Name: Date:
TEACHER VERSION: Suggested Student Responses Included

Ocean Inter-annual Variability: El Niño and La Niña

Guiding Question:

- How does *El Niño* influence the oceans and climate patterns?

Introduction

What is El Niño/La Niña?

The *El Niño/La Niña* cycle is a natural climate oscillation of the ocean-atmosphere system that occurs in the Pacific Ocean.   *El Niño* was first observed by scientists as an unusual ocean warming along the coasts of Peru and Ecuador in South America. The timing of this warming often coincided with the Christmas season, so it was called *El Niño* for the coming of the Christ Child.   Although it occurs in the Pacific Ocean, the impacts of *El Niño/La Niña* are felt around the world and illustrate how our Earth system is inter-connected. The *El Niño/La Niña* cycle occurs every 3-7 years usually starting in December, but its impacts can last for months.

What controls El Niño?

The cycle is the result of the trade winds that blow over the central Pacific Ocean. Under 'normal' conditions, the trade winds blow from the east to the west and warm water 'piles up' on the western side of the Pacific near Australia.   As the water moves away from the equatorial and eastern side of the Pacific, the surface water is replaced by cold, nutrient rich water, a process called **upwelling**. Because it is nutrient rich, upwelled water sustains high levels of phytoplankton and fish productivity. These upwelling systems are most pronounced along the equator and off the coast of Peru.

During an *El Niño* event, the trade winds lessen in strength in the central and western Pacific, allowing the warmer water near Australia to flow back towards the East (Figure 1).   This warmer water has lower amounts of nutrients than the colder upwelling waters.   The arriving nutrient-poor, warm water limits phytoplankton production in the equatorial upwelling system, as phytoplankton growth depends on nutrients. During a strong *El Niño*, the warm water can also reach Peru and can limit the phytoplankton and fishery production there as well, sometimes causing fisheries to collapse in this region.
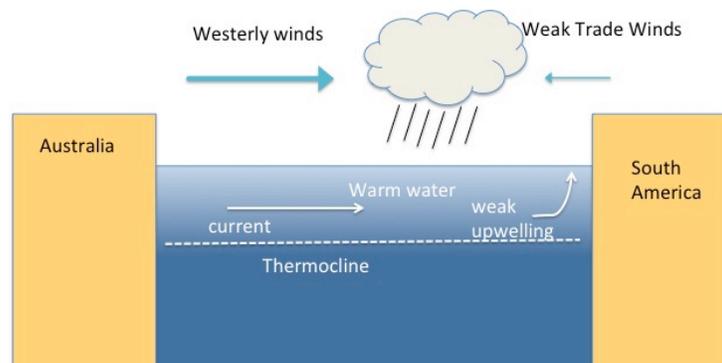

Figure 1. *El Niño* conditions in the Pacific

Student Climate Data. University of New Hampshire. 2015

<u>What is *La Niña*?</u>

La Niña is the below normal cooling of sea surface temperatures in the eastern tropical Pacific Ocean, and has the opposite effects of *El Niño*. *La Niña* means 'The Little Girl'. *La Niña* usually follows an *El Niño* event, but not always. *La Niña* events, like *El Niño* events, will vary year to year.

In *La Niña* conditions (Figure 2), the trade winds blow towards the west across the tropical Pacific. These winds pile up warm surface water in the west Pacific, so that the sea surface is about ½ meter higher at Indonesia than at Ecuador. This brings the return of colder, nutrient-rich deep water surfaced by the Peruvian Upwelling, and higher phytoplankton and fish productivity.
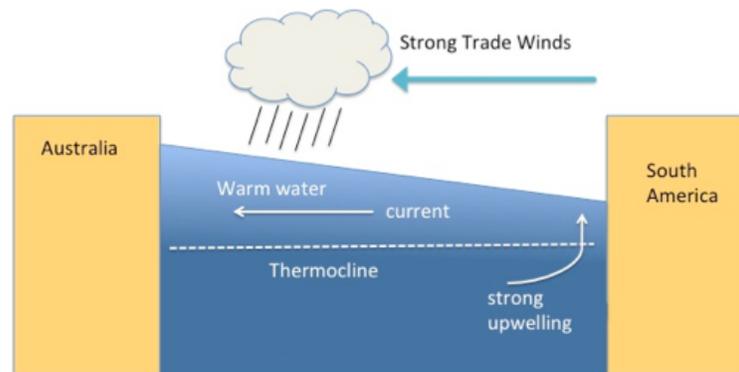

Figure 2. *La Niña* conditions in the Pacific

Global weather effects

  Both El Niño and La Niña events have important consequences for weather around the Earth. Some of the impacts related to *El Niño* are increased rainfall in southern parts of the US and in Peru, and drought in the West Pacific, sometimes associated with devastating brush fires in Australia. The east coast of southern Africa often experiences drought during *El Niño*. La Niña generally causes the opposite effects of El Niño events- droughts in South America and flooding in Australia. Typical *El Niño* effects on the United States include:

- A drier than normal fall and winter in the Pacific Northwest.
- A wetter than normal winter in the Gulf Coast states from Louisiana to Florida.
- A warmer than normal late fall and winter in the northern Great Plains and the upper Midwest.
- Fewer Atlantic Ocean hurricanes.
- An increase in the number of East Coast winter storms.

Detecting *El Niño/La Niña*

To determine if an *El Niño* or *La Niña* event is occurring, scientists use observations of conditions in the tropical Pacific including satellite measurements of sea surface temperature and winds. This module will help you understand the effects of *El Niño* on the ocean and climate, and how to observe it with NASA tools.

Part 1. Questions

Using the Introduction, or other sources, answer the following questions:

1. In your own words, describe what *El Niño* is.

   El Niño is a result of lessening trade winds in the Pacific, which causes warmer water to flow East towards South America.

2. How are *El Niño* sea temperatures and weather conditions different from *La Niña* conditions?

   El Niño and La Niña cause opposite effects. During an El Niño year, warmer water reaches the west coast of South American causing increased rainfall in Peru and parts of the US, as well as drought in the West Pacific. During La Niña, colder weather upwells in South America and there is flooding in Australia and droughts in South America.

3. What effects does *El Niño* have on the United States?

   In the United States, El Niño causes a drier fall in the Northwest, wetter winter in the Gulf Coast, a warmer fall and winder in the Midwest, and more storms in the East Coast.

4. What effects does *El Niño* have on sea life and productivity?

   El Niño decreases productivity off the coast of South America because warmer waters flowing east have lower amounts of nutrients than the colder, upwelling water.

Part 2. How does an El Niño event affect sea surface temperature?

1. From the Student Climate Data website (http://studentclimatedata.unh.edu), click on the 'Ocean Data' tab at the top of the page.
2. Under 'Tools and Data' in the left panel, click 'DICCE Portal' to bring you out to the NASA DICCE data portal.
3. Click on the map, and drag your mouse across the screen to create a box that encompasses the equatorial Pacific.
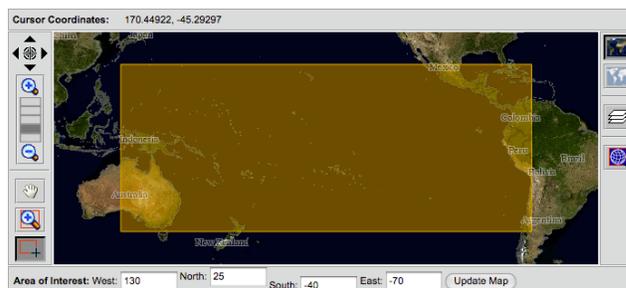
4. Under the '**Physical Ocean**' parameter section, click the box next to 'Sea Surface Temperature.'

> Ocean
> ☐ The Physical Ocean(2002/07/01 - 2012/03/31)
> Parameter
> ☐ Euphotic depth
> ☑ Sea Surface Temperature (11 micron day)

5. In the '**Temporal**' section, set both the Begin and End Date years to '2002' and months to 'Nov.'

> Begin Date Year (2002 ⬍) Month (Nov ⬍)
> End Date Year (2002 ⬍) Month (Nov ⬍)

6. Using the '**Select Visualization**' drop-down menu, select 'Lat-Lon map, Time-averaged.'
7. Click [**Generate Visualization**]
8. Once the map loads, take a few minutes to observe the patterns in sea surface temperature.
9. Observe and **describe** the pattern of sea surface temperature from Australia (left side of the image) to South America (right side of the image) in November 2002.

Sea surface temperature is highest around the equator (> 30°C), stretching from 130E (near Australia) to 160W (eastern Pacific). The sea surface temperature decreases on either side of the equator, and towards South America.

10. Return to the data portal page by clicking the [Home] tab on the top-left of the page.
11. Keep all parameters the same, except in the **Temporal** section, change both of the years to '2008' (leaving the month as 'Nov').
12. Click [**Generate Visualization**]
13. How does sea surface temperature change from South America (right side of the image) to Australia (left side of the image) in November 2008 compared with November 2002?

The overall pattern is similar, however the west to east range of the warmest temperature (> 30°C) is much smaller, only from 130 E to 180 W).

14. Based on your knowledge from the Introduction, which year do you think was an *El Niño* year? How can you tell? *Hint: you can view the previous map by clicking the* [Result #1 ❐ ×] *tab at the top of the screen.*

I think that 2002 was an El Niño year because warmer waters had moved towards the east, causing sea surface temperature to be higher closer to South America.

Part 3. How does an El Niño event affect chlorophyll?

1. Return to the data portal page by clicking the ⬚Home tab on the top-left of the page.
2. Click *off* the Sea Surface Temperature box, and click *on* the box next to 'Chlorophyll a concentration.'

☐ Ocean Biosphere(1997/09/01 - 2014/12/31)		
Parameter	Data Product Info	
☑ Chlorophyll a concentration	SWFMO_CHLO.CR	SeaWiFS
☐ Chlorophyll a concentration	MAMO_CHLO_9km.CR	MODIS-Aqua

3. Repeat the image generation for 2002 and 2008 for chlorophyll.
4. How does the pattern of chlorophyll concentration change from Australia to South America for each year? Based on your knowledge of the effects of *El Niño*, why are you seeing these patterns?

   Chlorophyll concentrations are slightly lower in 2002, especially off the coast of Peru and in the equator. The nutrient- poor, warmer water flowing towards South America during an El Niño year limits phytoplankton productivity, likely causing the patterns seen in the chlorophyll data.

5. Return to the data portal page by clicking ⬚Home.
6. Now, change the map to isolate the equatorial upwelling system by typing the coordinates shown below into the **Area of Interest** section (below the map) and clicking 'Update Map.'

   Area of Interest: West: 145   North: 10   South: -9   East: -120   (Update Map)

7. Set the Begin year to '1997' and End year to '2007.' Using the '**Select Visualization**' drop-down menu, select 'Time Series.'
8. Click (**Generate Visualization**). It may take a few minutes for DICCE to create the graph.
9. What is the dependent variable on this graph (x-axis)? What is the independent variable (y-axis)?

   The dependent variable is the year. The independent variable is chlorophyll concentration (measured in mg/m³).

10. What is the range of chlorophyll concentration in the equatorial upwelling zone?

    The chlorophyll concentration range is 0.08 to 0.18 mg/m³.

11. What happens to chlorophyll concentration during the winter of an *El Niño* event? What is the difference in chlorophyll between a strong *El Niño* and a strong *La Niña* winter? Refer to Table 1 to help identify *La Niña* and *El Niño* years.

Table 1. El Niño and La Niña events. *Bold years are strong El Niño or La Niña events.*

El Niño	La Niña
1997-1998	***1998-1999***
2002-2003	***1999-2000***
2004-2005	2000-2001
2006-2007	2005-2006
2009-2010	***2007-2008***

During the winter of an El Niño event, chlorophyll concentration drops to the lower part of the range.   For example, in the strong El Niño year 1997-1998, chlorophyll concentrations were close to 0.08 mg/m³. In a strong La Niña year (1998-1999), chlorophyll concentrations were close to 0.15 mg/m³. The difference between the two years is 0.07 mg/m³.

Part 4. Final Investigation (work with a partner)
STUDENT RESPONSES WILL DEPEND ON STUDENT DEVELOPED INVESTIGATION
Task: Using your knowledge from the Introduction and your data investigations, use the DICCE Data Portal to determine the year of the most recent *El Niño* event.

Record Investigation Plan. (What variables will you investigate? What visualization tools will you use? How will you tell if it is an *El Niño* year?)

Conduct Investigation. Record observations and data below in text, tables, and/or graphs.

Conclusions.

1. According to your investigation, what was the year of the most recent *El Niño* event?

2. What climate clues might you use to predict when the next *El Niño* will come?

3. If we want to predict how the oceans might respond to climate change in the future, why is it important to understand inter-annual variability in ocean processes, such as *El Niño* events?