Today I Learned About the Changing Ocean

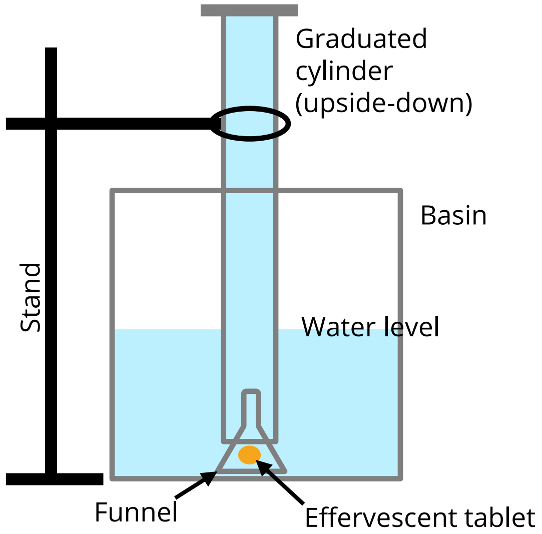
"Because of the ability of the ocean to absorb the temperature, it holds the heat over a longer period of time than at the surface or on the land. It's a gradual process, but the ocean is becoming warmer, overall."
Dr. Sylvia Earle, Explorer-at-Large, National Geographic and founder of Mission Blue
TILclimate podcast: Today I Learned About the Changing Ocean

How Does Warm Water Affect Carbon Dioxide?

Extra carbon dioxide in the atmosphere (from burning fossil fuels like coal, oil, and natural gas) traps heat, warming the ocean. But the ocean also interacts with carbon dioxide directly – by absorbing it. Many factors affect how much carbon dioxide the ocean can absorb, such as the presence of photosynthesizing organisms, how much the water is mixing, and temperature. Today, we will explore how water temperature affects the ocean's ability to absorb carbon dioxide.

Procedure

1. Fill the basin **half-full** of water and place the stand beside it.
2. Fill the graduated cylinder **to the brim** with the same temperature water.
3. Place a Petri dish cover over the top of the graduated cylinder and carefully turn the cylinder over, placing the top in the water. Remove the Petri dish once the mouth of the cylinder is underwater. Make sure that **no air bubble** is formed inside the graduated cylinder.
4. Secure the graduated cylinder to the stand or hold the cylinder in place with your hands.
5. Place the **funnel inside the mouth** of the graduated cylinder, with the mouth of the funnel on the bottom of the basin. (See diagram)
6. Carefully place an effervescent tablet **inside the funnel**.
7. Measure the bubble of carbon dioxide that forms at the top of the graduated cylinder.



ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About the Changing Ocean

Collect the Data

For best results, perform this demonstration multiple times with each water temperature. (Your team may perform multiple trials in a row, or your class may perform multiple trials simultaneously.) Collect all data from all trials in the chart below. Mark the temperature of cold and warm water, and then the volume of air at the top of the graduated cylinder in ml.

	Volume of air formed in graduated cylinder (ml)			
Trial	Cold Water		Warm Water	
	Temperature		Temperature	

Questions

1. Which produces a larger volume of air space inside the graduated cylinder, cold water or warm water?
2. Why do you think this is? What is happening here?
3. What will be the consequence of a warming ocean? How will this affect the role of the ocean as a CO_2 sink? (A *sink* is a system that absorbs more than it releases. A *source* is a system that releases more than it absorbs.)
4. Where in the world's ocean will you expect more CO_2 uptake? Where will it be less?
5. In what ways is this model accurate? In what ways does the ocean behave differently than this model? (Consider currents, storms, etc. – how would these systems affect the ocean's ability to uptake CO_2?)

Today I Learned About the Changing Ocean

"[The ocean] will take carbon dioxide up, but it doesn't remain as CO_2. It becomes carbonic acid, which is changing the chemistry of the ocean, [making] the pH of the ocean more acidic."
Dr. Sylvia Earle, Explorer-at-Large, National Geographic and founder of Mission Blue
TILclimate podcast: Today I Learned About the Changing Ocean

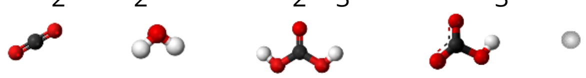
What Is Ocean Acidification?

As we burn fossil fuels like coal, oil, and natural gas, and cut down forests, we release carbon dioxide (CO_2) into the atmosphere. Most of this carbon dioxide stays there, trapping heat like a blanket and warming our Earth and ocean, but around 25-30% of atmospheric carbon dioxide is absorbed by the ocean. The ocean can absorb some carbon dioxide in its gas form, and this is the CO_2 used by photosynthesizing organisms like plankton and algae. However, as we add more CO_2 to the ocean, it begins to change the chemistry of the ocean water – pushing it from a higher pH to a lower pH. This is called *ocean acidification* (OA).

OA and climate change are caused by the same thing (too much carbon dioxide in the atmosphere), but OA is not caused by climate change. However, temperature does affect how much CO_2 the ocean can absorb, and there are other more complex interactions between the effects of climate change and the effects of ocean acidification. In the podcast episode, Dr. Earle calls OA "climate change's evil twin."

What's the Actual Chemistry?

$$CO_2 + H_2O \rightleftharpoons CH_2O_3 \rightleftharpoons HCO_3^{-} + H^{+}$$

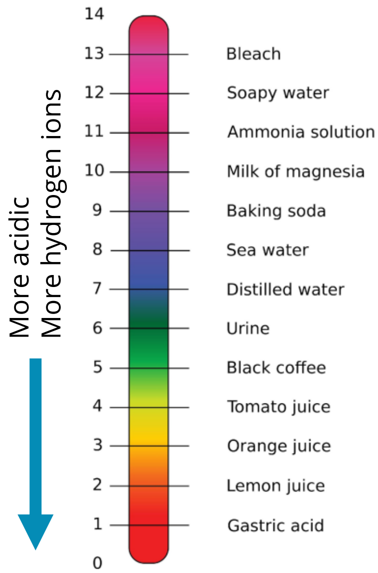


Carbon dioxide + water creates carbonic acid, a weak acid that is unstable and quickly forms bicarbonate ions and hydrogen ions. More hydrogen ions means a lower pH.

Is the ocean turning into lemon juice?

Ocean water is usually around an 8 on the pH scale, meaning it is *alkaline* (also called *basic*). With the addition of carbon dioxide, the pH is getting lower, towards the acidic side, but is still above the neutral point of 7.

We say that the ocean is *acidifying* because it is moving in the direction of acidity. In the same way, we can say that a hot day is *cooling down* if it goes from 90ºF to 80ºF – even if we wouldn't call 80ºF cold.



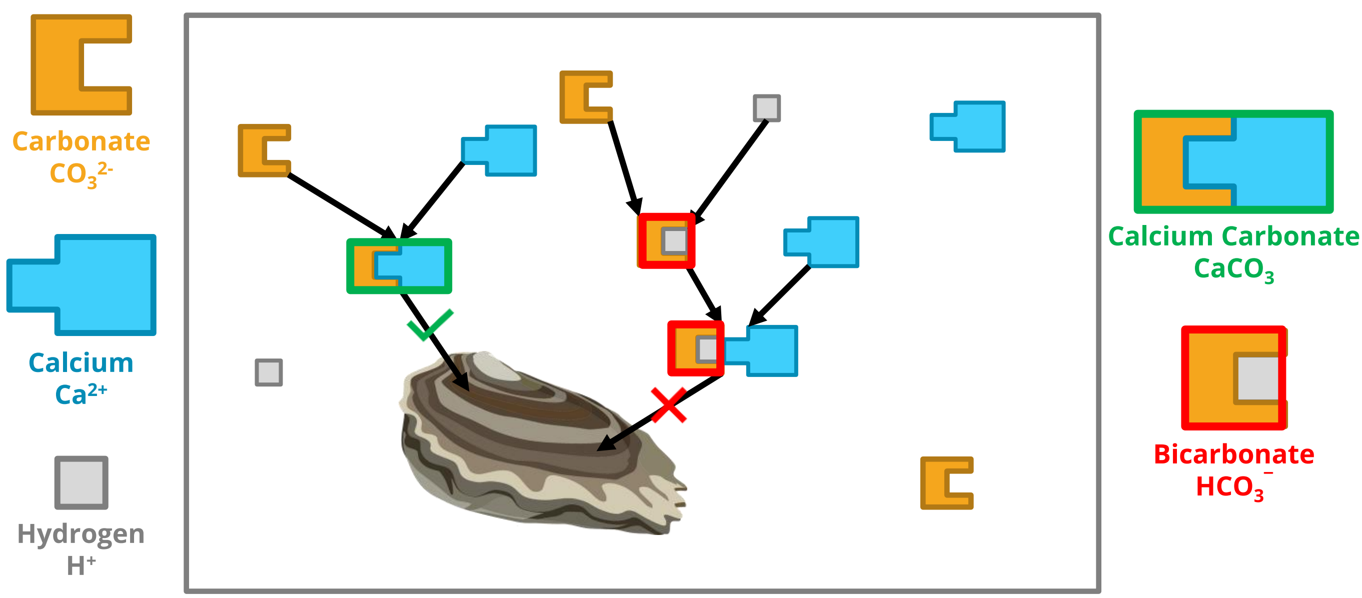
Today I Learned About the Changing Ocean

Osteoporosis of the Sea

Ocean acidification (OA) causes many impacts to ocean life – the most famous and well-studied being effects on shell-building creatures such as clams, oysters, snails, and corals. Like our bones, these animals need calcium in a specialized form to build their shells. For this reason, OA is sometimes called *osteoporosis of the sea.*

One way to think about this story is that it's all about building blocks. In the diagram below, an oyster needs one orange block (carbonate ion) and one blue block (calcium ion) to make its shell (green box). As we add more gray blocks (hydrogen ions) to the ocean, they are more likely to bind with the orange blocks (red box). This means the orange and blue blocks can't link up, and the oyster must work harder to find the pieces it needs to make its shell.

In this way, the hydrogen ions are "stealing" one of the building blocks the oyster needs to make its shell. It's like trying to build something out of blocks while a smaller kid runs around taking the blocks from your pile.



Try It

Model this interaction with magnets, blocks, or other kinds of building toys.

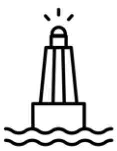
Oyster image from Pixabay

Today I Learned About the Changing Ocean

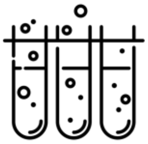
Ocean Acidification Solutions

Ocean acidification (OA) is caused by extra carbon dioxide in the atmosphere from the burning of fossil fuels like coal, oil, and natural gas and by the cutting of forests. The first solution to OA, then, is to reduce the amount of excess carbon dioxide going into the atmosphere – any solutions that reduce fossil fuel use, capture carbon, and protect forests will help the impacts of OA.

While this is happening, there are other projects that can help reduce the impact of OA, especially on communities that depend on shellfish and other shell-building organisms:



Monitor. We can't manage what we don't measure. The National Oceanic and Atmospheric Administration (NOAA) measures changes in ocean chemistry in coastal regions around the world to see what influences more dramatic changes in certain places. https://oceanacidification.noaa.gov/



Research. In labs, where the chemistry can be controlled very closely, scientists are studying the effects of various levels of OA on organisms such as fish, shellfish, corals, and plankton. By knowing how each kind of organism is affected by OA, scientists can predict the effects on these populations in the future. https://www.fisheries.noaa.gov/about/northeast-fisheries-science-center

Aquaculture. Early warning tools are being used to forecast ocean acidification and other effects, allowing shellfisheries and other aquaculture to adjust their plans. Research is revealing techniques that can reduce impacts, such as growing seaweed. https://hakaimagazine.com/news/seaweed-and-seagrass-buffer-the-acidity-of-the-nearby-ocean/

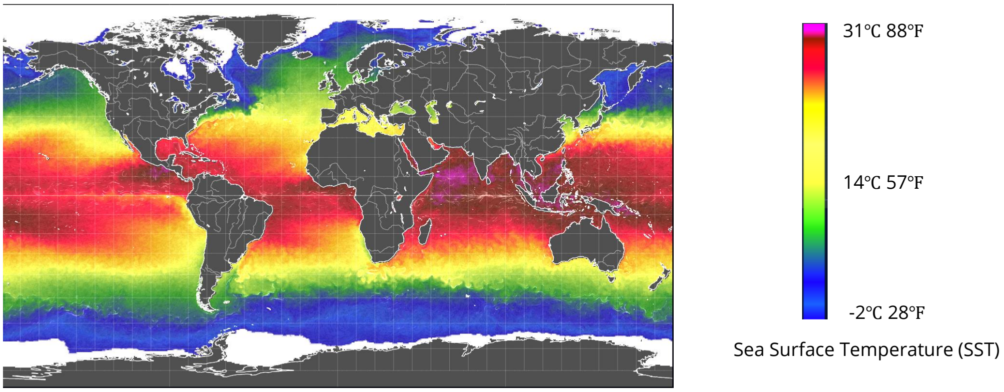
Share

One of the challenges of ocean acidification is that few people have heard of it. How would you explain it to a friend or family member who doesn't know much about chemistry? Which of these solutions do you find the most exciting?

Images from The Noun Project by Boyan, UNiCORN, and FoodIcons

Today I Learned About the Changing Ocean

"You change the temperature, and you change everything."
Dr. Sylvia Earle, Explorer-at-Large, National Geographic and founder of Mission Blue
TILclimate podcast: Today I Learned About the Changing Ocean



The Ocean is the Heart of the Climate

The ocean moves constantly. We may be familiar with waves and tides, but there are also large ocean currents that move huge amounts of water around the planet. Like our heart moves blood – and along with it, cells, nutrients, vitamins, and hormones – around our bodies, the ocean moves heat, moisture, nutrients, and even living things around Earth.

As you can see in the map above, temperature is not evenly distributed around the ocean. While it is warmer at the equator and colder at the poles, there are warm-water and cold-water currents that bring warm water poleward and cold water towards the equator. Temperature is not in even, straight-lined bands around the world.

This movement of heat and moisture has dramatic effects on the climate and weather patterns on land. Warm water brings warm air, moisture – and often more storms. Cold water keeps land temperatures cooler all year.

Major Ocean Currents

There are at least 25 major named ocean currents[1]. Five are visible on the map on the next page and have significant effects on land weather, animal distribution, and more. See if you can find them on the map.

A. California: Brings cold water along the coast from Alaska to Baja California.
B. Peru: Brings cold water from Antarctica to Ecuador.
C. Gulf Stream: Brings warm water from the Gulf of Mexico across to Europe.
D. Benguela: Brings cold water from Antarctica to Namibia.
E. Kuroshio: Brings warm water from the South China Sea across the North Pacific.

Map from Earth.Nullschool.net
1 National Weather Service, JetStream Max https://www.weather.gov/jetstream/currents_max

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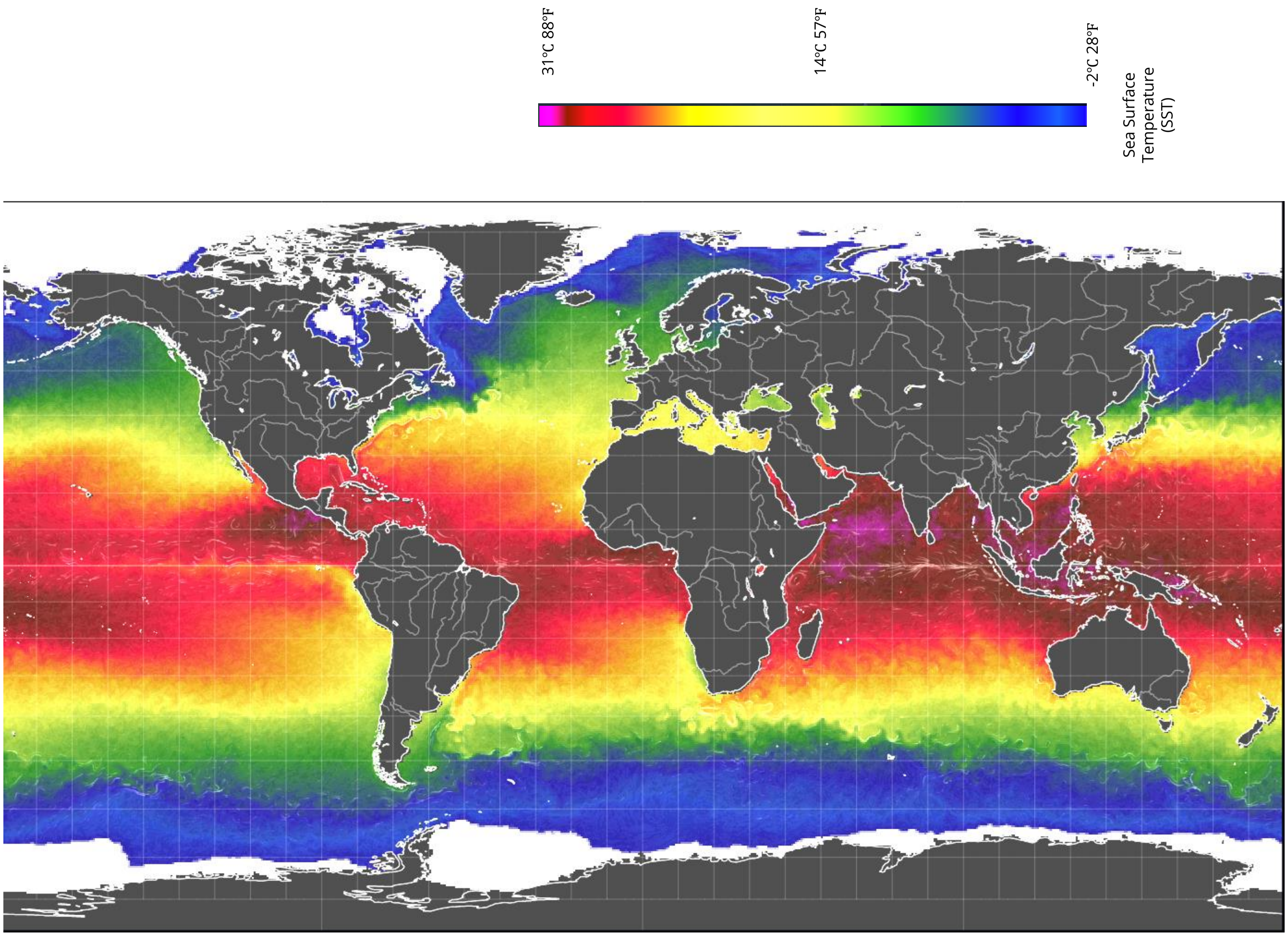

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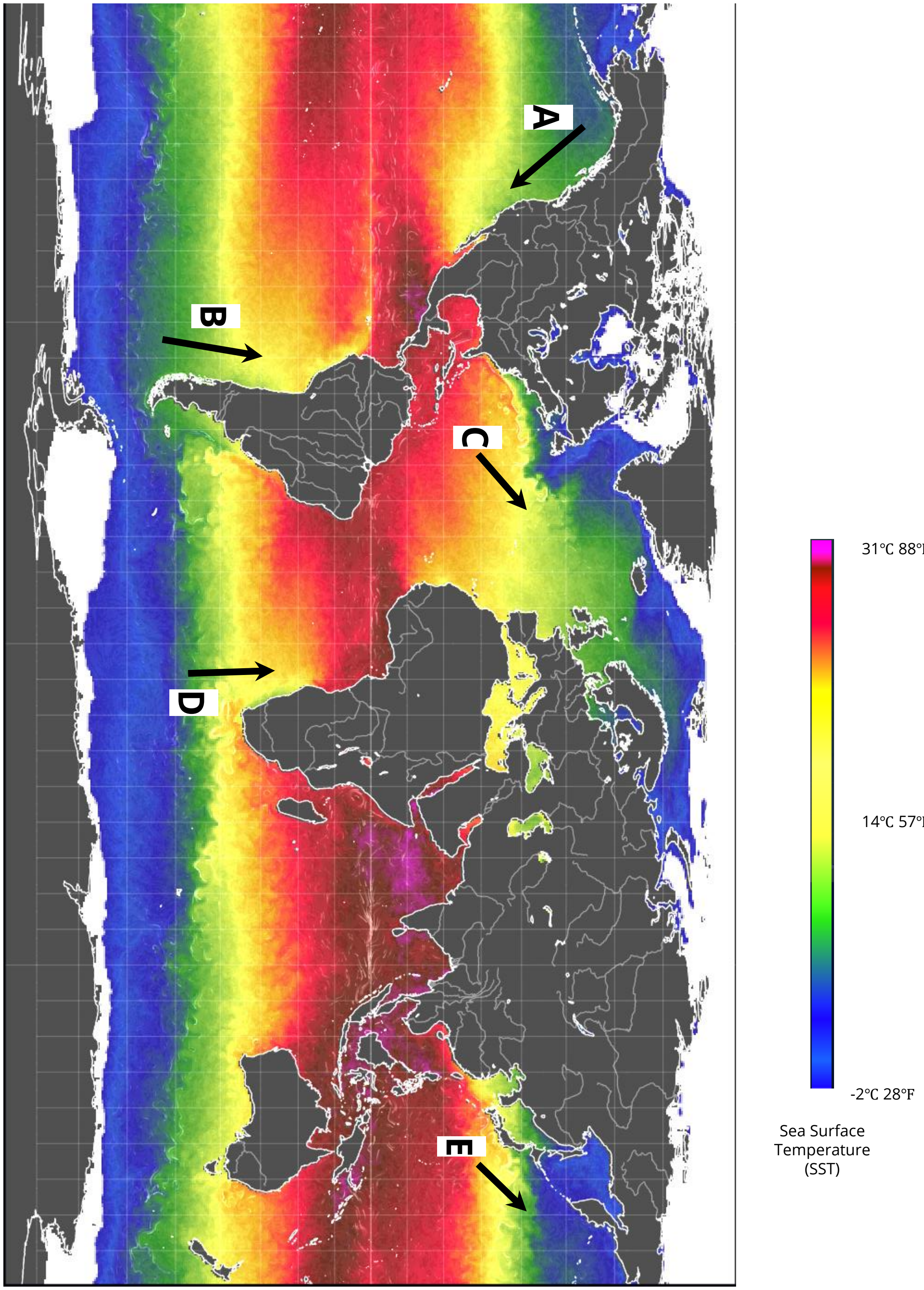
Map from earth.nullschool.net

Today I Learned About the Changing Ocean



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Map from earth.nullschool.net

Today I Learned About the Changing Ocean

Watch the Currents

1. Choose one of the five major currents listed on the previous page.
2. Visit **earth.nullschool.net**
3. Click the word **earth** in the bottom left-hand corner.
4. Turn on Mode **Ocean**, Animate **Currents**, Overlay **SST** (sea surface temperature).
5. You may leave the view in global form or choose a different Projection.
6. Click and drag to the location of your chosen current.

Observe

What do you notice about this current? What temperature of water is traveling along this current? Where does it begin, and where does it lead to?

Analyze

Choose a place where the current crosses a line of latitude (parallel to the Equator). Follow that line of latitude out into the ocean. Is the general temperature at that latitude different from the temperature in the current? (For example, the water West of the Kuroshio current is much cooler.)

Predict

How might the climate on land around this current be affected by it? (For example, warm water tends to move storm systems along it.)

How might the distribution of animal species be affected by this current? (For example, cold water holds more nutrients and more food.)

Compare

Visit one of the other currents on the map and compare them. There are three cold-water currents and two warm-water currents – choose a different water temperature for your second current.

Today I Learned About the Changing Ocean

Ocean Current Examples & Questions

These large ocean currents shape local biology, climate, culture, and economies. Research some of the examples below. What other examples can you think of?

The Gulf Stream brings such warm water across the North Atlantic that there are palm trees in southern England.

What part of North America is at the same latitude as southern England? Describe the weather in each of these locations.

Penguins are found on the Galápagos Islands, almost at the equator.

How does the cold water of the Peru current support this species? (Hint: It has to do with their food.)

Tropical *typhoons* follow the Kuroshio current north to Japan.

How else does this warm water affect Japan's weather?

The western coast of South Africa and Namibia is an *ocean productivity* hotspot due to the cold water of the Benguela current.

What species depend on this ocean productivity?

Visitors to southern California are often surprised at how cold it is for surfing.

Why is the water so much colder than it is in Florida, Texas, or Hawai'i?

Images from The Noun Project by Flatart, Dreamicons, Mungyu Kim, Beatriz Rubio, and Eric Lind

ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About the Changing Ocean

"The Argo floats descend from the surface and look at the water column and travel with the currents, and then come back up to the surface to put their data back into those listening from above."
Dr. Sylvia Earle, Explorer-at-Large, National Geographic and founder of Mission Blue
*TILclimate podcast: Today I Learned About *****

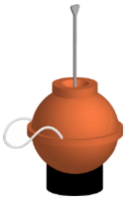
Argo Floats

In the podcast episode, Dr. Earle talks about the Argo float program, which is giving scientists data about the ocean. Argo floats are autonomous robots that float around the ocean, diving and surfacing to collect data – sometimes at depths up to 3.72 miles (6000m). At the surface, they connect with the Jason satellite system, making their data available in near-real-time to scientists all over the world. The first floats were deployed in 2000. By 2022, there were almost 4,000 floats in all (see map, next page). While early floats only lasted 1-2 years before their batteries died, new floats have a life expectancy of almost 7 years.

Even with almost 4,000 robots collecting data continuously, there are gaps – but our understanding of the complexity of the ocean grows every day. While satellites can measure the surface of the ocean, the Argo floats give us an image of the changes in temperature, salinity, pressure, and other factors as they dive below the surface.

Argo Float Designs

Most Argo floats (called "core floats" can measure temperature, pressure, and salinity (saltiness) in the top 1.24miles (2000m) of the ocean. (See next page for a more detailed view of the inside of a core float.)



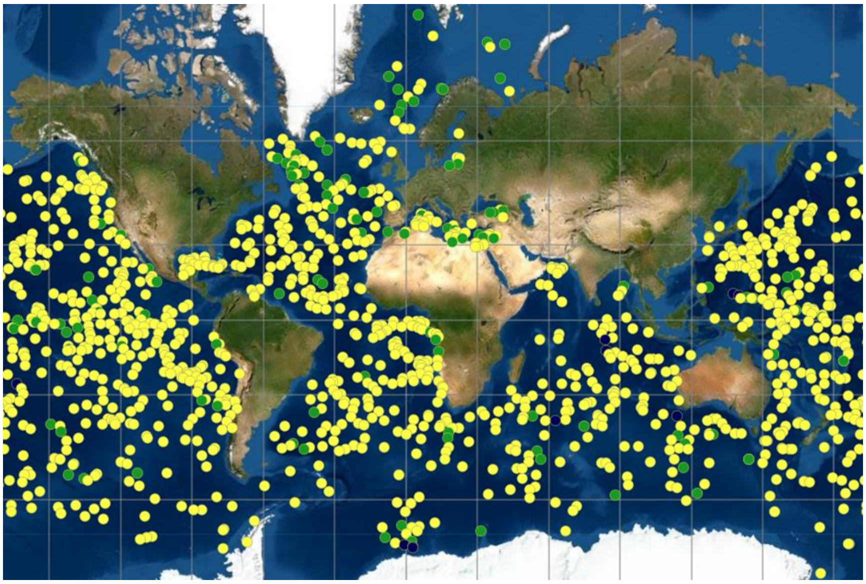
Specialized Deep Argo floats can dive to 3.72miles (6000m) to collect data about the water at the bottom of the ocean, where the pressure can be almost 600 times that at the surface.

New Biogeochemical (BGC) Argo floats can measure a range of more complex ocean factors, such as dissolved oxygen, light levels, and photosynthesis.

All images from https://argo.ucsd.edu/outreach/media/schematics/

Today I Learned About the Changing Ocean

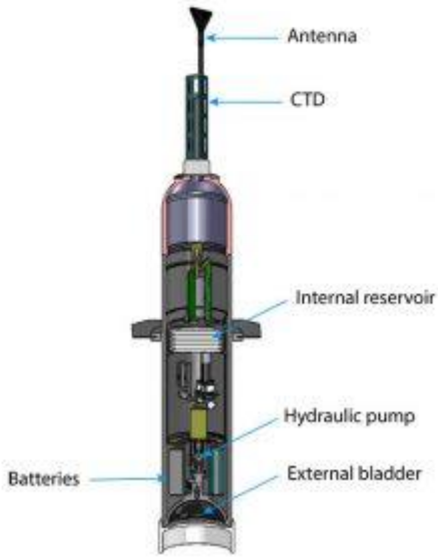
Where in the World is Argo?



Argo Float locations, April 2022.

Argo floats have been deployed in every ocean basin, and some are even adapted to go under sea ice. For near-real-time data on current Argo locations, visit http://data.scripps.earth/argoviz/ and turn on Floats>Recent.

What Is Inside Argo?



While there are a few different styles of Argo float, they mostly follow the same design – a cylinder a little over 3ft long. A set of sensors (called CTD) at the top collect conductivity (salinity), temperature, and pressure (depth) measurements. Inside the cylinder, pumps and reservoirs allow the float to sink slowly to a depth of 1.24miles (2000m) or more and rise again to transmit data.

Every ten days, the float sinks to a drifting depth (often around 0.62miles or 1000m), drifts with the current for 8-9 days, sinks to an even deeper depth, and then rises to the surface, collecting data all the while. At the surface, it sends its data to a Jason satellite, and then the cycle begins again. Most floats last 4-5 years, meaning they can perform more than 140 cycles.

Argo Float locations from https://argovis.colorado.edu/ng/home.
Argo Float schematic from https://argo.ucsd.edu/outreach/media/schematics/

Today I Learned About the Changing Ocean

What Can Argos Measure?

One of the most exciting features of the Argo float program is that anyone can access the data. This allows scientists from all over the world – and from many different areas of science – to ask new questions about the ocean.

Ask Questions

For each of the types of information an Argo can collect, write one question or idea that you imagine a scientist may want to pursue. You may find some questions that combine one or more dataset.

Data Type	Description
1. Time & Location	The date, time, latitude, and longitude at the time when the Argo surfaced to send its data to the Jason satellite.
2. Pressure	At 200ft, the pressure is around 6atm (6 times the pressure at the surface.) By 6000ft, it is over 180atm.
3. Temperature	The water temperature around the Argo. Ocean temperatures range from below freezing to above 95ºF.
4. Salinity	The amount of salt in the water. Ocean salinity varies from 33 to 37 parts per thousand (ppt).
5. Dissolved Oxygen	Animals with gills (fish, crustaceans, gastropods, etc.) need dissolved oxygen to breathe. Oxygen also affects various chemical processes.
6. Dissolved Nitrate	Nitrate is a key nutrient for phytoplankton (photosynthesizing plankton.)
7. pH	The acidity of water varies on short and long timescales and affects photosynthesis, animal breathing, and shelled organisms' growth.
8. Chlorophyll-a Concentration	Photosynthesizing plankton (phytoplankton) produce chlorophyll-a – and more than half the oxygen in Earth's atmosphere.
9. Suspended Particles	Tiny living things, such as phytoplankton, bacteria, and microscopic predators are a key part of ocean ecosystems.
10. Downwelling Irradiance (Light)	Light reaches to different depths in different parts of the ocean, depending on how many suspended particles (both living and nonliving) are in the water.

Read Questions

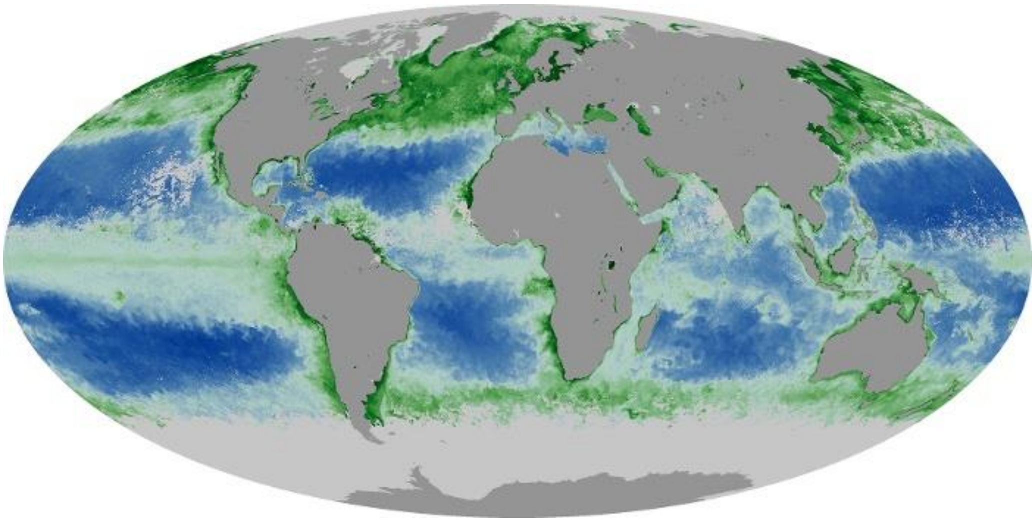
Visit https://argo.ucsd.edu/science/ to read about some of the key findings that scientists have discovered using Argo data. Do any of these questions line up with any of yours?

For more on measures 5-10, see https://biogeochemical-argo.org/measured-variables-general-context.php

Today I Learned About the Changing Ocean

"From space, Earth looks blue. Earth is dominated by the existence of the ocean... It's important to recognize that... the ocean is the basic system that drives climate. Without the ocean, what we think of as climate could not exist.

Dr. Sylvia Earle, Explorer-at-Large, National Geographic and founder of Mission Blue
*TILclimate podcast: Today I Learned About ****



Chlorophyll (photosynthesis & oxygen production) levels in the ocean, May 2021. Dark green = highest levels.
NASA Earth Observatory https://earthobservatory.nasa.gov/global-maps

The Role of the Ocean: Communication Challenge

Even though many of us know we live on a blue planet, and many of us like to visit the beach, we don't often think about the effect of the ocean on our day-to-day lives. For example – if you ask most people where the oxygen they breathe comes from, they will say trees. But more than half the oxygen we breathe every day comes from photosynthesis in the ocean.[1]

To deepen public understanding, scientists and educators have teamed up to write 7 principles of Ocean Literacy – ideas that everyone should understand about the ocean.

Each group will dive deep into **one** of the Ocean Literacy Principles and decide how to explain it to someone. As you work, consider your goal, audience, medium, and platform.

Try It!
Image search results reveal the most-often-chosen images for a topic. Try doing an image search for the word "ocean." What do you notice? Often, most of the images show the surface of the ocean, or empty water. The ocean is anything but empty, and most of it is not at the surface. How does this "surface thinking" about the ocean affect how we interact with it? What do you think are some other common misconceptions about the ocean?

1 https://oceanservice.noaa.gov/facts/ocean-oxygen.html

Today I Learned About the Changing Ocean

The Ocean Literacy Principles

1 The Earth has one big ocean with many features.
The ocean is the defining physical feature on Earth, covering about 70% of the surface. There is one interconnected circulation system that moves through ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic.

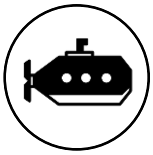
2 The ocean and life in the ocean shape the features of Earth.
Many materials, rocks, and geochemical cycles begin in the ocean. Tectonic activity, coastal erosion, sea level changes, and force of waves influence the physical structure and landforms of the coast.

3 The ocean is a major influence on weather and climate.
The interaction of oceanic and atmospheric processes controls weather and climate by dominating Earth's energy, water, and carbon systems. Heat exchange between the ocean and atmosphere drives the water cycle and oceanic and atmospheric circulation.

4 The ocean made Earth habitable.
Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. The earliest evidence of life is found in the ocean. The ocean provided and continues to provide water, oxygen and nutrients, and moderates the climate needed for life to exist on Earth.

5 The ocean supports a great diversity of life and ecosystems.
Ocean life ranges in size from the smallest living things, microbes, to the largest animal that has lived on Earth, blue whales. Ocean life is not evenly distributed through time or space due to differences in factors such as oxygen, salinity, temperature, light, nutrients, pressure, and substrate.

6 The ocean and humans are inextricably connected.
The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. The ocean moderates the Earth's climate and weather and affects human health. The ocean sustains life on Earth and humans must live in ways that sustain the ocean.



7 The ocean is largely unexplored.
Less than 5% of the ocean has been explored. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes.

Text quoted and adapted from The Ocean Literacy Principles. http://oceanliteracy.wp2.coexploration.org/
Images from The Noun Project by Martin Vanco, HeadsOfBirds, Brand Mania, Tom Farrell, Alexander Skowalsky, Phạm Thanh Lộc, Lars Meiertoberens, and Saeful Muslim

Today I Learned About the Changing Ocean

Goal

1. Rewrite your Principle in your own words. How would you describe it to a friend, family member, or someone younger than you?
2. Read some of the details of your Principle at **oceanliteracy.wp2.coexploration.org**. Does one of these give you a new idea?
3. Choose one idea you want to focus on for your communication project.

Audience

4. Who is your audience for this project? This may be part of the assignment, or you might choose your audience.
5. Consider the age, reading ability, interests, and other aspects of your audience when designing your project.
6. How much time will your audience have to take in your information?

Medium

7. How do you want to present your information? Consider the time, resources, and goals of your project.
8. Consider: art, dance, music, posters, podcasts, flyers, murals, skits, videos, games, lessons, demonstrations, etc. What skills does your group have that could be used?

Platform

9. Where will your information be presented? Does the platform affect the medium? (For example, if everyone's projects will be in the same space, audio may be difficult to here.)
10. Does your platform meet your audience? (For example, if you are doing a social media campaign, but your audience is elementary-aged kids, you may need to rethink.)

Check Your Goal

11. After you finalize your plan but before you begin making your project, check that your project still meets your goal – does it simply and easily explain the Ocean Literacy Principle you were assigned?