AMERICAN METEOROLOGICAL SOCIETY



Project Ocean

El Niño / Southern Oscillation (ENSO)

TEACHER'S GUIDE

Project Ocean

This guide is one of a series produced by Project Ocean, a U.S. Office of Naval Research-sponsored initiative of the American Meteorological Society (AMS), in recent partnerships with St. Mary's College of Maryland, Washington College, and the United States Naval Academy. Project Ocean is a continuation of past projects focused on creating and training a network of master teachers to provide peer training sessions in pre-college (K-12) physical oceanographic education. To support these teachers in their teacher training, Project Ocean develops and produces course modules and other educational materials.

For further information, and the names of the trained master teachers in your state or region, please contact:

American Meteorological Society
Education Department
45 Beacon Street
Boston, MA 02108
amsedu@ametsoc.org

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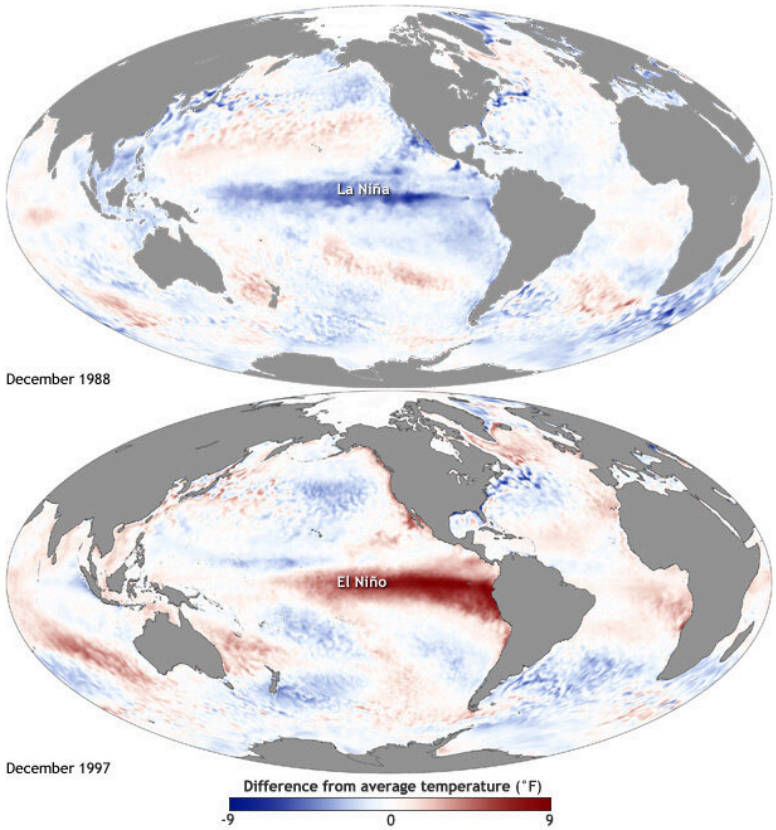


Figure i. SST anomaly maps during a strong La Niña and El Niño. [NOAA]

"ENSO, the warm phase of which we refer to as El Niño and the cold phase La Niña, represents the strongest year-to-year climate fluctuation on the planet. ENSO events significantly disrupt normal patterns of weather variability, affecting agriculture, transportation, resource management, energy production, and the lives of millions of people around the globe. ENSO also affects Pacific marine ecosystems and commercially valuable fish stocks such as tuna and anchovy."

- NOAA Pacific Marine Environmental Laboratory

"In years with El Niño or La Niña conditions, floods, droughts, and other climate-related disasters may be more predictable, allowing decision makers to take action and prepare for such events."

- Columbia Climate School
  International Research Institute for Climate and Society

Module: El Niño / Southern Oscillation (ENSO)
Audience/Grade Level: K-12 Educators

Learning Objectives

After completion of this module participants will be able to:

3. Open Ocean Water Column Structure

- Describe the relationship between temperature, salinity, pressure, and seawater density.
- Describe how vertical changes in ocean salinity and temperature, and thereby density, drive the position of the halocline, thermocline, and pycnocline.
- Analyze how stratification contributes to ocean stability and inhibits mixing.

5. Open Ocean Surface Currents

- Describe how wind transfers momentum to the ocean surface and generates surface currents.
- Explain the Coriolis effect, resulting from the Coriolis force, and describe how it influences the direction of surface water movement in the Northern and Southern Hemispheres.
- Analyze the roles of divergence and convergence in driving upwelling and downwelling.
- Explain how coastal wind patterns influence productivity via upwelling and downwelling.
- Describe equatorial upwelling and its relation to the Coriolis effect and surface current divergence.

9. Shallow-Water Waves

- Describe tidal waves as planetary-scale shallow-water waves and explain the roles of gravity and inertia.

11. The Ocean and Climate Variability

- Define El Niño, La Niña, the Southern Oscillation, and ENSO, explaining their roles as interconnected components of the ocean-atmosphere system in the tropical Pacific.
- Describe the typical duration, frequency, and historical significance of El Niño and La Niña events, including extreme occurrences.
- Explain the long-term average conditions in the tropical Pacific, including the role of trade winds, upwelling, thermocline variations, and their influence on biological productivity and regional climates.

- Identify the contrasting oceanic and atmospheric conditions of the eastern and western tropical Pacific under normal and ENSO-influenced states, and their effects on sea level, precipitation, and weather patterns.
- Evaluate the variability of El Niño and La Niña events, recognizing that no two events are identical and that regional impacts may vary.
- Explore current scientific research questions about El Niño and La Niña, such as their initiation, duration, and variability, as well as efforts to improve prediction accuracy.
- Assess the role of observational tools, including satellite sensors and buoy networks, in tracking oceanic and atmospheric conditions critical for understanding and forecasting El Niño and La Niña events.
- Discuss the societal and economic importance of predicting El Niño and La Niña events, including applications in agriculture, fishing, forestry, energy, water management, and disaster preparedness.
- Understand NOAA resources related to ENSO

Standards

Project Ocean Fundamental Understandings:

Open Ocean Water Column Structure (3.6, 3.10, 3.12-3.14)
Open Ocean Surface Currents (5.3-5.5, 5.5, 5.9-5.16)
Shallow-Water Waves (9.2)
The Ocean and Climate Variability (11.1-11.6)

Applicable Ocean Literacy Principles:

1.C, 3.C, 3.D, 3.E, 3.G, 6.A

Next Generation Science Standards

Performance Expectations

2-ESS1-1. Use information from several sources to provide evidence that Earth events can occur quickly or slowly.
3-ESS2-2. Obtain and combine information to describe climates in different regions of the world.
4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features.
5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.*

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems
ESS2.C: The Roles of Water in Earth's Surface Processes
ESS2.D: Weather and Climate

Crosscutting Concepts

1. Patterns.
2. Cause and effect: Mechanism and explanation.
4. Systems and system models.

5. Energy and matter: Flows, cycles, and conservation.
7. Stability and change.

Science and Engineering Practices

2. Developing and Using Models
4. Analyzing and Interpreting Data
5. Using Mathematics and Computational Thinking
7. Engaging in Argument from Evidence
8. Obtaining, Evaluating, and Communicating Information

Engage | What and where?

Figure 1 shows two maps that do not have any labels or dates to encourage observations and curiosity about what they mean.

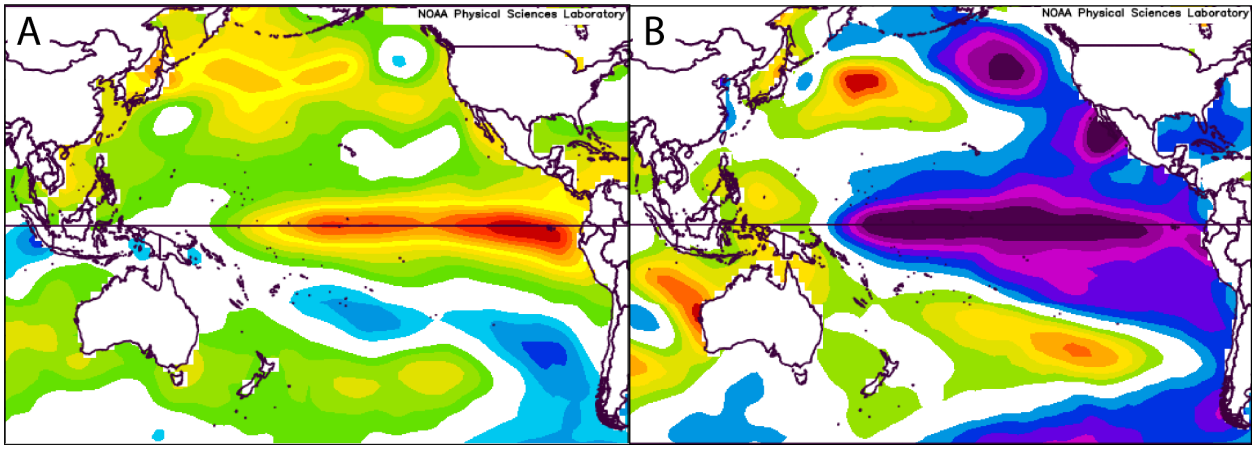


Figure 1. Maps for observation and comparison. [NOAA PSL]

Study the maps and answer the following questions with observations and educated guesses. Come up with as many answers as you can.

1) What area do these maps cover? How can you tell?
2) Make observations about the colors on each map. Then, compare the two.
3) What variable(s) might the colors represent? Why do you think that?

After you have answered the questions, click on these links for the maps with labels and scales.

Map A, Map B

4) What do the colors actually mean? With this knowledge, compare the maps again.
5) How did your educated guesses compare to the correct ones, and what does that tell you about your previous knowledge of the concept?

In this module, we delve into the **El Niño-Southern Oscillation (ENSO)**, a key driver of climate variability and a critical component of ocean-atmosphere interactions.

Read through "What is ENSO in a Nutshell?," then watch the "Understanding El Niño" and "Understanding La Niña" videos.

Group Review and Discussion:

1) *Explain the oceanic and atmospheric components of ENSO.*
2) *What is a teleconnection, and what variables do ENSO teleconnections influence?*
3) *How does El Niño shift the jetstream, and what are the implications for U.S. climate and weather?*
4) *Compare the average duration of El Niño and La Niña events.*

Explore | Identifying ENSO Phases

NOAA's Data in the Classroom provides an investigation of the ENSO phases using real historical data. We will use the Investigating El Niño Online Module to complete the following activity modified from the NOAA lesson plan. Additional resources for the module are at the bottom of the page.

Go to the Online Module and click the "Level 1" tab in the top left. As you work through the lesson in the left panel, answer the questions and use the "Check my Answer" button to check your work. When you are finished with that section, complete the "Level 2" tab to learn about how data from a graph compares to data on a map. Then, click "Level 3" and complete questions 1–3. On Level 3, make sure to click on each question first to bring up a new set of images.

Your Mission: During the summer of 2023, hundreds of California sea lions and dozens of dolphins washed up on the beaches in Southern California, as seen in **Figure 2**.



Figure 2. California sea lions and dolphins washed ashore, showing symptoms of domoic acid poisoning. [NOAA Fisheries]

The rapid growth of the algae *Pseudo-nitzschia*, which produces a neurotoxin called domoic acid, is thought to be responsible. The neurotoxin is ingested by filter feeders and then transferred up the marine food web. This leads to animal strandings, as the toxin is ingested by seabirds and marine mammals, such as sea lions and dolphins, when they eat affected prey. Among other factors, harmful algal blooms occur more often and are larger when there are more nutrients due to upwelling, but there is a lag between the algal bloom and seeing the effects as it takes several months for the toxin to spread up the marine food chain.

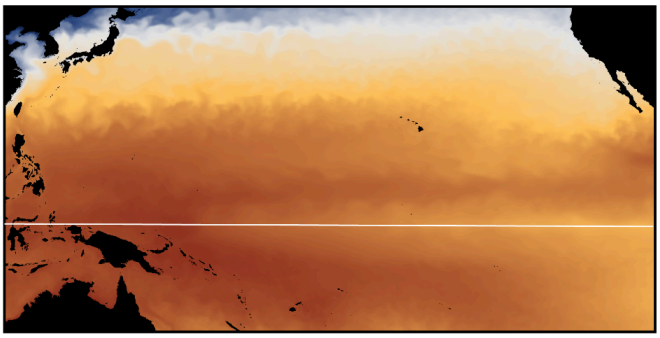
1) Based on the information above, write a Hypothesis about which ENSO phase was most likely and when.
2) What data would you need to determine which ENSO phase occurring during the fall/winter 2022-2023 could have caused this event? Make a list below of the specific temperature data you might need to answer the question. Include the date and whether you would use a map or graph.
3) Then, click on the "Get Data" tab in the Investigation El Niño Online Module and follow the directions to obtain the data you decided was necessary, or use the data in **Figure 3** to construct your explanation. (Downloaded maps take a few minutes to download and require refreshing the page between each one.)
4) Use the Claim-Evidence-Reasoning model to explain your findings What ENSO phase occurred several months before the stranding event in June 2023?
   From NOAA:
   Claim: Record a simple statement that answers your question.
   Evidence: Include specific data from the data maps, graphs or charts you have analyzed.
   Reasoning: Connect the evidence to your claim.
5) Write a conclusion based on your evidence and reasoning.
6) Expand on your conclusion by collecting the data and predicting the likelihood of another stranding event in summer 2024.

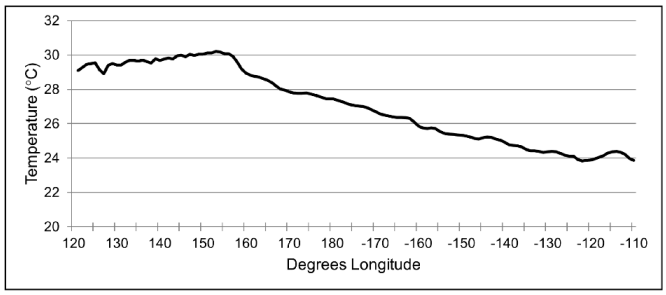
Reference Data

Sea Surface Temperature in the Equatorial Pacific

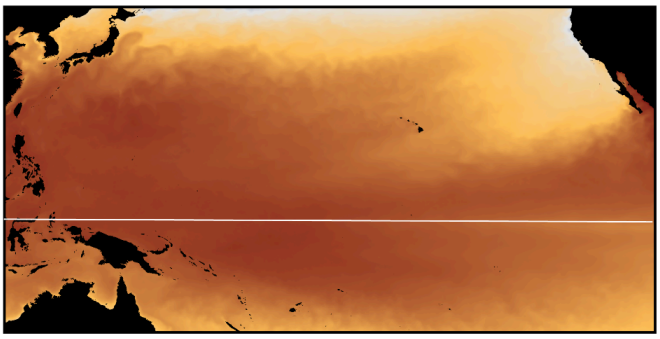
Sea Surface Temperature at the Equator

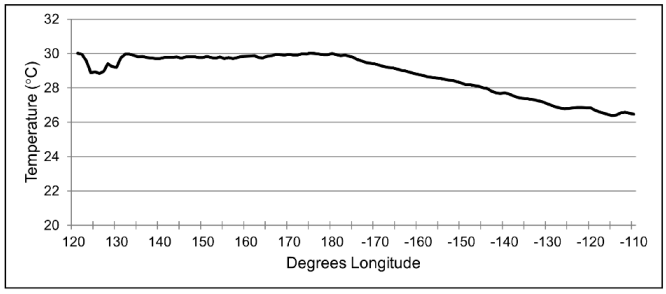
January 2023



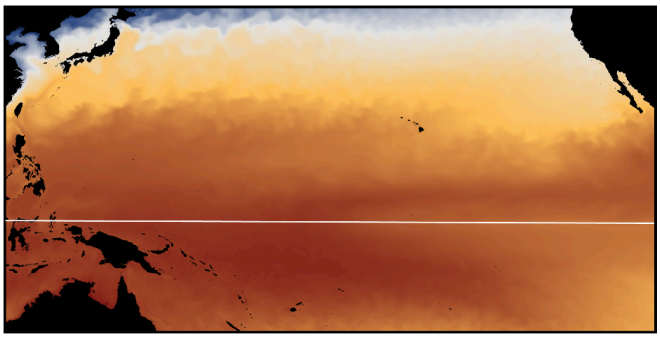


July 2023





January 2024



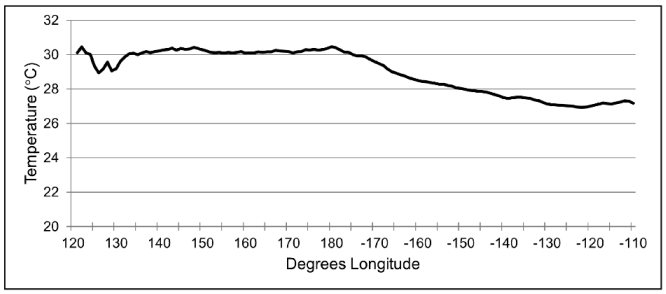


Figure 3. Reference maps and graph data for the above investigation into ENSO phase, upwelling, and potential of a harmful algal bloom. [NOAA El Niño Online Module]

Group Review and Discussion:

1) *Explain the process that led you to your conclusion.*
2) *What additional data would you like to have to explore this problem further?*

Explain | ENSO in Perspective

Background: El Niño: The Atmosphere-Ocean Connection

The term *El Niño* or *El Niño de Navidad* originally described a weak warming of ocean water that flows southward along the coast of Peru and Ecuador around Christmas Time each year, resulting in poor fishing. Today, **El Niño** refers to a large-scale disturbance of the ocean and atmosphere in the tropical Pacific. A persistent El Niño shifts planetary-scale atmospheric and oceanic circulations, leading to weather extremes and significant ecological, social, and economic disruptions worldwide.

Under **ENSO neutral** or **normal conditions**, westward-blowing trade winds drive warm surface water away from the west coast of South America, pushing it toward the western tropical Pacific. This accumulation of warm water in the west leads to lower air pressure, rising air, and abundant rainfall, as illustrated in **Figure 4**. In contrast, the eastern tropical Pacific experiences upwelling, where cold water from below rises to replace the displaced warm surface water. This *upwelling* not only creates cooler surface temperatures, fostering high air pressure and minimal precipitation but also brings nutrient-rich water to the surface, fueling phytoplankton growth and sustaining productive fisheries.

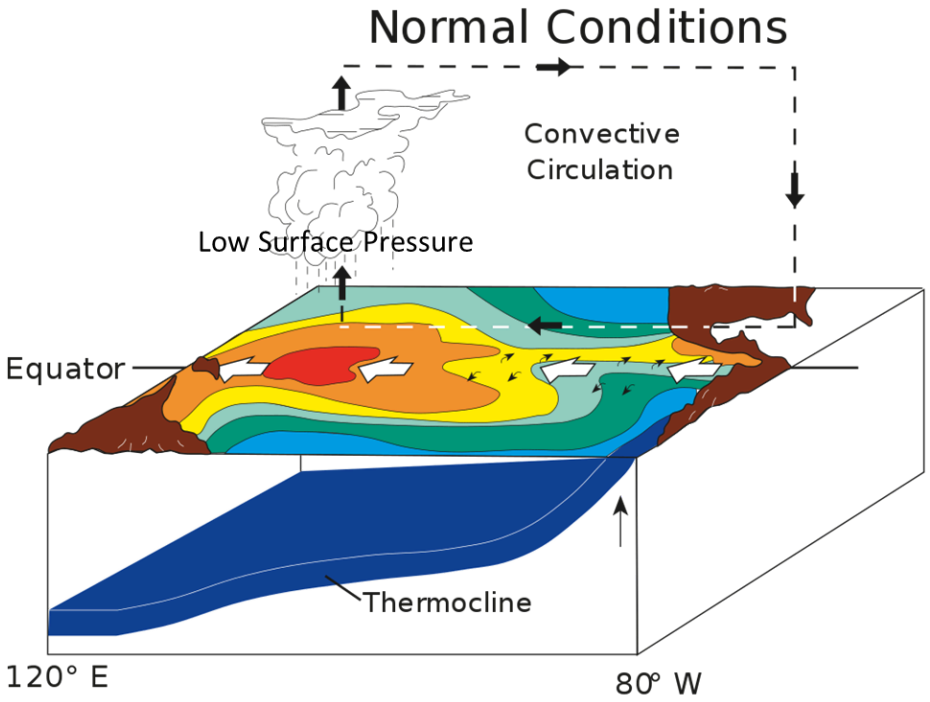


Figure 4. Normal Pacific circulation pattern with atmospheric circulation, sea surface temperatures, and the thermocline. [Adapted from NOAA/PMEL/TAO, Public Domain]

The first sign of an El Niño occurs in the atmosphere with a weakening of the trade winds. Under normal conditions, the contrast between relatively high air pressure over the eastern tropical Pacific and low air pressure over the western tropical Pacific drives the trade winds. With the onset of El Niño, air pressure falls over the eastern tropical Pacific and rises in the west, with the steepest pressure drop occurring over the central Pacific. As the air pressure gradient across the tropical Pacific weakens, the trade winds slacken and may even reverse in the west. These changes disrupt tropical weather patterns and, in turn, shift planetary-scale winds, including jet streams. The altered jet streams steer storms and air masses at higher latitudes, leading to weather extremes in many areas beyond the tropics. This oscillation in air pressure between the western and central tropical Pacific is known as the Southern Oscillation.

During El Niño, changes in atmospheric circulation over the tropical Pacific are accompanied by shifts in ocean currents and sea surface temperature (SST) patterns. The weakening or reversal of the trade winds causes the pool of warm surface water in this region to drift eastward along the equator toward the coast of South America. This west-to-east movement of warm water occurs during the downwelling phase of an equatorial **Kelvin wave**, a planetary-scale oscillation with a wavelength spanning much of the Pacific Ocean that drives changes in sea level, which in turn affect SSTs and thermocline depth. During the downwelling phase of an Equatorial Kelvin wave, the **thermocline**—the transition zone between the warm surface layer and the cold deep water—sinks in the east, greatly weakening or even halting cold-water upwelling along the west coast of South America, sharply reducing biological productivity. The downwelling phase is usually followed by an upwelling phase in which the thermocline and cold water rise toward the surface. The Kelvin wave takes approximately 2–3 months to cross the Pacific Ocean basin. Together, the SST changes of El Niño and the air pressure variations known as the Southern Oscillation are abbreviated as ENSO. The typical characteristics of the El Niño phase are shown in **Figure 5**.

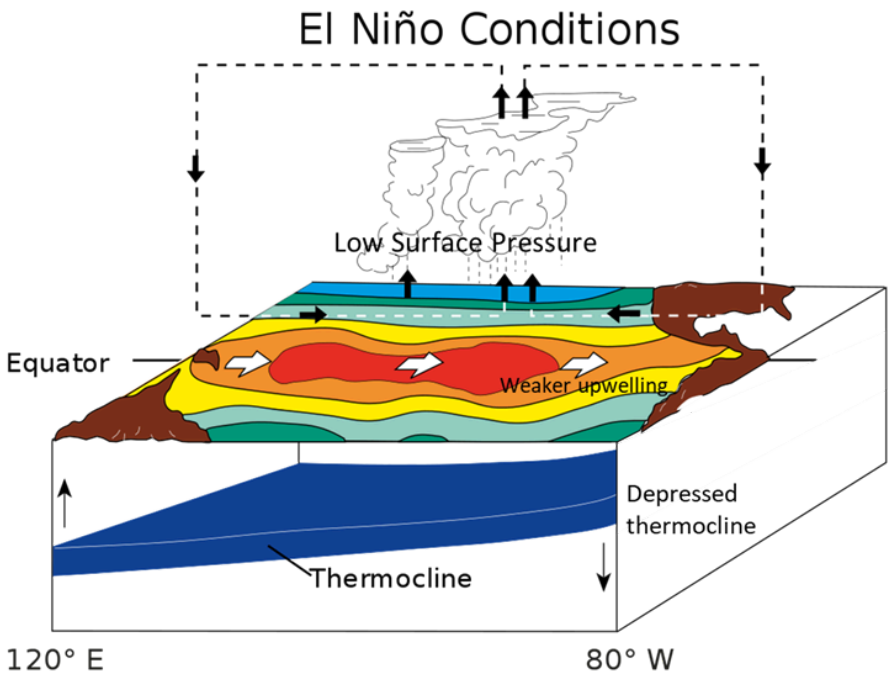


Figure 5. El Niño circulation pattern with atmospheric circulation, sea surface temperatures, and the thermocline. [Adapted from NOAA/PMEL/TAO diagrams, Public Domain]

Sometimes, but not always, El Niño alternates with **La Niña** with conditions essentially opposite of El Niño. During La Niña, unusually strong trade winds carry more warm water to the western basin, causing higher than average SSTs. Conversely, SSTs are colder than usual over the central and eastern tropical Pacific. The characteristics of a La Niña phase are shown in **Figure 6**.

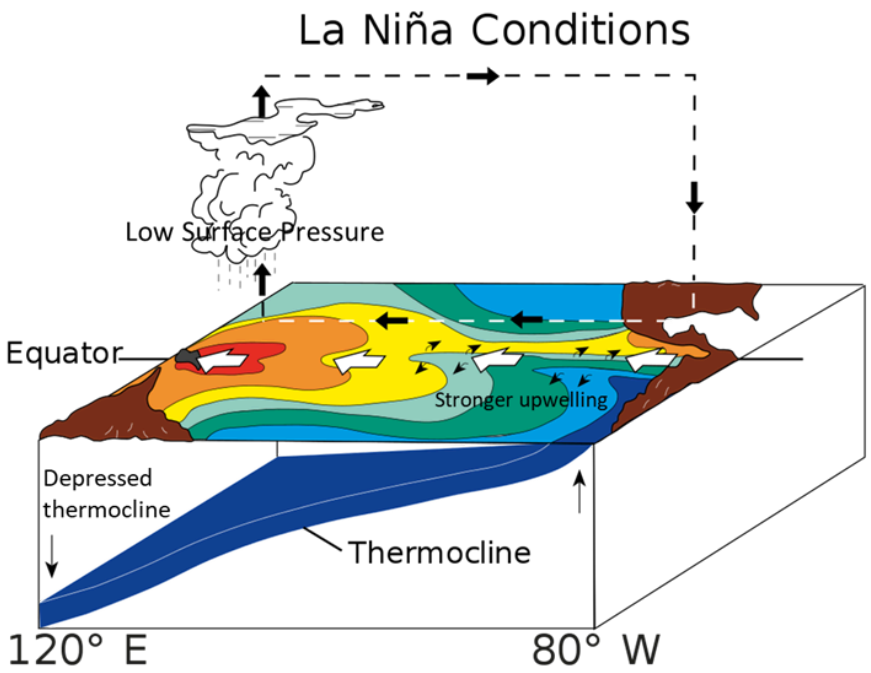


Figure 6. La Niña circulation pattern with atmospheric circulation, sea surface temperatures, and the thermocline. [Adapted from NOAA/PMEL/TAO diagrams, Public Domain]

Table 1 compares the conditions in the eastern Pacific during El Niño and La Niña with those under normal conditions.

Table 1: Conditions in the Eastern Pacific

Phase	Trade Winds	Atmospheric Surface Pressure	SSTs	Thermocline	Biological Productivity	Coastal Upwelling
El Niño	weaker	lower	higher	deeper	lower	reduced
La Niña	stronger	higher	lower	shallower	higher	increased

El Niño lasts an average of 9 to 12 months and occurs about once every 2 to 7 years. 12 events have occurred over the past 42 years (1982–2024), with three of the most intense (“very strong”) events happening in 1982–83, 1997–98, and 2015–16, followed by a “strong” event in 2023–24. La Niña typically lasts for a time frame similar to El Niño, though some episodes can persist for up to two years. Over the past 42 years (1982–2024), 14 La Niña events have been recorded, including “strong” events in 1988–89, 1998–2000, 2007–08, and 2010–11. Much of the period from late 2020 to 2022 also experienced La Niña conditions.

Global El Niño and La Niña Conditions

Changes in oceanic and atmospheric circulation in the tropical Pacific influence global weather and climate, often causing extremes like droughts or heavy rainfall in regions beyond the tropics. These regional effects, known as **teleconnections**, can alter temperature or precipitation patterns. **Figures 7 and 8** illustrate typical seasonal El Niño and La Niña teleconnections. However, no two events are identical, and weather extremes may not always accompany a particular El Niño or La Niña.

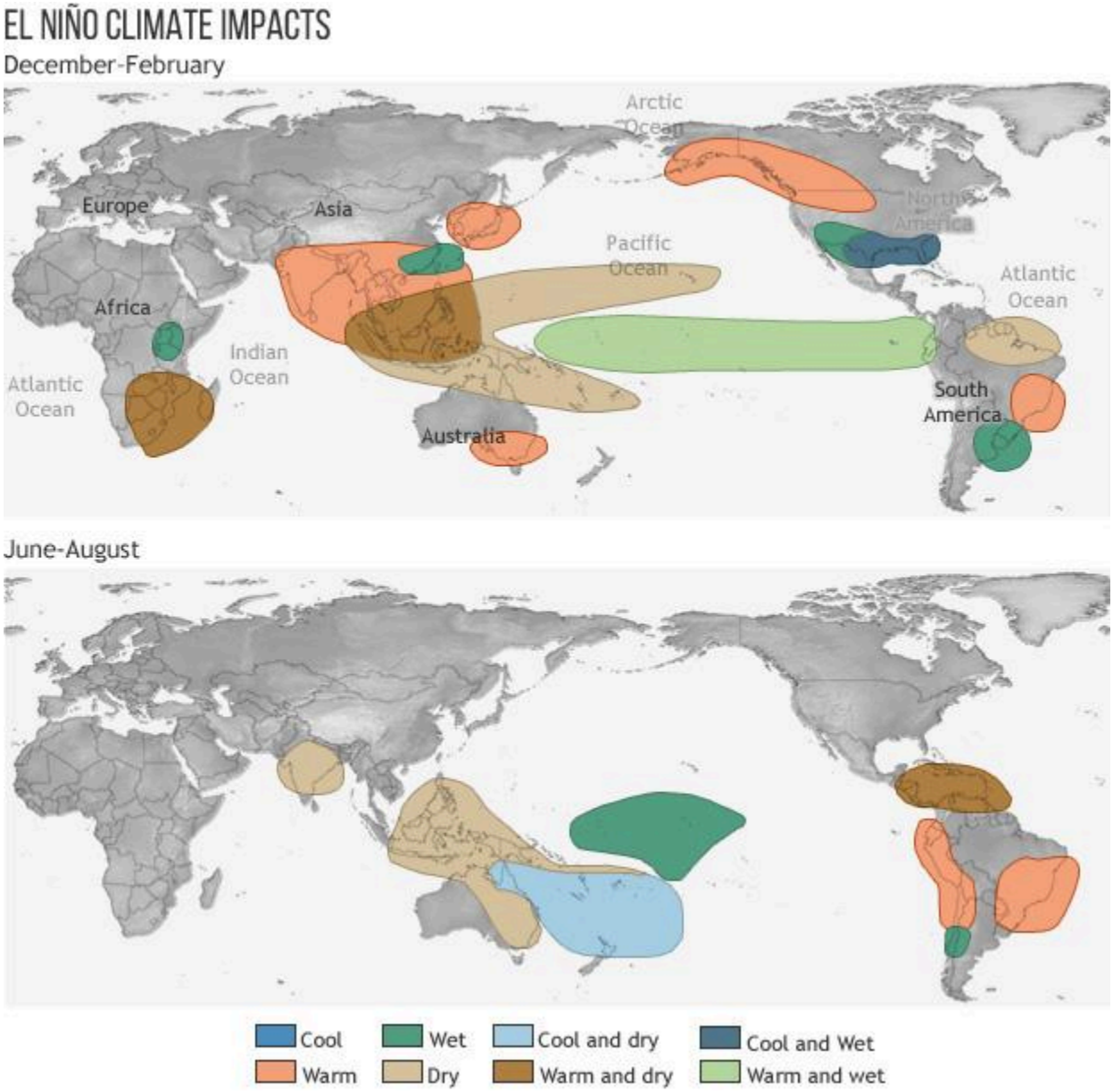


Figure 7. Typical El Niño teleconnections in the winter (DEC-FEB) and summer (JUN-AUG). [NOAA Climate.gov]

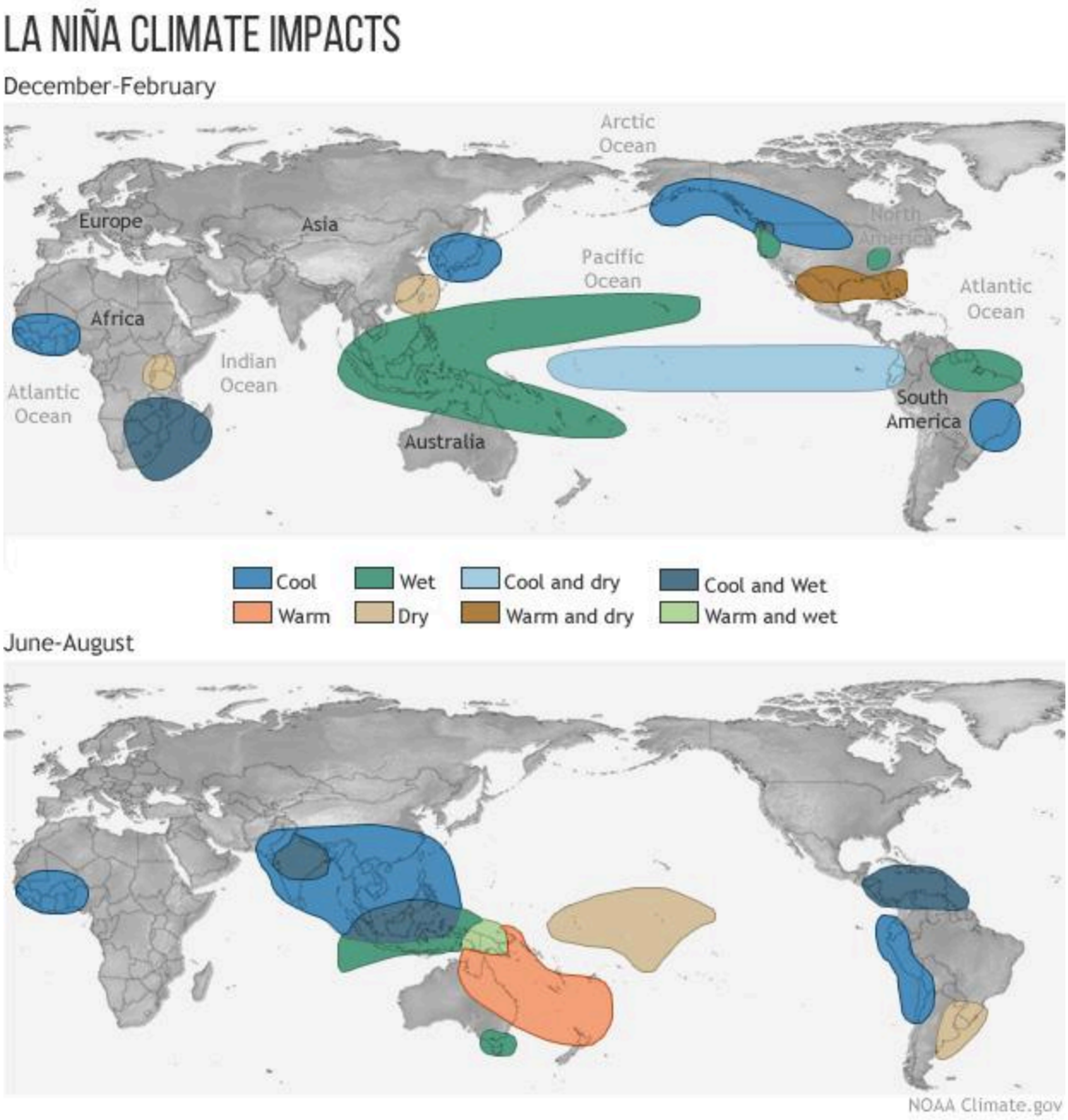


Figure 8. Typical La Niña teleconnections in the winter (DEC-FEB) and summer (JUN-AUG). [NOAA Climate.gov]

Warm water evaporates more readily than cool water, so the motion of warm water in the tropical Pacific alters precipitation patterns. Regions with relatively warm surface waters contribute heat and moisture to the atmosphere, promoting the development of thunderstorms that play a key role in shaping planetary-scale atmospheric circulation, altering the paths of jet streams and moisture transport at higher latitudes.

In the United States, El Niño winters are typically wetter across the southern states and drier than usual in the Pacific Northwest and Midwest. These conditions are reversed during La Niña winters, which bring drier weather to the southern states and wetter conditions to the Pacific Northwest and Midwest. Additionally, the Atlantic hurricane season tends to be more active and hurricanes more destructive during La Niña, as the cooler Pacific waters shift atmospheric circulation patterns, leading to reduced vertical wind shear over the Atlantic Ocean and more favorable conditions for storm formation and intensification. Conversely, during El Niño, increased wind shear typically suppresses hurricane activity in the Atlantic.

Group Review and Discussion:

1) *The impacts of ENSO in the tropical Pacific are relatively well understood. Select a different region of the world and describe its typical weather patterns during El Niño and La Niña years.*
2) *ENSO influences precipitation, temperature, or both. How might this oscillation affect either or both in your local area, and why?*

Ecological, Social, and Environmental Impacts of ENSO

Many aspects of the environment and global economy are impacted by variations in the ocean/atmosphere system of the tropical Pacific. These impacts also have human and social consequences.

Too little or too much precipitation can have devastating effects. In some areas, drought, especially when accompanied by high temperatures, causes crops to wither and die, reduces the public water supply, and increases the likelihood of wildfire. In other areas, exceptionally heavy rains trigger flash flooding that drowns crops, washes away motor vehicles, destroys houses and other buildings, and disrupts public utilities.

Temperature and precipitation extremes associated with El Niño often cause global-scale disruptions in food production. Sea surface temperature anomalies during the El Niño phase in the tropical Pacific have been correlated with corn, rice, soybean, and wheat crop yield anomalies worldwide. Significant crop failures occurred during the strong El Niño in 1983.

El Niño conditions–as well as those associated with La Nina–can significantly affect coffee production in countries across the Pacific Basin by altering regional weather patterns. Depending on the area, excessive rainfall or drought may disrupt the flowering and maturation cycles of coffee plants, impacting soil health and tree vitality. During El Niño, for example, countries like Indonesia and Vietnam in the western Pacific often

face an increased risk of drought during critical growth periods, which can stress plants and reduce yields. In contrast, coastal countries in the eastern Pacific, such as Colombia, Ecuador, and Peru, are more likely to experience excessive rainfall, which can lead to flooding and increased fungal diseases. Meanwhile, eastern regions of South America, including Brazil, typically experience drier-than-normal conditions during El Niño events, potentially hindering flowering and fruit set.

Weather extremes associated with El Niño and La Niña have implications for public health by creating conditions that increase the incidence of diseases such as malaria, dengue fever, encephalitis, cholera, and plague. Also, smoke from wildfires in drought-stricken regions can cause respiratory problems for people living up to thousands of miles from the fires.

Advance warning of El Niño and La Niña and their accompanying weather extremes can save lives and billions of dollars in property and crop damage by allowing adequate time for preparation and appropriate responses. Measurements of ocean conditions from an array of moored buoys in the equatorial Pacific and from satellite-borne sensors enable oceanographers to observe, model, and forecast conditions that lead to El Niño and La Niña.

For further information on the global impacts of ENSO, see this summary by the International Research Institute for Climate and Society at Columbia University.

Group Review and Discussion:

1) *How could El Niño's impact on coffee production in the Pacific Basin influence global supply chains, pricing, and the livelihoods of coffee farmers?*
2) *Where might the likelihood of malaria increase in a summer during El Niño? What about La Niña?*
3) *What areas of the U.S. are more prone to wildfires during El Niño? What about La Niña?*

El Niño and La Niña Research

1. Scientists are actively investigating the ocean/atmosphere system in the tropical Pacific for answers to many questions including: What gets El Niño and La Niña started? Why do they stop? Why do regional impacts differ from one El Niño (or La Niña) to the next? When will scientists be able to reliably predict the duration and regional impacts of El Niño and La Niña?

2. Observations of tropical Pacific conditions are essential for the investigation and prediction of short-term climate variations like El Niño and La Niña. A wide variety of sensors collect ocean and atmospheric data from this vast and remote region of the ocean.

3. Satellite-borne temperature sensors and altimeters track the movement of warm surface water across the tropical Pacific. Complementing these are data from a network of buoys that directly measure temperature, currents, and surface winds along the equator.

4. Accurately predicting the onset and duration of El Niño and La Niña is vital for helping water, energy, and transportation managers, as well as farmers, to plan for, mitigate, or avoid potential losses.

5. Advances in El Niño and La Niña prediction are expected to greatly enhance economic opportunities—particularly in the agriculture, fishing, forestry, and energy sectors—while also providing significant societal benefits

Elaborate | Identifying El Niño and La Nina Episodes

NOAA has used the Oceanic Niño Index (ONI) to identify El Niño and La Niña episodes since 1950. The ONI is calculated from the 3-month running average of sea surface temperature (SST) anomalies in the Niño 3.4 region of the tropical Pacific Ocean, bounded by 5°N to 5°S latitude and 120°W to 170°W longitude. **Figure 9** illustrates the critical regions in the Pacific that may be used to classify the ENSO phase. ONI values are calculated relative to the most recent 30-year base period, which shifts every 5 years.

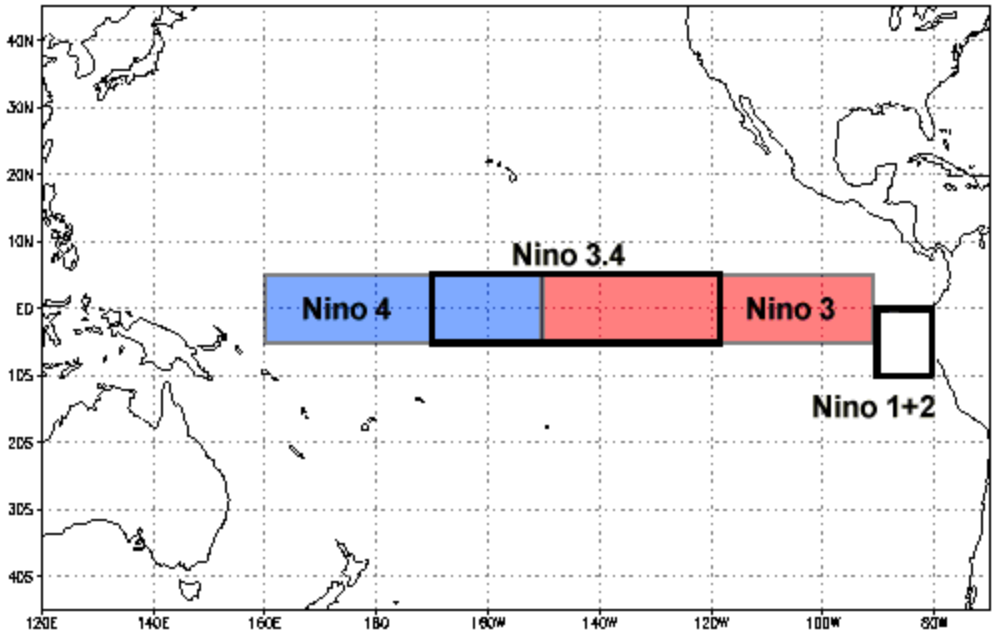


Figure 9. Location of various Niño index regions, including Niño 3.4 used for the Oceanic Niño Index. [NOAA]

ENSO Phase definitions

- **El Niño (Warm Phase):** Characterized by a sea surface temperature (SST) anomaly in the Niño 3.4 region that is +0.5°C or greater that has persisted or is expected to persist for several consecutive overlapping three-month periods and evidence of a weaker-than-average Walker circulation.
- **La Niña (Cold Phase):** Characterized by an SST anomaly in the Niño 3.4 region of -0.5°C or less that has persisted or is expected to persist for several consecutive overlapping three-month periods and evidence of a stronger-than-average Walker circulation.
- **Neutral Conditions:** Defined as SST anomalies in the Niño 3.4 region that remain between -0.5°C and +0.5°C, without meeting the thresholds for El Niño or La Niña over a prolonged period.

Note: For operational purposes, El Niño or La Niña conditions can be declared based on one month of the Niño-3.4 SST anomaly meeting or exceeding the threshold if there is an expectation that the anomaly will persist for several more months. In contrast, five overlapping three-month periods are used to fully characterize an ENSO event in a retrospective analysis. While these are the thresholds for each phase, the strength of each El Niño or La Niña is classified by the peak magnitude of the Niño-3.4 anomaly. These definitions, which are unofficial, are as follows: weak (±0.50–1°C), moderate (±1–1.5°C), strong (±1.5–2°C), or very strong (<2°C).

While the ONI is the primary index for classifying ENSO episodes and NOAA's official metric, additional indices are used to account for other atmosphere-ocean variations, providing a more comprehensive picture of ENSO conditions. Evidence of atmospheric conditions is required for the declaration of the onset of El Niño or La Niña conditions.

The NOAA Climate Prediction Center's ENSO Alert System updates the current ENSO status and outlook monthly. An El Niño or La Niña *Watch* is issued when conditions in the equatorial Pacific suggest their development is likely within the next six months. An *Advisory* is issued when El Niño or La Niña conditions have developed or are highly likely to develop and are expected to persist. To issue an Advisory, the following three criteria must be met: (1) The one-month Niño 3.4 SST value exceeds the ±0.5°C threshold; (2) there is an expectation that El Niño or La Niña will continue for consecutive upcoming seasons, and (3) an atmospheric circulation pattern over the tropical Pacific Ocean exhibits one or more of the changes commonly associated with either El Niño or La Niña, particularly in the trade winds, which are weaker than usual during El Niño and stronger during La Niña.

The difference between using one-month SST anomalies for issuance of an Advisory or five overlapping three-month average periods for retrospective analysis depends on the context and purpose of their usage.

Figure 10 shows a graph of ONI data from 1990–2024. NOAA also provides a detailed table of the running 3-month ONI values.

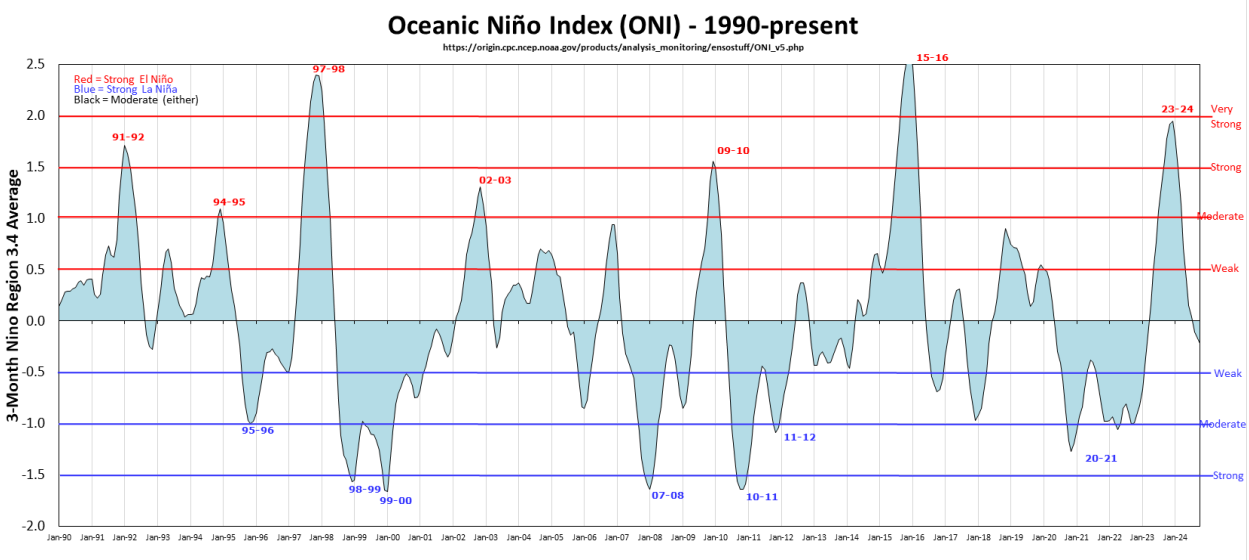


Figure 10. Oceanic Niño Index (ONI) for 1990–2024. [Graph from GGWeather, data from NOAA CPC]

1. What is the SST anomaly criteria for a Strong El Niño episode?
   a. –1.5°C
   b. –1.0°C
   c. +1.0°C
   d. +1.5°C

2. During the 2023-24 El Niño, the peak SST anomaly in the Niño 3.4 region was
   a. –1.1°C
   b. +0.7°C
   c. +1.9°C
   d. +2.5°C

3. The last “Strong” La Niña occurred during the _____ winter.
   a. 2020–21
   b. 2017–18
   c. 2010–11
   d. 2007–08

Forecasters obtain tropical Pacific Ocean SSTs from satellite-based observations and a network of buoys. The tropical Pacific Ocean is monitored continuously via about 70 anchored buoys in the TAO/TRITON Tropical Moored Buoy Array supported by the U.S. and Japan. **Figure 11** displays the SST and wind anomalies across the tropical Pacific in June and July 2010. A dashed blue rectangle marks the Niño 3.4 region.

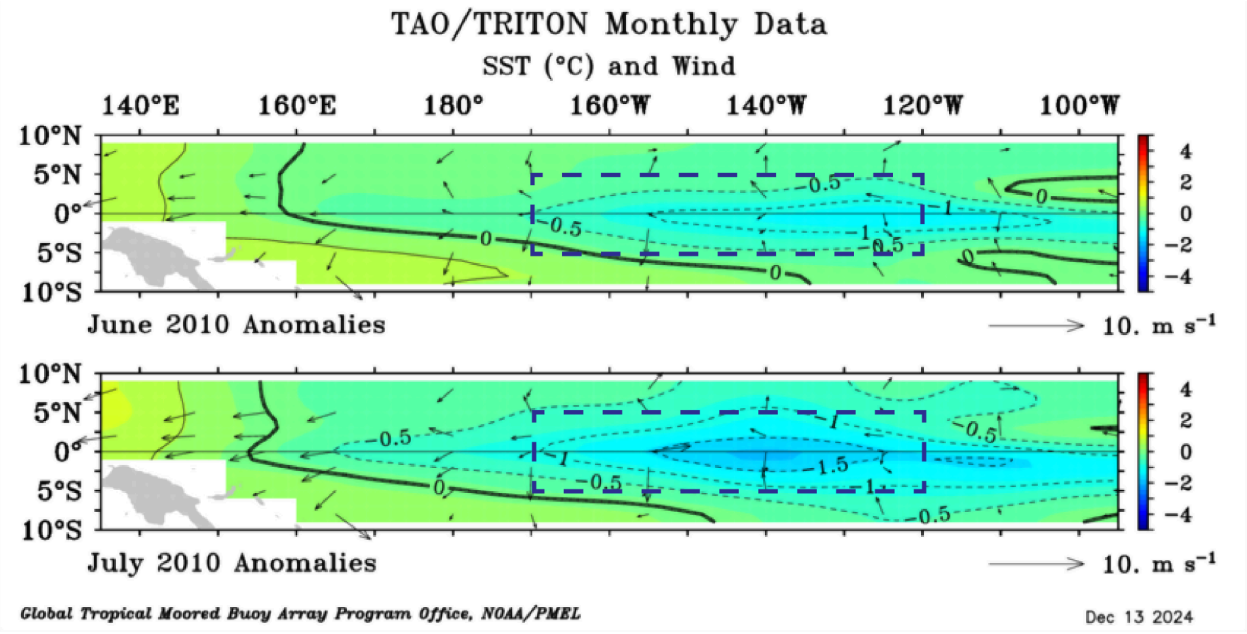


Figure 11. SST anomalies in June and July 2010. [TAO/PMEL/NOAA]

4. Compare the top and bottom panels in Figure 11. In the month from June to July 2010, what happened to the maximum SST anomalies in the Niño 3.4 region?
   a. They decreased by about 0.5°C
   b. They showed little variation
   c. They increased by about 0.5°C

5. A La Niña Watch was issued in June, and forecasters expected current trends to continue. What pattern of the trade winds is revealed by the anomalies in the wind vectors near 170°W?
   a. The wind was blowing stronger toward the west than usual, showing a strengthening of the trade winds
   b. The wind was consistent with the average, so no wind vector anomaly arrows are seen
   c. The wind was blowing stronger toward the east than usual, showing a weakening of the trade winds

6. Given the persistence of the wind anomalies from June into July 2010 and the change in the SST anomalies, which type of ENSO alert would you expect was issued in July 2010?
   a. El Niño Watch
   b. El Niño Advisory
   c. La Niña Watch
   d. La Niña Advisory

Figure 12 displays the SST and wind anomalies across the tropical Pacific in August and September 2023. A dashed blue rectangle marks the Niño 3.4 region.

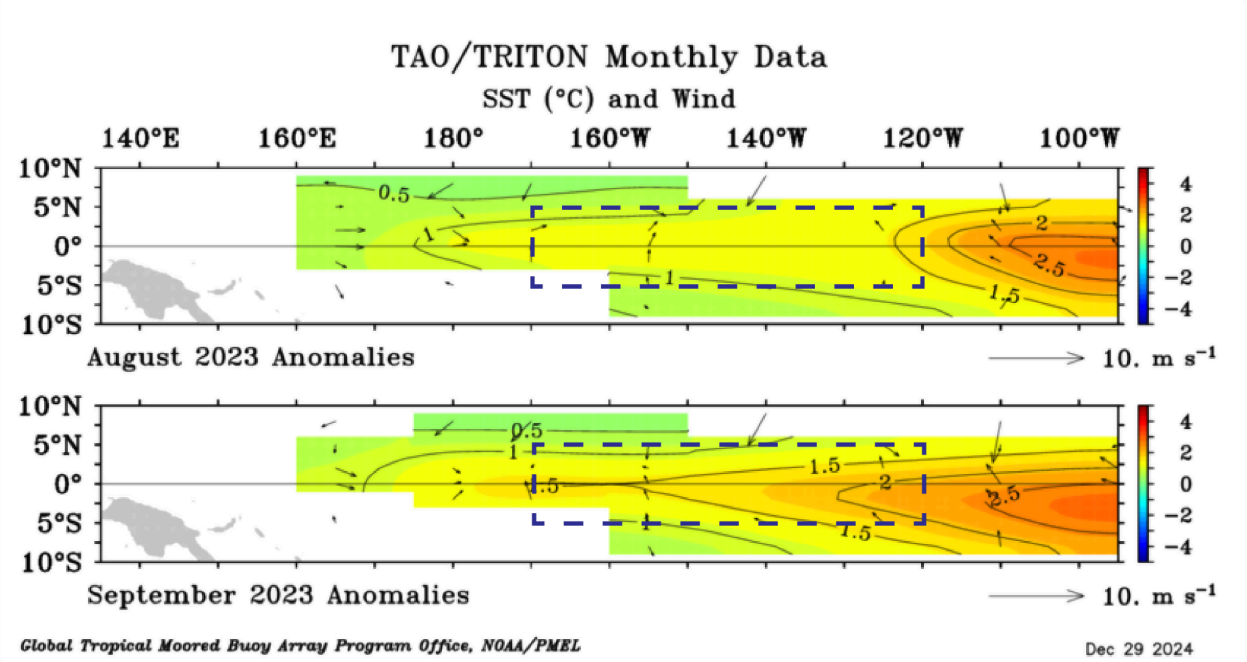


Figure 12. Means and anomalies of SSTs and surface winds for AUG and SEP 2023. [TAO/PMEL/NOAA]

7. Examine the SST anomalies in the top panel in Figure 12. In August 2023, they were about _____ over nearly all of the Niño 3.4 region.
   a. –1.0°C
   b. –0.5°C
   c. +0.5°C
   d. +1.0°C

8. Compare the top and bottom panels in Figure 12. In the month from August to September 2023, what happened to the SST anomalies in the Niño 3.4 region?
   a. They decreased by about 0.5°C
   b. They showed little variation
   c. They increased by about 0.5°C

9. What pattern of the trade winds is revealed by the anomalies in the wind vectors near 170°W in the top and bottom panels?
   a. The wind was blowing stronger toward the west than usual, showing a strengthening of the trade winds
   b. The wind was consistent with the average, so no wind vector anomaly arrows are seen
   c. The wind was blowing stronger toward the east than usual, showing a weakening of the trade winds

10. Given this SST anomaly and wind anomaly data, which type of ENSO alert would you expect to be in place for August and September 2023?
    a. El Niño Watch
    b. El Niño Advisory
    c. La Niña Watch
    d. La Niña Advisory

Evaluate | ENSO

11. Under normal conditions in the equatorial Pacific, the trade winds tend to push warm surface waters _____.
    a. eastward, toward the coast of South America
    b. westward, away from the coast of South America
    c. northward, away from the equator
    d. southward, toward the equator

12. Under normal conditions in the equatorial Pacific, surface waters are warmest, and sea level is highest in the _____.
    a. Western Pacific
    b. Eastern Pacific
    c. Central Pacific

13. Under normal conditions in the equatorial Pacific, the thermocline is shallowest, and coastal upwelling is more productive in the _____.
    a. Western Pacific
    b. Eastern Pacific
    c. Central Pacific

14. Under normal conditions in the equatorial Pacific, surface air pressure is lower, and rainfall is heavier in the _____.
    a. Western and Central Pacific
    b. Eastern Pacific

15. In the eastern equatorial Pacific, during _____ conditions, the trade winds are weaker than normal, sea surface temperatures are higher, the thermocline is deeper, biological productivity associated with coastal upwelling is reduced, and atmospheric surface pressure is lower.
    a. El Niño
    b. La Niña

16. In the eastern equatorial Pacific, during _____ conditions, the trade winds are stronger than normal, sea surface temperatures are lower, the thermocline is shallower, biological productivity associated with coastal upwelling is increased, and atmospheric surface pressure is higher.
    a. El Niño
    b. La Niña

17. During La Niña conditions, the southern states in the U.S. are _____ than normal in the winter, and Australia and Indonesia are _____ than normal.
    a. drier … wetter
    b. drier … wetter
    c. wetter … drier
    d. wetter … wetter

18. During La Niña conditions, the Atlantic hurricane season is _____ active.
    a. less
    b. more

19. Winter rainfall is likely to be heavier than normal in southern California during
    a. El Niño conditions
    b. La Niña conditions
    c. ENSO neutral conditions

Extension | El Niño La Niña Slide Chart

1. Examine ENSO Long-Term Average (normal) conditions and those of ENSO phases if you have the Slide Chart received from the Project Ocean course. How can you use this to help students and/or your colleagues better understand this phenomenon?

Additional Resources

General Information

NOAA Climate Prediction Center FAQs:
https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/prelude_to_ensofaq.shtml

NOAA Climate Prediction Center ENSO Page:
https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml

NOAA Climate.gov ENSO Page and ENSO blog:

https://www.climate.gov/enso
https://www.climate.gov/news-features/blogs/enso

International Research Institute for Climate and Society (IRI), Columbia Climate School, ENSO Essentials: IRI – International Research Institute for Climate and Society | ENSO Essentials (columbia.edu)

NOAA Pacific Marine Environmental Lab El Niño Theme Page:
https://www.pmel.noaa.gov/elnino/

NASA JPL ENSO Overview:
https://sealevel.jpl.nasa.gov/data/el-nino-la-nina-watch-and-pdo/overview/

Climate Impacts of ENSO

NOAA Climate Prediction Center
El Nino Impacts:
https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/impacts/warm_impacts.shtml

La Nina Impacts:
https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/cold_impacts.shtml

International Research Institute for Climate and Society (IRI), Columbia Climate School:
https://iri.columbia.edu/our-expertise/climate/enso/why-do-we-care-about-el-nino-and-la-nina/

Educational Resources

NOAA Educational Resources including videos:
https://www.noaa.gov/education/resource-collections/weather-atmosphere/el-nino

NOAA Data in the Classroom, Investigating El Nino:
https://dataintheclassroom.noaa.gov/content/el-nino

UCAR El Nino Teaching Box:
https://scied.ucar.edu/teaching-box/el-nino-southern-oscillation

UCAR Center for Science Education ENSO Page:
https://scied.ucar.edu/learning-zone/how-climate-works/el-nino-southern-oscillation

References

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Trujillo, A., and Thurman, H. (2019). *Essentials of Oceanography*, 13th ed., Pearson

UCAR (2015). Congressional Briefing: Impacts of El Niño on the U.S. https://www.youtube.com/watch?v=BBzEBY8OT68&t=17s

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