming above large colonies of Porites lobata, from the earth, not only will we lose one of the most fascinatingly beautiful [ecosystems](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=ecosystem&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) on the planet, we will also lose one of our most important tools for understanding how our planet works. Both beauty and information are increasingly valuable and scarce commodities in this rapidly changing world of ours, and we can ill afford to lose either.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_244_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_244_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/13/13_244_bslide.html)  [Download 2040 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coral20.zip) |

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| ***The anatomy of a coral polyp*** | |
| Think of a [polyp](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=polyp&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) as a hollow, fleshy column sitting inside a hard cup. The portion of the column that comes into contact with water has a ring of tentacles which are used to capture minute organisms called [plankton](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=plankton&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). After capturing the plankton, the tentacles direct these organisms down the polyp column and into the [pharynx](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=pharynx&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) to be digested.  The polyp is seated in a pit inside the coral skeleton. The surrounding skeleton is composed of [calcium carbonate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=calcium+carbonate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (CaCO3) crystals which are secreted by the [epidermis](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=epidermis&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (the skin) of the lower half of the column. As long as the colony is alive, calcium carbonate is deposited beneath its living tissues. The colony lies entirely above the skeleton, covering it with a network of interconnected polyps. As a polyp grows outward from the colony, the bottom leaves behind a skeleton made of calcium carbonate. This process forms the structure of the reef. (Polyps can move slightly up and over, but not enough to search for food or escape from predators.)  How do polyps reproduce? One way a polyp reproduces is by budding or splitting in half. This process creates a [clone](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=clone&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) of the polyp. A more prolific way to reproduce is to release gametes (egg or sperm cells). Amazingly, entire reef populations of polyps, many kilometers across, release their [gametes](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=gamete&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) during the same week at the time of the year when the tides are weaker allowing the gametes a degree of protection. Three to six days after the spring [equinox](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=equinox&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2), after the full moon, millions of gametes are released. They then mate and set out to find a new [habitat](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=habitat&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). Sometimes they settle on dead coral nearby, other times they attach to drifting tree trunks and travel long distances. Within a week, the gametes have either survived their trip and have begun to grow, or they have died. Because the survival rate is so low, nature ensures the existence of the species by releasing many gametes from each polyp.   Photo Credits: Sarah H. Dawson  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_248_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_248_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_248_bslide.html)  [Download 2269 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs04.zip) |

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| ***Bleached (Pocillopera) 1983, shows how an El Niño year can affect coral growth.*** | |
| Most reef-building corals support an algae called [zooxanthellae](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=zooxanthellae&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2), which lives within the fleshy parts of the coral [polyp](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=polyp&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2)s. These algae give living coral their brownish color. Zooxanthellae grow and therefore supply the coral polyps with food and oxygen by a process called [photosynthesis](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=photosynthesis&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). In turn, the food the corals filter feed through their tentacles supplies both the corals and the zooxanthellae with the crucial nutrients, phosphorous and nitrogen. These elements are then cycled back and forth between the two organisms. How else might coral help the algae? Coral provides a habitat for the algae. Without algae populations, the corals would be unable to produce substantial reef structures. This interdependent relationship between the coral and the algae is an example of [symbiosis](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=symbiosis&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2), a relationship in which two organisms work together to survive.  A dramatic sign that a coral is living under stressful conditions is [coral bleaching](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=coral+bleaching&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). The [algae](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=algae&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) are expelled (kicked out) and the coral loses its color causing the polyps to look clear and the colony to turn white hence, the term "bleaching". (No bleach is involved.) Corals might bleach when they face water that is too hot or cold, live above water for too long, have a nutrient deficiency or when they encounter waters that are clouded with silt or pollution. Adverse organism reactions to the environment can often be the first sign that something has gone wrong in terms of temperature, amount of nutrients or an imbalance in the food chain.   Photo Credits: Peter W. Glynn  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_249_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_249_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_249_bslide.html)  [Download 1970 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs05.zip) |

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| ***Food pyramid illustrating the transfer of energy.*** | |
| This food pyramid shows some of the plants and animals that exist in a coral ecosystem. At the bottom is the basis of the food chain: the [autotrophs](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=autotroph&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). (Autotrophs are phytoplankton (microscopic plants) and other plants that convert carbon dioxide and water in the presence of sunlight and chlorophyll into food and oxygen. This process is called [photosynthesis](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=photosynthesis&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). At the second level of the pyramid are zooplankton. Zooplankton are microscopic animals, that are often the immature stages of other organisms, such as lobsters or clams. They receive their energy by consuming phytoplankton. For the most part, all [plankton](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=plankton&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) ride the ocean currents and are an easy target for larger organisms. Larger animals, such as sponges, feed on the zooplankton, adding the third level to the pyramid. The great white shark is at the top of the food pyramid and it has no natural predators.   Photo Credits: Sarah H. Dawson  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_250_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_250_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_250_bslide.html)  [Download 2001 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs06.zip) |

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| ***Coral reefs only grow under certain conditions.*** | |
| Coral reefs exist in the warm tropics at latitudes between 23.5N and 23.5S. Sometimes coral will grow above or below these latitudes if there are warm currents such as the Gulf Stream that pull warm water north or south from the tropics. At the equator, the sun's rays are most direct and shine for a longer period of the year than at other latitudes. The tropics, between the Tropic of Cancer in the south and the Tropic of Capricorn in the north, are a range in which the sun is directly overhead during a large part of the year keeping the waters at a constant, warm temperature.  The closer to the surface of the water, the more sunlight the corals receive, which is essential for photosynthesizing algae. Yet the coral cannot live above water for long. The depth at which coral can exist also depends on the cloudiness of the water. The waters in the Caribbean tend to be clear because there are not a lot of dissolved nutrients floating in the currents promoting [plankton](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=plankton&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) growth. In other parts of the world the water is not as clear due to high plankton activity, therefore the sun's rays do not penetrate as deeply.  Large amounts of nutrients such as nitrogen and phosphorous, brought in by the ocean waves are essential for the growth of coral. However, even though there are a lot of nutrients flowing out of the mouths of rivers, corals do not grow in these areas because the water is clouded with mud or silt. Corals also cannot survive near or in freshwater sources, such as a river or a lake.   Photo Credits: Sarah H. Dawson  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_252_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_252_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_252_bslide.html)  [Download 2123 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs08.zip) |

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| ***Coral bleaching at Uva Island, Panama during thermocline shoaling in 1993.*** | |
| This coral reef off the coast of Uva Island, Panama in the eastern Pacific, has been above the surface for too long in the mid-day sun. The coral reef has bleached and died along with the algae, fish and invertebrates trapped on the reef flat. This was caused by a low [spring tide](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=spring+tide&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) that happened at the same time as an unusually extreme [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) event, highlighted by strong pressure variations and winds which drive surface waters westward off the eastern Pacific coastline. A spring tide occurs when the moon, sun and earth are positioned in a straight line (at either a full or new moon). The increased gravitational pull causes lower than normal low tides and higher than normal high tides. (More about this unusual climate event in slide 20.)  In addition to being an important [habitat](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=habitat&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) for 100's of creatures, coral reefs are also important to scientists who study past climates.  What is climate and how is it different from weather? Weather is what we experience from hour to hour and day to day. Climate is the average of weather (temperature, humidity, pressure, wind, etc.) over decades, centuries or millennia. The climate of a region does not vary greatly from year to year, although over long periods of time it does.  Why would we want to know what the climate was like hundreds or thousands of years ago? Isn't it only necessary to know what the climate will be like in the future? Studying past climate actually assists scientists in forecasting future climate conditions. By knowing how climate has changed over the course of geologic time, scientists will be able to identify patterns and thereby predict what climate changes we are likely to see in the future. They can also compare the rate at which the climate changed in the past to the rate of climate change in today�s industrial age. It is necessary to establish what is "normal" in order to determine what changes are causes for alarm. Scientists who study past climates are called paleoclimatologists. "Paleo" means ancient (as in paleontologist, one who studies ancient life, including dinosaurs) and "climatologist" is a person who studies the average of daily weather events over time.  Humans have kept an accurate record of the weather and climate conditions over the past 100-150 years using scientific instruments. (We know climate varied much more before the "instrumental period" of observation.) To understand climate change that occurred before the instrumental period, scientists study older human records: sailing logs of early traders, letters sent home from world explorers, clothing drawn on pottery remains and the dairies of early settlers. Scientists can also utilize the natural climate record by investigating tree rings, layers of ice in glaciers, corals, ocean and lake sediments and other sources to arrive at a more accurate portrayal of the Earth's past climate.  Photo Credits: Mark Eakin  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_253_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_253_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_253_bslide.html)  [Download 1987 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs09.zip) |

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| ***5-meter high colony of massive coral (Pavona clavus), Urvina Bay, Galapagos Islands.*** | |
| It is important that we understand the climatic system, especially in the face of possible global warming. Most scientists agree that it is a possibility that global warming is occurring. However, the rate and amount of expected change are not entirely clear. There have been other warm periods in the Earth's history. We are now in an interglacial, or warm period, that began when the last Ice Age ended, about 10,000 years ago. Scientists know that many changes in climate have been, and can be, caused by natural forces.  Scientists need to know how much of the Earth's present warming is due to natural factors and how much is due to human activity. They also need to know at what rate climatic changes are happening. By knowing how much human and natural factors influence climate, scientists can suggest a plan of action to postpone global warming or help people adapt to it.  Just as the Earth's [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) changes, the earth's surface changes too, as this slide shows. The earth's surface is constantly shaped and reshaped by incredibly powerful processes such as earthquakes. This 5-meter high colony of coral (*Pavona clavus*) is from the Galapagos Islands off the coast of Ecuador in the Pacific Ocean. This reef, once underwater, was lifted high and dry during a turbulent period of earthquake activity in 1954. Examples such as this terrestrial reef are evidence that our planet is always changing. Most of these environmental changes however, are less dramatic than the rise of the ocean floor or the eruption of a volcano. One less dramatic change that we are able to investigate is the rate at which coral grows. By examining the growth rate of coral, scientists are able to determine what the climate was like when the coral was submerged and alive in the ocean.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_254_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_254_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_254_bslide.html)  [Download 2066 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs10.zip) |

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| ***Colonies of Pavona clavus and branching coral Pocillopora robusta, Baja California.*** | |
| The branching coral Pocillopora robusta that you see in the edges of this photo, are beautiful but not particularly useful for paleoclimatic research. Others, like the massive coral Pavona clavus that dominates this picture, are perfect candidates: large, easily sliced open and sometimes hundreds of years old. These characteristics generate enough information to produce a long and interesting climatic record.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_257_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_257_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_257_bslide.html)  [Download 2001 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs13.zip) |

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| ***Extracting core with hydraulic drill on a Porites lobata colony, Clipperton Atoll.*** | |
| Scientists take samples from the center of the coral. Here is a slide of scientists taking a core sample. With a hydraulic drill connected to a compressor on a boat, they begin to take their core. The most important part of the drilling process is getting a core that follows the coral's axis of maximum growth. A coral's structure is very similar to an onion when sliced in half. If you wanted to drill into an onion to sample as many rings as possible, you would cut the core from the top directly towards the center. Drilling at right angles to [growth bands](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=growth+band&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) is how scientists go about getting as long of a sample as possible from each coral.   Photo Credits: Maris Kazmers  SharkSong Photography, Okemos, Michigan | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_258_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_258_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_258_bslide.html)  [Download 2107 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs14.zip) |

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| ***Extracting core with hydraulic drill on a Porites lobata colony, Clipperton Atoll.*** | |
| While drilling does kill a few [polyp](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=polyp&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2)s living on the core surface, it does not damage the colony as a whole. In fact, polyps often grow over the drilling holes within a couple of years. As we discussed earlier, only the surface of the colony is alive, the rest is the [calcium carbonate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=calcium+carbonate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) skeleton deposited by the polyps. When a polyp grows and leaves the skeleton behind, the chemistry of that portion of skeleton is locked in. In other words, every time a piece of skeleton is created, an indelible record of the conditions under which it was created are contained within it. Some colonies live as long as 800 years! It is this ancient record that paleoclimatologists are trying to unlock by drilling long cores into the coral skeleton.  Once the drill reaches the center of the coral, scientists carefully extract the core pieces, label them and box them up for safe shipment home. Back in the laboratory, the excitement of the field work will be followed by new discoveries and new insights into our planet's past. Coral paleoclimatologists travel around the world to find coral in order to compare the chemistry and growth of different areas. Most spend a few weeks a year doing their field work. The rest of the year, paleoclimatologists analyze samples like this core segment that they have gathered in the field, teach courses to college students and write articles and books about their research.   Photo Credits: Maris Kazmers  SharkSong Photography, Okemos, Michigan | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_259_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_259_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_259_bslide.html)  [Download 2015 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs15.zip) |

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| ***Positive x-radiograph collage of Galapagos Pavona clavus coral.*** | |
| Here is an X-ray of a coral sample. You can see lines called [growth bands](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=growth+band&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2), very much like those in most trees. A light and a dark band together represent one year's growth. The amount of seasonal growth is determined by temperature, cloud coverage and the amount of nutrients present. As you can see, in some years the corals grew more than others, due to climatic events. The ring from winter growth is darker because growth is slowed and the coral skeleton becomes more compacted. The ring from spring and summer growth is lighter because growth speeds up and the skeleton formed is less dense. Paleoclimatologists count the bands to determine the age of the sample. They can also identify significant [weather](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=weather&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) events by looking at the uneven bands.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_260_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_260_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_260_bslide.html)  [Download 2263 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs16.zip) |

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| ***Two sections of a core of (Pavona clavus) from Urvina Bay, Gal�pagos (0�, 91�W).*** | |
| Would you be convinced that scientists could get an accurate portrayal of what the [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) was like by looking at just the ring data? The bands can tell them the age and growth rate, but not what caused the increase or decrease in growth. The chemistry of the coral closely reflects the surrounding environmental conditions when that part of the coral formed, so scientists examine the chemistry to determine what caused a specific growth rate.  After the core has been x-rayed, bands are drawn with black lines representing annual bands, and blue and red lines divide the year into quarters.   Photo Credits: Rob Dunbar  Department of Geology and Geophysics, Rice University | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_261_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_261_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_261_bslide.html)  [Download 1991 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs17.zip) |

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| ***A mass spectrometer measures chemical isotopes*** | |
| The core is then taken to the laboratory where scientists analyze the chemical composition of each year, band by band. In samples of Galapagos corals, scientists look at the ratios of Cadmium (Cd) to Calcium (Ca) and Barium (Ba) to Calcium. A high ratio of Cd/Ca and Ba/Ca indicates that more [upwelling](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=upwelling&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) has occurred because upwelled waters have more Barium and Cadmium.  Scientists also investigate two [isotopes](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=isotope&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) of oxygen that are found in the individual coral bands. Different atom numbers of the same element are called isotopes. An isotope has a different number of neutrons from the common form of the element. For example, 12C (carbon 12) has 12 neutrons. Its isotope 14C has two more neutrons than the most common form of carbon (12C). Both being present in all sea water, the light oxygen isotope is called 16O and the heavy oxygen isotope is 18O (16+2). Because the coral builds its skeleton using sea water and the elements dissolved in sea water, both oxygen isotopes 16O and 18O are found in the coral bands. Since there is a correlation between the number of 18O present in the coral skeleton and the temperature of the water, less 18O present than 16O indicates that the air and ocean temperatures were warmer at the time the coral formed.  To measure the relative abundance of these oxygen isotopes, the core is first ground into powder. The powder is dissolved in a strong acid, forming a carbon dioxide (C02) gas. The C02 gas is released as an ionized stream and passed through a strong magnetic field. Within the magnetic field, the lighter C02 (C16O2) molecules are bent more than the heavier ones (C18O2). After the two types of C02 have been separated the scientists count the different molecules using a computer and determine a ratio of 18O to 16O. This complex process provides an accurate measurement of the environmental conditions the coral was exposed to during that year. Scientists use as many clues as possible to put the pieces of past climate together.   Photo Credits: Sarah H. Dawso  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_262_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_262_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_262_bslide.html)  [Download 1973 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs18.zip) |

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| ***This map shows where El Niño occurs in the South Pacific*** | |
| Scientists do not collect coral samples from just anywhere. The location of a site is extremely important. Paleoclimatologists are interested only in those sites where a clear, identifiable climate signal can be detected. Scientists want to spend their time studying an area that will give them the clearest picture of past [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) change and so they explore areas of the globe where climate changes have been most dramatic.  El Niño transforms the [weather](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=weather&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) in the Pacific Ocean significantly, making it an important area for the study of climate history. An El Niño is the appearance of warm waters in the eastern Pacific. El Niño is Spanish for the Christ Child originally named by South American fishermen because the event occurs near Christmas time. Because El Niño waters are much warmer than waters in other years, dramatically different regional climate patterns result.   Photo Credits: Sarah H. Dawson  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_263_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_263_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_263_bslide.html)  [Download 2068 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs19.zip) |

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| ***South Pacific cross-section during normal years.*** | |
| ENSO (El Niño-[Southern Oscillation](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=Southern+Oscillation&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2)) refers to changes of the entire Pacific [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) system. This slide displays the Pacific Ocean during a normal period. The trade winds continually push the water and air from the east to the west. The sea level on the west side of the Pacific Ocean (Australia), is about a half of a meter higher than on the South American side during this time! The cold water rises (upwells) from the deep ocean replacing the warm water in the eastern Pacific, and carrying to the surface the nutrients from decomposing animals at the bottom. This process of cold water bringing nutrients to the surface is called [upwelling](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=upwelling&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2).  Water warms as it is transported through the tropics to the west via the trade winds. The warm water causes the moist maritime air to rise. As the air rises it cools, causing water to condense into droplets (just like humid air that cools on the outside of a glass of ice water). This process brings abundant rainfall to Indonesia and other parts of the western Pacific region.   Photo Credits: Sarah H. Dawson  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_264_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_264_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_264_bslide.html)  [Download 2194 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs20.zip) |

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| ***South Pacific cross-section during El Ni�o years.*** | |
| During El Niño years, the trade winds weaken. Warm water is no longer pushed westward and cold nutrient-rich water is no longer upwelled to the surface along the South American coast. Interestingly, because there is more rainfall in the interior of Peru (a normally dry region) during an El Niño, the local agricultural industry fares well. However, fish catches decline markedly during these warm periods, producing economic hardships not only for individual fishermen, but also for entire nations such as Chile and Peru.  El Niño is a natural event that has been occurring for thousands of years, so Peruvians should expect its arrival. Unfortunately, no one knows exactly when the next El Niño will occur, how intense it will be, or how long it will last. We only know that the average occurrence is every 3-7 years and it lasts for an average of 1-2 years. Scientists are working to find ways to better predict when the next El Niñ o will come and how strong it will be. Buoys are set up along the equator of the central Pacific to take records of the [sea surface temperatures](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=sea+surface+temperatures&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) (SSTs), wind speeds and barometric pressures. When the winds slow down an El Niñ o is on its way.  Scientists can also detect the past occurrences of El Niñ o by looking at the past sea-surface changes in corals. El Niño affects the growth and chemistry of the coral bands. Isotopes of oxygen locked in the coral skeleton record past water temperatures and can indicate an El Niño. The information recorded in the coral bands can tell us more about the frequency and duration of El Niños.  During the strongest ENSO of the century in 1982-83, the temperatures in the western Pacific increased by up to 5 degrees Celsius. The stress due to warmer than normal temperatures caused some of the coral polyps to bleach. Although bleaching after El Niño is normal, the amount of coral bleaching seems to be on the rise, and El Niño appears now to be affecting areas that have not been affected in the recent past.   Photo Credits: Sarah H. Dawson  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_265_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_265_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_265_bslide.html)  [Download 2113 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs21.zip) |

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| ***Global effects ("teleconnections") of ENSO warm events.*** | |
| Other changes occur across the Pacific during an El Niño. As the warm water moves eastward towards the central Pacific, the westward descending cool, dry air brings high pressure, drought conditions and often wild fires to Indonesia. The low pressure zone usually located over Indonesia, shifts to the mid-Pacific. This region of low pressure coupled with the rising moist air above the warm water pool, greatly increases rainfall to the mid-Pacific. This shifting of the pressure zones is known as the [Southern Oscillation](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=Southern+Oscillation&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2).  The impacts of El Niño, extend far beyond the South American coast and the Indonesian interior. As this map shows, El Niño events produce ripples of change throughout the world's [climate](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=climate&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) system; ripples that occur far away but are related are known as [teleconnection](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=teleconnection&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2). Teleconnections stretch across the globe, from flooding in the Peruvian Andes and the southeastern United States, to severe drought in Indonesia and central India, to voracious wildfires that hurtle across the forests and brush of eastern Australia.  An El Niño ends as the Pacific waters become warmer and the water at the equator flows from west to east and also towards the poles. Gradually, this flow decreases the pool of warm water at the equator, which leads to intensification of the [tradewinds](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=tradewinds&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) and an eventual return to normal conditions.   Photo Credits: Thomas.G. Andrews  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_266_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_266_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_266_bslide.html)  [Download 1991 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs22.zip) |

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| ***Erosion of (Pavona), Saboga Island, Panama*** | |
| The 1982-83 El Niño killed many corals in the eastern Pacific. All or part of the coral colonies bleached and therefore died. In the year following the El Niño, conditions were favorable for the growth and survival of young sea urchins. Unfortunately, sea urchins scrape away the coral skeleton of a reef as they graze on algae. Due to the increase in the sea urchin population, the death of the corals was followed by increased erosion, destroying the reef structure. These two events occurring in succession destroyed corals that might be used to obtain a record of past climate. This slide from Saboga Island, Panama shows the erosion by sea urchins of a coral partially killed in the 1982-83 El Niño. Fifteen years after these events, many reefs in the eastern Pacific are still eroding faster than corals are depositing skeletons.  Photo Credits: Mark Eakin  NOAA Paleoclimatology Program | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_267_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_267_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_267_bslide.html)  [Download 1990 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs23.zip) |
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| ***A school of goatfish (Mulloidicthys dentatus) at Clipperton Atoll.*** | |
| The modern age, an era where human beings have attained an uneasy control over the natural world, is a direct threat to many of the species with which we share this planet. If in coming years, pollution or [anthropogenic](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Like&query_0=anthropogenic&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) climate change erases scenes such as this, a school of goatfish serenely swimming above large colonies of Porites lobata, from the earth, not only will we lose one of the most fascinatingly beautiful [ecosystems](http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=ecosystem&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2) on the planet, we will also lose one of our most important tools for understanding how our planet works. Both beauty and information are increasingly valuable and scarce commodities in this rapidly changing world of ours, and we can ill afford to lose either.   Photo Credits: Jerry Wellington  Department of Biology, University of Houston | [[Click to View Larger Image](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_268_bslide.html)](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_268_bslide.html)  [Click on above image to enlarge.](http://www.ncdc.noaa.gov/paleo/slides/slideset/14/14_268_bslide.html)  [Download 2013 KB TIF Image](http://www.ncdc.noaa.gov/paleo/slides/images/hi_res/coralhs24.zip) |