Exploring El Niño & Impacts of Changing Ocean Temperature

Grade Level

5–8 or higher

Timeframe

45 minutes or more

Materials

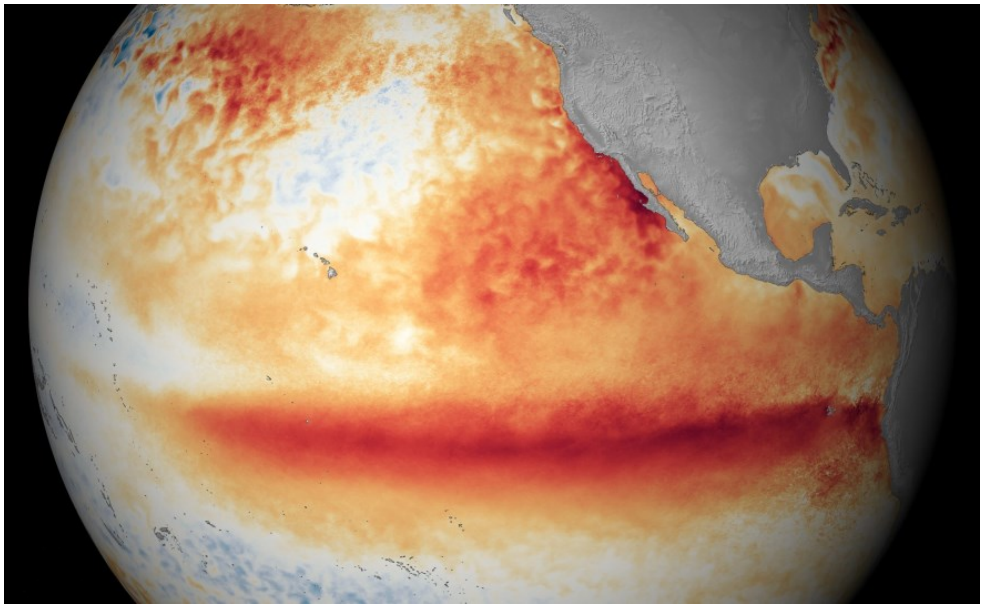
- Computer, projector and screen
- Student handout (available for download)
- Student access to internet-enabled devices

Key Words

Absorption, climate, data, El Niño, GIS, La Niña, ocean currents, phytoplankton, trade winds, upwelling

Standards

NGSS: MS-ESS2.D1. MS-LS2-1. MS-LS2-4.
CCSS: W.6.10. SL.6.4.
Ocean Literacy Principles: 1, 3.
Climate Literacy Principles: 3.
Details at end of lesson



Satellite sea surface temperature departure from normal in the Pacific basin during an El Niño event, where darker orange-red colors are above normal temperatures. Graphic: NOAA

Activity Summary

Students explore ocean temperature data visually with NOAA View Global Data Explorer. They record historic ocean data related to national marine sanctuaries and monuments, then graph and analyze it. They consider impacts of changing ocean conditions on marine sanctuaries and wildlife, as well as global impacts of El Niño and La Niña and other changes that impact the ocean and Earth's climatic and living systems that depend on it.

Learning Objectives

Students will:

- Use a geographic information system (GIS) to collect historical data about national marine sanctuaries and monuments
- Argue from evidence about how changes in sea surface temperature, upwelling and phytoplankton populations could impact marine sanctuaries, wildlife and Earth's systems
- Discuss how the ocean moderates climate and makes life on Earth habitable

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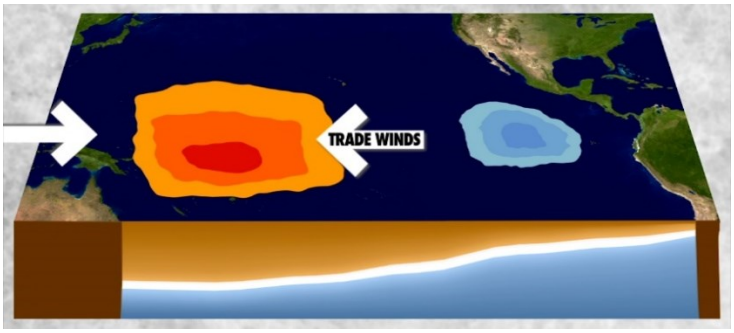
Background Information

During normal conditions, trade winds blow west along the equator, pushing warm water from South America towards Asia in the Pacific basin of our global ocean. To replace that warm water, cold water rises from the depths—a process called upwelling.



Trade winds blow warm ocean water east in the Pacific basin during typical years. Upwelling brings cold, nutrient-rich water to the surface near the west coast of the Americas. Graphic: NOAA

El Niño and La Niña

El Niño and La Niña are two opposing climate patterns that break these normal conditions. During El Niño, trade winds weaken. Warm water is pushed back east, toward the west coast of the Americas. This "Ocean Today" NOAA video shows how it works: https://oceantoday.noaa.gov/observingelnino/welcome.html. Warmer or colder than average ocean temperatures in one part of the world can influence weather around the globe.

Scientists call these phenomena the El Niño-Southern Oscillation (ENSO) cycle. El Niño and La Niña can both have global impacts on weather, wildfires, ecosystems and economies. Episodes of El Niño and La Niña typically last nine to 12 months, but can sometimes last for years. El Niño and La Niña events occur every two to seven years, on average, but they do not occur on a regular schedule. Generally, El Niño occurs more frequently than La Niña.

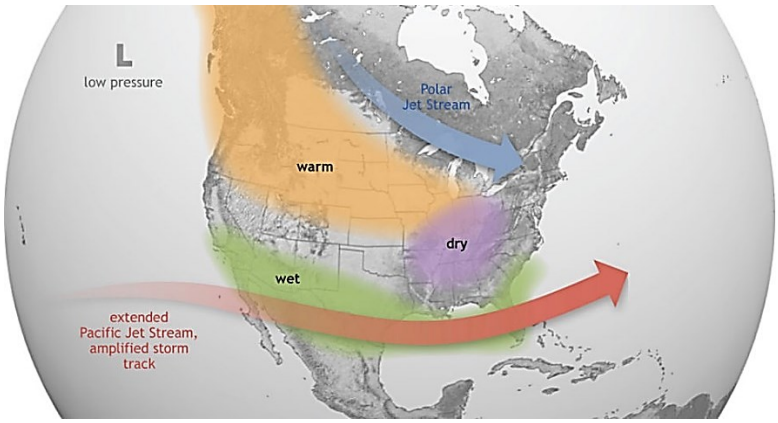
The Ocean Moderates Climate

One way the ocean affects weather and climate is by keeping our planet warm. The majority of radiation from the Sun is absorbed by the ocean, particularly around the equator. Land areas also absorb some sunlight, and the atmosphere helps to retain heat that would otherwise quickly radiate into space after sunset.

The ocean also helps distribute heat around the globe. When water molecules are heated, they exchange freely with the air through evaporation. Ocean water is constantly evaporating, increasing the temperature and humidity of the surrounding air to form rain and storms that are carried by winds. In fact, almost all rain that falls on land starts off in the ocean.

El Niño's Impacts on Weather and Climate

The warmer waters of El Niño cause the Pacific jet stream to move south of its neutral position. With this shift, areas in the northern U.S. and Canada are dryer and warmer than usual. But in the U.S. Gulf Coast and Southeast, these periods are wetter than usual and have increased flooding. Warmer ocean and land temperatures also mean increased evaporation, more moisture in the atmosphere and greater chance of heavy precipitation.



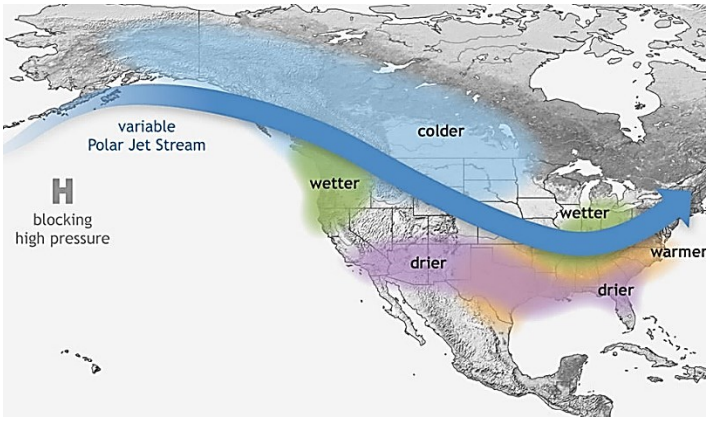
El Niño causes the Pacific jet stream to move south and spread further east. During winter, this leads to wetter conditions than usual in the Southern U.S. and warmer and drier conditions in the North. Graphic: NOAA

El Niño means Little Boy in Spanish. South American fishermen first noticed periods of unusually warm water in the Pacific Ocean in the 1600s. The full name they used was El Niño de Navidad, because El Niño typically peaks around December.

La Niña's Opposite Impacts

La Niña means little girl in Spanish. At these times, trade winds are even stronger than usual, pushing more warm water toward Asia. Off the west coast of the Americas, upwelling increases, bringing cold, nutrient-rich water to the surface.

These cold waters in the Pacific push the jet stream northward. This tends to lead to drought in the southern U.S. and heavy rains and flooding in the Pacific Northwest and Canada. During a La Niña year, winter temperatures are usually warmer than normal in the South and cooler than normal in the North. La Niña can also lead to a more severe hurricane season.



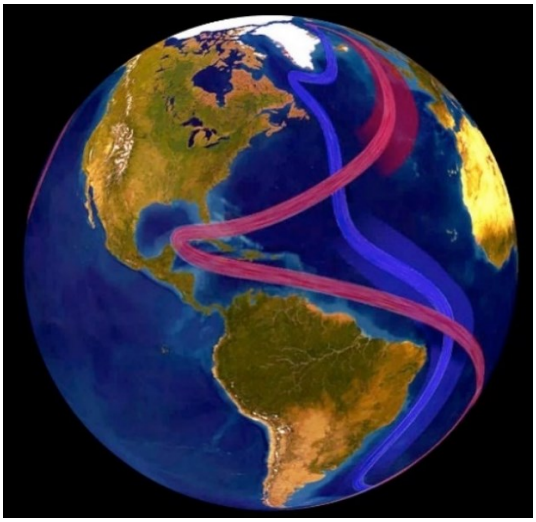
La Niña causes the jet stream to move northward and to weaken over the eastern Pacific. During La Niña winters, the South sees warmer and drier conditions than usual. The North and Canada tend to be wetter and colder. Graphic: NOAA

During La Niña events, waters off the Pacific coast are colder and contain more nutrients than usual. This environment supports more marine life and attracts more cold-water species, like squid and salmon, to places like national marine sanctuaries along the California coast.

Ocean Currents Drive Weather

Outside of Earth's equatorial areas, weather patterns are driven largely by ocean currents**.** Currents are movements of ocean water in a continuous flow, created largely by surface winds but also partly by temperature and salinity gradients, water density, Earth's rotation and tides. Major current systems typically flow clockwise in the northern hemisphere and counterclockwise in the southern hemisphere, in circular patterns that often trace the coastlines.

Ocean currents act much like a conveyor belt, transporting warm water and precipitation from the equator toward the poles and cold water from the poles back to the tropics. Thus, ocean currents regulate global climate, helping to counteract the uneven distribution of solar radiation reaching Earth's surface. Without currents in the ocean, regional temperatures would be more extreme—super hot at the equator and frigid toward the poles—and much less of Earth's land would be habitable.



Model of the Atlantic Meridional Overturning Circulation (AMOC), a critical part of our global ocean's great conveyor belt. Graphic: NOAA

Due to increased melting of polar ice caps and other impacts of climate change, research indicates some ocean currents are slowing down. This is of concern to scientists, although the rate of slowing is being debated in the scientific community. More research is needed into this phenomenon that could have catastrophic impacts around the globe.

National Marine Sanctuary System

National marine sanctuaries and monuments are a network of special underwater areas in the ocean and Great Lakes that protect America's most iconic natural and cultural marine resources. Marine sanctuaries and monuments are found on the East and West Coast, Gulf of Mexico, northwestern Hawaiian Islands and American Samoa. Explore them at https://sanctuaries.noaa.gov.

A humpback whale breeches at Stellwagen Bank National Marine Sanctuary off the coast of New England. How might wildlife and global climate be impacted by changing ocean temperatures and currents? Photo: Anne Smrcina/NOAA

Learn more:

"El Niño and La Niña." NOAA: https://www.noaa.gov/education/resource-collections/weather-atmosphere/el-nino

"El Niño." National Geographic Society: https://education.nationalgeographic.org/resource/el-nino

"The Global Conveyor Belt." NOAA: https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html

"How Does the Ocean Affect Climate and Weather on Land?" NOAA: https://oceanexplorer.noaa.gov/facts/climate.html

"Impacts of El Niño" PMEL/NOAA: https://www.pmel.noaa.gov/elnino/impacts-of-el-nino

"Ocean Currents." NOAA: https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-currents

"What Causes Ocean Currents?" NOAA: https://oceanservice.noaa.gov/facts/sea-ice-climate.html

"Trade Winds." NOAA: https://oceanservice.noaa.gov/facts/tradewinds.html

"What are El Niño and La Niña?" NOAA: https://oceanservice.noaa.gov/facts/ninonina.html

"What is the Atlantic Meridional Overturning Circulation (AMOC)?" NOAA: https://oceanservice.noaa.gov/facts/amoc.html

Vocabulary	
Absorption (of energy)	Process in which matter converts the energy of photons to internal heat energy
Climate	Long-term average of temperature, precipitation and other weather variables at a given location
Data	Evidence, facts and statistics collected for analysis or reference
El Niño	Event in Pacific basin when trade winds weaken; warm water is pushed back east, toward the west coast of the Americas
GIS	Geographic Information System: a computer system for capturing, storing, checking and displaying data related to positions on Earth's surface
La Niña	Cooler than normal sea-surface temperatures in the central and eastern tropical Pacific basin that impact global weather patterns.
Ocean currents	Continuous and directed movements of ocean water driven by winds, water density and tides: on the ocean's surface and in its depths, flowing both locally and globally
Phytoplankton	Microscopic marine algae that provide food for a wide range of sea creatures
Trade winds	Prevailing easterly winds that circle the Earth near the equator
Upwelling	Process in which deep, cold water rises toward the water's surface

Preparation

- Print copies of the "Mystery of El Niño de Navidad" handout for each student, or distribute it electronically.
- Prepare to show these with a data projector (if available) or ask students to view them on other devices:
    - NOAA View Global Data Explorer: https://www.nnvl.noaa.gov/view/globaldata.html

      Practice using the Explorer tool for locating sea surface temperatures, as described below.
    - "ClimateBits: El Niño" video from NOAA (1:58): https://sos.noaa.gov/catalog/datasets/climatebits-el-nino
- Review the Enrich/Extend options at the end of the lesson.
- *Optional:* Document camera

Procedure

Engage

- Before students can see the screen, load a map of ocean temperature data using NOAA View Global Data Explorer: https://www.nnvl.noaa.gov/view/globaldata.html
    - Direct link: https://www.nnvl.noaa.gov/view/globaldata.html#SURF

- Or click: **+ Add Data** > **Ocean** > **Temperature** > **At the Surface**
- When the map loads, click the "- " button in the upper-right corner of the two map legend boxes to hide them from students.

Show the map (without the legend) to the class and ask the students to think about what they are observing and why the colors vary so much in the ocean. Invite them to talk to a partner about their observations and ideas. Circulate to answer questions and encourage critical thinking.

- After a minute or two, ask students to share their observations and ideas. Then:
  - Click the "Menu +" button on the left to reveal the legend (and what the map is showing).
  - Click the "Time +" button and show students how they can display the data over time using the blue triangle buttons.

Explore

- Pass out the handout, one for each student. Ask students to work with a partner on their own computer or tablet to observe the map more fully. They can adjust the variables in the legend of the Geographic Information System (GIS) to view the data over different time periods. Show them how they can click the small "Data Values" box in the lower-right of the Time legend and point out how temperatures in degrees Celsius are then displayed when you point to the map.

- Ask the students to open another browser tab to load NOAA's National Marine Sanctuary System webpage and explore the map lower on the page: https://sanctuaries.noaa.gov. Also show them how to access the detailed maps through the navigation bar: Multimedia > Maps to load https://sanctuaries.noaa.gov/about/maps.html.
  - Ask them to try to find the location of Papahānaumokuākea Marine National Monument on the annual surface temperature data map. (Coach them how they can approximate by clicking Northwest of the Hawaiian Islands visible on the map.) Tell them they should record the most recent average weekly surface temperature in the table on the handout.
  - They should continue this same process for the other sites listed on the table, recording average annual temperatures for the years in the table, as well as the most recent average weekly surface temperatures, being careful to click on the same location on the map each time as closely as they can.
  - *Optional:* Ask students to choose one or more additional sanctuaries or monuments to investigate, such as nearby sites. Temperature data can be added to the table and/or science notebooks.

- Circulate to answer questions and help guide the learning process. When groups are close to completing their data collection, graphing and analysis, give them a 2-minute warning. Tell them they should be ready to discuss their ideas and results of their investigations with the class.

Explain

- Ask students to share their results and discuss them. What did they find most interesting? Invite them to show maps on the screen and talk about their observations and ideas. If you have a document camera, they could show completed graphs and/or recorded observations in their notebooks.
- Ask students to share their ideas about what years may have been El Niño years and why they think so. Years listed in the table that had El Niño events were 1983 and 1997. Others are listed on the "El Niño Southern Oscillation (ENSO)" page here: https://psl.noaa.gov/enso/climaterisks/years/top24enso.html
- Ask students to share their ideas about what years may have been La Niña years and why they think so. Years listed in the table that had La Niña events were 1988, 1998 and 1999. Others are listed on the page linked above.
- Show the "ClimateBits: El Niño" video from NOAA (1:58) to help explain the concept and how it impacts the ocean and Earth's system: https://sos.noaa.gov/catalog/datasets/climatebits-el-nino
- Ask:
    - Why do temperatures vary so much in the global ocean from year to year and in individual years?
    - Why are some ocean waters warmer or colder than we might expect based on their latitude (distance from the Equator)?

  Discuss student ideas about El Niño and La Niña and how ocean currents play such an important role in temperature, beyond what latitude alone would suggest (due to solar radiation hitting the tropics more directly than at the poles).
- Ask students to think about the huge scale of the Earth and global ocean. Ask:
    - How might small changes in factors like sea surface temperature lead to big changes in Earth's system?
    - How does the ocean moderate climate?
- Encourage students to reflect on how changes in oceanic and atmospheric forces could impact life on Earth. They should argue from evidence about how changes caused by El Niño and La Niño, as well as factors they might have learned about in other lessons, such as ocean currents, prevailing winds, etc. might impact national marine sanctuaries and monuments, your local area and other parts of the world. Ask:

- Does the sea surface temperature data provide evidence for the effects of El Niño and La Niña on phytoplankton populations (as shown in the Chlorophyll Concentration data/map)?
- How might El Niño, La Niña and other changes in Earth's system impact national marine sanctuaries and monuments, as well as coastal communities?
- How does the ocean help make life on Earth habitable?

- Ask students to discuss their ideas with a partner and record them in science notebooks. After a couple of minutes, ask them to share their ideas with the class and discuss them.

Enrich/Extend

- Continue the exploration process with your class using the "Investigating El Niño" resources from NOAA's Data in the Classroom collection: https://dataintheclassroom.noaa.gov/el-nino/investigating-el-nino-using-data-the-classroom.
  - Online modules: https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=7a6ff2dc781041bcad7f790a719a42dd
  - Student-fillable PDF: https://s3.amazonaws.com/ditcr-prod/2022-06/DITC%20ENSO%20Worksheets_L2-L5.pdf
  - Editable PowerPoint: https://s3.amazonaws.com/ditcr-prod/2022-06/DITC%20ENSO%20Worksheets_L2-L5.pptx
  - PDF answer key: https://s3.amazonaws.com/ditcr-prod/2022-06/DITC%20ENSO%20Worksheets_L2-L5_ANSWERS.pdf
- Give students the opportunity to explore more data about national marine sanctuaries and monuments, such as current weather conditions and annual precipitation data. Current data and maps from NOAA's National Weather Service are linked here: https://www.weather.gov/current.
- For younger students and those that need more support, work through more of the handout activities as a class. This could also be done with just part of the class.
- Encourage students to think of solutions to mitigate the destructive impacts of climate change, such as warming waters in the ocean and Great Lakes, evident in the data.
  - They can share their ideas with the class, school and larger community through a medium of their choice, such as posters, public service announcement videos and/or audio recordings, games or skits.
  - Invite students to explore the *Climate Resilience in Your Community Activity Book* from NOAA to help give them ideas: https://www.noaa.gov/sites/default/files/2022-07/Activity_Book_Online_Final_Small_07.13.22.pdf

- The "Blue Carbon StoryMap" might also provide inspiration: https://storymaps.arcgis.com/stories/c4604faf7036427e913e3d09eede76eb
- Ask the class to choose one or more projects you can do at your school or in your local community to help mitigate the impacts of climate change and make your community more resilient.

Evaluate

- Ask students to construct an argument supported by evidence that changes to physical or biological components of an ecosystem affect populations. These arguments can be written in science notebooks and/or discussed orally. Using data as evidence, students should explain how changes that occur in the tropical Pacific basin as a result of El Niño and La Niña lead to changes in sea surface temperature, upwelling and phytoplankton populations.
- Review student handouts and science notebooks. Provide feedback. You might offer students the opportunity to revise their written arguments.
- Evaluate student contributions to group and class discussions.

Education Standards	
Next Generation Science Standards	Earth's Systems • MS-ESS2.D1: Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Ecosystems: Interactions, Energy, and Dynamics MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. (Students analyze and interpret satellite data to provide evidence for the effects of disrupted upwelling on phytoplankton populations). MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. (Using data as evidence, students construct written or oral arguments that explain how changes that occur in the tropical Pacific Ocean as a result of El Niño lead to changes in sea surface temperature, upwelling and phytoplankton populations.) Science and Engineering Practices: • Analyzing and Interpreting Data • Constructing Explanations (for science) • Developing and Using Models • Engaging in Argument from Evidence • Obtaining, Evaluating and Communicating Information • Using Mathematics and Computational Thinking Crosscutting Concepts: • Patterns • Cause and Effect • Systems and System Models • Stability and Change • Energy and Matter
Common Core State Standards	Writing: W.6.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. Speaking and Listening: SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes.
Ocean Literacy Principles	1. Earth has one big ocean with many features. (c) 3. The ocean is a major influence on weather and climate. (a, b, c, f, g)
Climate Literacy Principles	3. Life on Earth depends on, is shaped by, and affects climate. (a, c) (If the last Enrich/Extend activity is completed.)

Additional Resources

"El Niño Theme Page." Pacific Marine Environmental Laboratory: https://www.pmel.noaa.gov/elnino/impacts-of-el-nino

"Information from NOAA's Satellite Fleet Helps Point to How Warming Ocean Temperatures Impact Marine Food Web and Whale Distribution." NOAA: https://www.nesdis.noaa.gov/news/information-noaas-satellite-fleet-helps-point-how-warming-ocean-temperatures-impact-marine

"Ocean Conveyor Belt." National Geographic Society: https://education.nationalgeographic.org/resource/ocean-conveyor-belt

"Realtime El Niño Measurements." Pacific Marine Environmental Laboratory: https://www.pmel.noaa.gov/elnino/realtime-data

"Voyager Lesson Plan." Pacific Islands Ocean Observing System (PacIOOS): http://www.pacioos.hawaii.edu/education/voyager

Try PacIOOS Voyager here: https://www.pacioos.hawaii.edu/voyager

"What is the Future of Earth's Climate?" National Geographic Education: https://education.nationalgeographic.org/resource/what-is-the-future-of-earths-climate

"World in Real Time: NOAA Satellites." https://www.nesdis.noaa.gov/imagery/interactive-maps/the-world-real-time

For More Information

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