DATA Series

Pulse of the Pacific: Tracking ENSO

Lesson Time : 60-90 minutes
Grade Level : 9-12
Vocabulary: El Niño-Southern Oscillation (ENSO), El Niño, La Niña, sea surface temperature (SST), anomaly, Niño 3.4 region, Oceanic Niño Index (ONI), trade winds, upwelling, Southern Oscillation Index (SOI)

Summary
Every few years, conditions in the tropical Pacific Ocean shift dramatically. Sometimes surface waters become unusually warm; at other times, they become unusually cool. These changes are part of the El Niño Southern Oscillation, or ENSO, and they can affect marine ecosystems, fisheries, rainfall, drought, storms, and weather patterns thousands of miles from the tropical Pacific.

In this activity, students will explore more than 70 years of ENSO data to identify El Niño and La Niña events and investigate their frequency, duration, and intensity. Students will graph the Oceanic Niño Index (ONI), compare ocean and atmospheric indicators of ENSO, and use their results to determine whether ENSO really behaves like a predictable cycle.

Objectives

- Describe normal, El Niño, and La Niña conditions in the tropical Pacific Ocean.
- Explain relationship between trade winds, sea surface temperature, and coastal upwelling.
- Define a temperature anomaly and distinguish it from an actual temperature.
- Graph ENSO data over time.
- Use the ONI to identify periods of warmer- and cooler-than-average ocean conditions.
- Compare the duration and intensity of different ENSO events.
- Evaluate whether El Niño and La Niña occur at regular intervals.
- Use data as evidence to explain potential effects of ENSO on marine ecosystems.

Introduction

The Pacific Ocean is enormous, covering nearly one-third of Earth's surface. Changes in its temperature and circulation can therefore have consequences far beyond the Pacific itself.

Under typical conditions near the equator, **trade winds** blow from east to west across the tropical Pacific. These winds push warm surface water toward Indonesia and other parts of the western

Pacific. Near the west coast of South America, surface water moving away from the coast is replaced by colder water rising from below. This process, called **upwelling**, brings cold, nutrient-rich water into the sunlit surface ocean.

Those nutrients support the growth of phytoplankton, which form the base of a highly productive marine food web. As a result, the waters off western South America support important populations of fish, seabirds, and marine mammals, as well as some of the world's largest commercial fisheries. But conditions do not always remain this way.

El Niño

During an **El Niño**, the easterly trade winds weaken. Warm surface water spreads farther east across the equatorial Pacific and sea surface temperatures in the central and eastern Pacific become warmer than average.

As the warm surface layer deepens in the eastern Pacific, less cold, nutrient-rich water reaches the surface. Reduced upwelling can decrease phytoplankton productivity and affect organisms throughout the marine food web.

The effects do not stop at the ocean. Changes in the location of warm water also change where air rises, where rain falls, and how winds move through the atmosphere. These changes can alter weather patterns around the world.

La Niña

During **La Niña**, the normal Pacific pattern becomes stronger. Trade winds are generally stronger than average and push even more warm surface water toward the western Pacific.

Upwelling in the eastern Pacific increases, and sea surface temperatures in the central and eastern tropical Pacific become cooler than average.

Like El Niño, La Niña can change rainfall, temperature, and storm patterns in locations far from the tropical Pacific.

El Niño and La Niña are opposite phases of a larger ocean-atmosphere pattern known as the **El Niño-Southern Oscillation**, or **ENSO**. Between El Niño and La Niña events, conditions are considered **ENSO-neutral**.

ENSO events usually occur every few years, but does that mean they follow a regular cycle?

The data can help us find out.

Measuring ENSO

Scientists monitor temperatures, winds, atmospheric pressure, precipitation, and other conditions throughout the tropical Pacific using satellites, ships, drifting instruments, and ocean buoys.

One important area is the **Niño 3.4 region**, located along the equator in the central tropical Pacific. Scientists compare sea surface temperatures in this region with the long-term average.

The difference between an observed value and an average value is called an **anomaly**.

For example:

- A sea surface temperature anomaly of **+1.2°C** means the water was 1.2°C warmer than average.
- An anomaly of **–0.8°C** means the water was 0.8°C cooler than average.
- An anomaly near **0°C** indicates conditions close to average.

One commonly used historical measurement of ENSO is the **Oceanic Niño Index**, or **ONI**. The ONI uses a running three-month average of sea surface temperature anomalies in the Niño 3.4 region.

Historically, sustained ONI values of approximately **+0.5°C or higher** have been associated with El Niño conditions, while sustained values of **–0.5°C or lower** have been associated with La Niña conditions. Values between these thresholds generally represent ENSO-neutral ocean temperatures.

Scientists also examine the atmosphere before declaring an ENSO event because ENSO is not simply an ocean temperature change, it is a **coupled ocean-atmosphere phenomenon**.

Data Activity

The ENSO dataset contains monthly climate observations beginning in 1950. For the core activity, students will use the following variables:

- Date
- Year
- Three-month season
- Oceanic Niño Index (ONI)
- Niño 3.4 sea surface temperature anomaly
- ENSO phase

Graph the Pacific Pulse

Open the ENSO dataset in Microsoft Excel, Google Sheets, or another spreadsheet program.

Create a line graph showing **ONI over time**.

Place:

- **Date or three-month season** on the X-axis
- **ONI (°C)** on the Y-axis

Give your graph an appropriate title, such as:

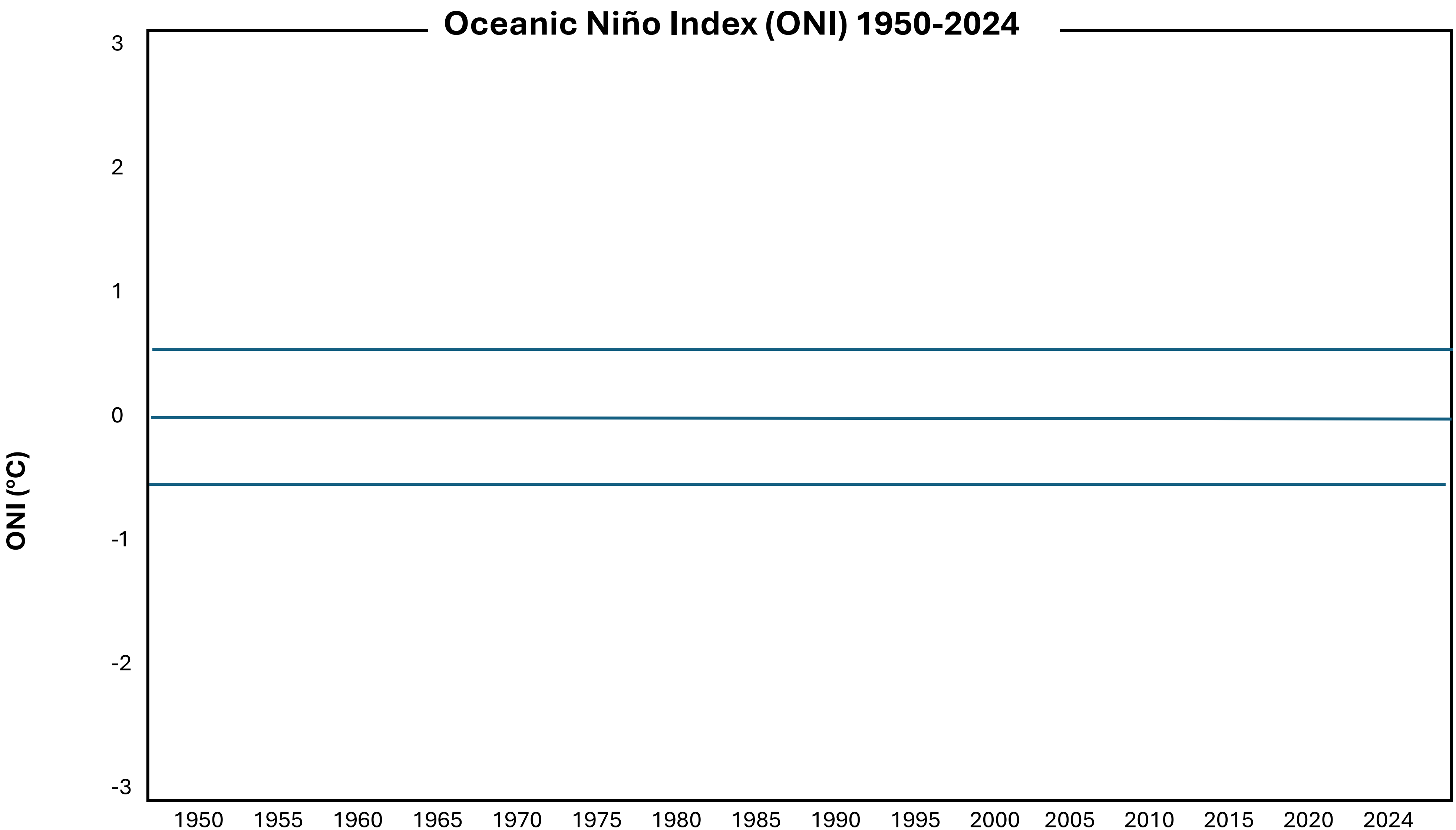
Oceanic Niño Index, 1950–Present

If possible, add horizontal reference lines at: **+0.5°C, 0°C, and –0.5°C**

The +0.5°C and –0.5°C lines will help you identify periods of warmer- and cooler-than-average conditions.

A blank graph is provided on the following page. If you would like your student to practice setting up a graph from scratch, please feel free to have them create their own. After plotting the data, students will use the attached worksheets to analyze their graph and answer questions.

This lesson was written by staff educators at the Bridge Ocean Education Resource Center in collaboration with Virginia Sea Grant. If reusing, presenting, or adapting this lesson please credit the Bridge Ocean Education Resource Center and include the URL below.


Oceanic Niño Index (ONI) 1950-2024
ONI (°C)
3
2
1
0
-1
-2
-3
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2024

Name: ______________________________

Graph the Pacific Pulse & Analyze Your Graph

1. What does an ONI value greater than zero tell you about sea surface temperatures in the Niño 3.4 region?

2. What does a negative ONI value indicate?

3. Find three periods when ONI remained at or above +0.5°C for several consecutive seasons. Record them below.

El Niño Event	Beginning	Ending	Highest ONI

4. Find three periods when ONI remained at or below –0.5°C for several consecutive seasons.

La Niña Event	Beginning	Ending	Lowest ONI

5. Which El Niño event in the dataset reached the highest ONI value?

6. Which La Niña event reached the lowest ONI value?

7. Does the strongest event appear to be the longest? Explain using evidence from your graph.

8. Approximately how many years separate the El Niño events you identified?

9. Is the amount of time between events always the same?

10. Based on your data, would you describe ENSO as:

- perfectly periodic,
- recurring but irregular, or
- completely random?

Explain your choice using evidence from the graph.

Measuring an ENSO Event

Choose **one El Niño event** and **one La Niña event** from your graph.

For each event:

1. Count the number of consecutive three-month periods that meet or exceed the appropriate +0.5°C or –0.5°C threshold.

2. Identify the highest or lowest ONI value during the event.

3. Calculate the mean ONI during the event.

	El Niño	**La Niña**
Event dates		
Number of three-month periods		
Maximum/minimum ONI		
Mean ONI		

Compare the Events

4. Which event lasted longer?

5. Which had the greater peak anomaly?

6. Are **duration** and **intensity** the same thing? Explain.

7. Suppose two El Niño events both lasted 12 months, but one reached an ONI of +0.8°C and the other reached +2.0°C. Would you expect their effects to be identical? Why or why not?

Ocean Conditions & Marine Life

During normal Pacific conditions, upwelling brings cold, nutrient-rich waters from the ocean depths to the surface off the west coast of South America. Use what you have learned about ENSO to complete the following table.

Condition	Trade Winds	Eastern Pacific SST	Upwelling	Expected Nutrient Supply
El Niño				
Neutral				
La Niña				

Then answer the following questions.

4. During which ENSO phase would you expect the weakest coastal upwelling?
5. During which phase might nutrient concentrations near the surface be greatest?
6. Phytoplankton need nutrients and sunlight to grow. Predict what could happen to phytoplankton abundance in the eastern tropical Pacific during a strong El Niño.

7. How could a change in phytoplankton abundance affect:
    - zooplankton?
    - small plankton-eating fish?
    - larger predatory fish?
    - seabirds and marine mammals?

8. Commercial fisheries for species such as anchoveta are extremely important along the west coast of South America. Explain how a change in ocean circulation could eventually affect people and economies on land.