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OCEAN!

Part 4:

Ocean and Heat

SUSTAINABLE DEVELOPMENT GOALS

developed by

Smithsonian
Science Education Center

in collaboration with

iap SCIENCE HEALTH POLICY
the interacademy partnership

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PART 4: OCEAN AND HEAT

Part 4

Find out More!

For additional resources and activities, please visit the *Ocean!* StoryMap at bit.ly/OCEAN2030.

Planner

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 1: How do ocean systems help regulate Earth's temperature?					
Discover	Explore how temperature affects you and your community, and begin to diagram this system.	• Paper or poster board • Pen, marker, or pencil	*Personal Identity Map*	25 minutes	129
Understand	Model how water acts as a heat sink and how density due to differences in temperature and salinity cause deep water currents.	• 2 identical boxes • 3 transparent water containers • Plastic wrap • Tape or rubber bands • Heat source • thermometers (optional) • Hot and cold water • Food coloring • Salt	*Ocean and Temperature System Diagram* *Ocean Identity Map*	45 minutes	133
Act	Analyze the ocean and global temperature system from different perspectives and share the important role the ocean plays in keeping Earth habitable.	• Markers, colored pencils, or crayons • Paper	*Ocean Identity Map*	25 minutes	140

Activity	Description	Materials and Technology	Additional Materials	Approximate Timing	Page Number
Task 2: How will a warming ocean affect people and the planet?					
Discover	Using real-world data as a basis, explore the changes caused by rising ocean heat energy in ocean systems and in your community.	• Colored pens or markers	*Ocean and Temperature System Diagram* *Ocean Identity Map*	20 minutes + investigation time	142
Understand	Investigate the concept of feedback loops in systems and model a feedback loop related to ice and reflectivity.	• White paper • Black paper • 10 to 20 ice cubes or 2 cupfuls of ice or snow • Timer • Sunlight	*Ocean and Temperature System Diagram*	35 minutes	147
Act	Decide what you think is important to know about the changing ocean and why we need to change our behavior. Create and share a way of expressing yourself.	• Any materials you need for your method of expression	*Ocean Identity Map* *Personal Identity Map* *Ocean and Temperature System Diagram*	15 minutes + Creation time	152

Part 4 Planner

Meet Your Research Mentor

Meet Dr. Jan Marcin Węsławski. Marcin (pronounced *Mar-CHIN*) will be your research mentor to help you understand more about the effect of temperature and heat on Earth's ocean.

Marcin is the director of the Institute of Oceanology at the Polish Academy of Sciences. He studies arctic ecosystems and how climate change is impacting biodiversity. He has a doctoral degree in biological oceanography. However, he also has knowledge and perspectives that come from other parts of his identity. Since Marcin is now working with you, it is important to understand who he is.

Marcin's Identity Map

- Male
- 68 years old
- Marine biologist-oceanographer
- Educated at University of Gdansk, Poland
- White, Polish, Central European
- Lives in Gdynia, Baltic Sea Coast, Poland
- Husband, father, grandfather, and brother
- Bald with a white beard and blue eyes
- Calm, tolerant, and curious
- Rather tall, 190cm (6′2″)
- Canoeist and birder
- Enjoys traditional archery and the outdoors
- Poland, Norway, and the Arctic are important
- A fan of Tolkien and books on nature, history, and fantasy
- Values undisturbed nature, kindness, and courage
- Values freedom, democracy, liberal values, and mindfulnesss
- Researcher, field ecologist, and director of large research institute
- Interested in evolution of life, climate change, and biodiversity

Part 4

Task 1: How does the ocean help regulate Earth's temperature?

Have you ever gone into a body of water on a hot day and found it refreshingly cool? Have you ever waited impatiently for water to boil? Water has a high **heat capacity**. That means it takes a lot of heat energy to raise or lower the temperature of water. Water absorbs and releases heat much more slowly than land or air. This ability of water to absorb a lot of heat energy makes it a **heat sink**.

The water of the ocean is the world's largest and most important heat sink. Earth's temperature and climate depend on the ocean's ability to absorb energy in the form of heat from the atmosphere. In this task you will ***discover*** how the ocean's temperature regulation role affects you and your local community. You will model the ocean's temperature regulation to ***understand*** how it works. Then you will ***act*** to share what you learned about the system of temperature and the ocean.

Before you begin the rest of Part 4, think quietly to yourself about Marcin's identity map and compare it to your *Personal Identity Map*.

- Are there things you have in common with Marcin?
- Are there ways in which you are different from Marcin?
- Can you see anything about Marcin's identity that relates to understanding the ocean system?

Throughout Part 4 you will notice Marcin sharing ideas and experiences with you. He may help you understand better ways to do your research or share some of the research he has done.

Discover: *How does the global temperature regulation system affect my community?*

Temperature affects our daily life and many things about our communities. The air temperature outside can be an important part of many decisions you make. Even though the temperature may change every day for you, there is still a range of how hot and cold it gets at your location. And in some places, temperatures change a lot in different seasons.

1. Think quietly to yourself, how hot does it get in your area? How cold does it get? What are some of the daily choices you make that are influenced by the temperature outside?
2. Take out your *Personal Identity Map* and examine it. Are there parts of your identity that are related to the typical range of temperatures where you live?
3. Have each member of your team share one choice or thing about their daily life that would be different if you lived in a place with a different temperature range.
4. As a team, take out a piece of paper and near the top add the words "people" and "air temperature." Draw a box around each word.
5. Break your team into four topic groups: food production, culture, environment, and economy.
6. In your topic group, think about the effect of temperature on your topic in your community. If it helps, you can consider how things would be different if temperatures were much higher or lower in your community. For example:
   a. For food production, how does the food produced in your area depend on the temperature and weather?
   b. For culture, how has temperature affected the habits and customs of people? For example, what people wear or what they do for fun.
   c. For environment, how does temperature affect both the natural and human-built environments around you?
   d. For economy, how does temperature affect the jobs people have and the industries in your area?
7. Draw an arrow from *air temperature* to *people*. Have each group add a few words to the arrow describing what they thought about in step 6. The arrow should now be labeled with ways air temperature affects people in your community.
8. Title this paper "Ocean and Temperature System Diagram." On one side add the words "ocean water." On the other side add the words "sun," "land," and "atmosphere."
9. Read *Heat Sink and Redistributor*.

Heat Sink and Redistributor

Energy from the sun, also called **solar radiation**, is the reason Earth is not freezing. Some solar radiation bounces off Earth back into outer space. Around half of it is absorbed by Earth's land or water. Most of that solar radiation is absorbed by ocean water.

a. Draw and label arrows between *sun*, *land*, and *ocean water* on your *Ocean and Temperature System Diagram* to show what happens to solar radiation that is absorbed when it reaches Earth.

The remaining solar radiation is trapped by the blanket of our atmosphere and warms the air.

b. Draw and label arrows from *sun* to *atmosphere* to *air temperature* to show how solar radiation that is trapped by the atmosphere causes the air temperature to rise.

Heat Sink

The ocean covers around 71% of Earth's surface area. Ocean water can absorb a lot of solar radiation without changing temperature. This makes it an incredible heat sink. In fact, some scientists estimate that if there was no ocean absorbing heat, the average global temperature would rise from 15°C (59°F) to 50°C (122°F). But a higher average global temperature is not the whole story of the impact of the ocean on global temperatures.

c. Draw an arrow from *ocean* to *air temperature*. Label it with a few words to help you remember how the heat sink of ocean water absorbs heat and keeps Earth's air temperature lower.

Heat Redistributor

The ocean's role goes beyond just absorbing heat. It also moves the heat around the planet. The area around Earth's equator, called the **tropics**, receives much more heat from solar radiation. Because of their position, Earth's poles receive much less heat from solar radiation.

d. Add two new elements, "tropical ocean" and "polar ocean," near the *ocean* element in your *Ocean and Temperature System Diagram*.

e. Draw an arrow from *sun* to *tropical ocean* and label it "more heat."

f. Draw an arrow from *sun* to *polar ocean* and label it "less heat."

The ocean moves heat from the tropics to the poles. Water warmed in the tropical ocean moves through ocean currents toward the poles, distributing heat along the way. When the ocean cools towards the poles, the cool water cycles back toward the equator. Without the ocean, the area around the equator would be much hotter and the area nearer the poles would be much colder.

g. Draw and label an arrow to show what happens to heat as water moves from the *tropical ocean* to the *polar ocean*.

h. Draw and label an arrow to show what happens as water moves from the *polar ocean* to the *tropical ocean*.

Part 4 Task 1

10. Examine the map in Figure 4.1 and find your location.

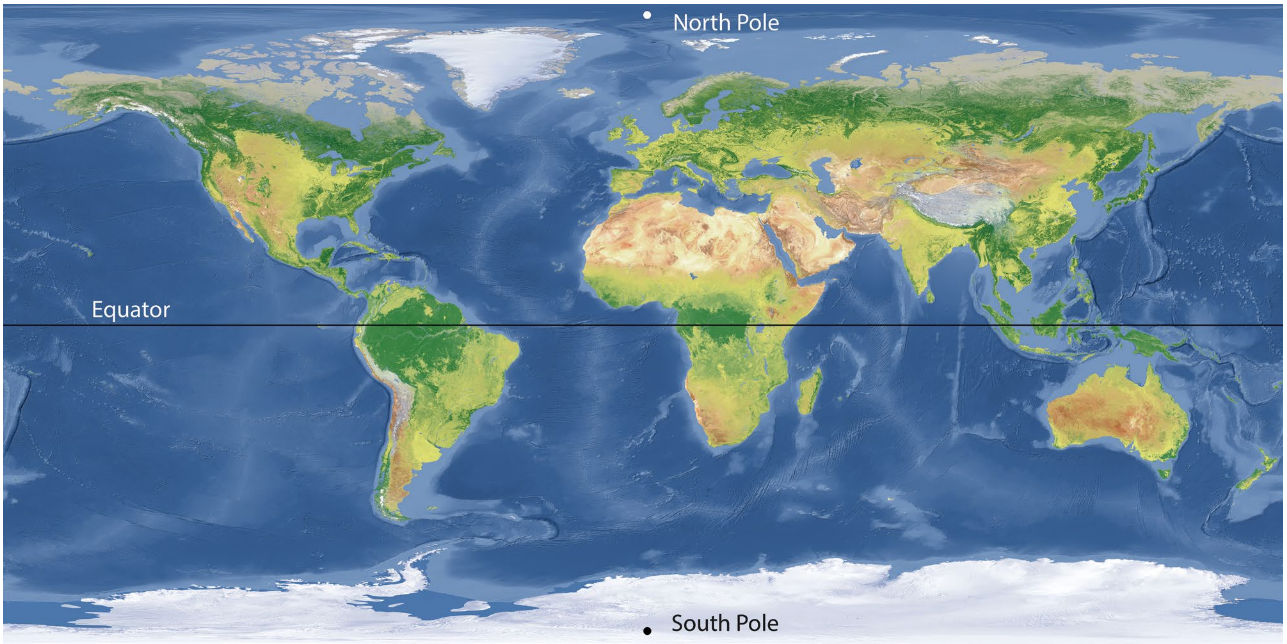

Figure 4.1: Map of the world.

11. Think with your team:
    a. Are you closer to the equator or to a pole?
    b. How might your community's temperature change if you did not have the ocean redistributing energy from the sun? Would it get hotter, cooler, or remain around the same?

c. If you are closer to the equator, your average temperature would be hotter. If you are closer to a pole, your average temperature would be cooler.

12. Examine your *Ocean and Temperature System Diagram* arrow between *air temperature* and *people*. Think about how that relationship might change if your average temperature changed. For example, if your community is far away from the equator, you might think temperatures would be cooler and it would be harder to be outside to play sports.
13. Keep your *Ocean and Temperature System Diagram.* You will need it throughout this part.

***Understand**: How do ocean systems regulate temperature?*

You know that the ocean helps regulate Earth's temperature. But how does this system work? In this activity you will be modeling some different relationships between the water of the ocean and heat.

1. Divide your team into two groups.
2. Have each group complete either *Modeling the Ocean as a Heat Sink* or *Modeling Water Density in the Ocean.*
3. If you have time, switch, so both groups do both investigations.

Modeling the Ocean as a Heat Sink

What makes the water of the ocean so good at absorbing heat? Water has a very high heat capacity. It takes a lot of heat energy for the temperature of water to change even one degree. You learned that the ocean is a heat sink, but how does this work in practice?

Modeling Instructions

a. Gather your materials. You will need:
- 2 identical boxes made out of cardboard or other materials (shoeboxes work well)
- 1 container of water that will cover most of the bottom of a box

- Clear plastic wrap (cling film) to cover the top of the boxes
- Tape or rubber bands to secure the plastic wrap
- A heat source, such as sunlight, a warm light bulb, a heating pad or blanket, or a radiator. You can also use hot air from a hair dryer.
- 2 thermometers (optional)

b. Build your models by removing the top part of each box.
c. Place your boxes where they will have access to the heat source (either in sunlight or near another source of heat).
d. Fill the container with cool water and place it in one box.
e. If you are using thermometers, attach them so they measure the temperature inside the box.
f. Secure the plastic film so that it completely covers each box. Figure 4.2 shows an example.

Figure 4.2: Heat sink model setup; the box on the left has a container with water, the box on the right does not.

g. Leave the boxes near the heat source for around 15 minutes. Or, if you are using a hair dryer, blow hot air inside for 3 to 5 seconds.
h. Answer the *While You Are Waiting Questions*.
i. Return and measure the temperature in each box.
j. If you do not have a thermometer, just slip a hand below the plastic wrap in each box. Do you notice a difference in temperature?

Part 4 Task 1

While You Are Waiting Questions

Discuss with your group what you think might happen.

- Will the two boxes be the same temperature or different after you return?
- Why do you think that?
- Examine your *Ocean and Temperature System Diagram*. You just modeled a relationship between three of your elements. Which three do you think it was?

Review your results. As a group, think about whether your results would be different if the water was warmer when you added it to the box. Would it still help keep the air cooler?

You just modeled the relationship between the sun (your heat source), the ocean water (the water in your model), and air temperature.

Modeling Water Density in the Ocean

If you think about a container of water, you can probably imagine things that float on the top of it or sink to the bottom. Things that are less dense than water float. Things that are more dense than water sink. **Density** is a characteristic that describes how much mass is contained within a specific volume.

Imagine you have a small box half filled with rocks. The mass of the rocks compared to the volume of the box determines the density of rocks within the box. What if you added more rocks to the box? Then the mass of the rocks would increase and the volume would stay the same. The density of rocks inside the box would be greater. What if you took the same amount of rocks but put them in a much bigger box? There would be the same mass of rocks in a much bigger volume, so the density of rocks would be smaller.

Ocean water can be more or less dense. Less dense water tends to float near the top of the ocean. Denser water tends to sink to the deep sea. What do you think could cause differences in water density in the ocean?

Part 4 Task 1

Temperature

One of the most important characteristics of ocean water is its temperature. When water is warmer its volume expands. If the volume of the water increases, what do you think happens to the density? (Remember the example of the volume of the box increasing to help you think about this concept.)

Depending on where it is in the ocean, water temperatures can be very different. You can model what happens when cold water meets warm water.

a. Gather your materials. You will need:
   - A transparent water container that can hold hot water
   - A second container for cold water
   - Food coloring, or something similar to dye the water, such as tea leaves
b. Fill one container with hot water.
c. Fill the other container with very cold water. Add some food coloring to the cold water to make it easier to observe.
d. Gently pour the cold water down the inside edge of the container with the hot water. Figure 4.3 shows an example.
e. Observe closely. Where is most of the colored, cold water? What kind of water movement do you observe?
f. With your team, discuss: Do you think water is denser when it is hot or when it is cold?

Figure 4.3: Setup example for density and salinity modeling.

Salinity

Another important characteristic of ocean water is its **salinity**. Salinity means how much salt is dissolved in the water. Although all parts of the ocean are salty, some parts are saltier than others. The more salt that's dissolved in water, the greater the mass. If the mass increases, what do you think happens to the density? (Remember the example of adding mass to your box of rocks to help you think about this concept.)

Temperature has a big effect on salinity. When water evaporates the salt does not evaporate, so the water left behind is more saline (salty). When sea ice forms it does not include salt, so the water left behind will be more saline.

a. Gather your materials. You will need:
   - 2 transparent water containers
   - Food coloring or something similar to dye the water, such as tea leaves
   - Salt

b. Fill one container with water. Mix in half a spoonful of salt. Stir to dissolve.

c. Fill the other container with about the same amount of water and mix in three to four spoonfuls of salt. Stir to dissolve. Add food coloring to this saltier water to make it easier to observe.

d. Gently pour the colored water down the inside edge of the container with the uncolored water. Figure 4.3 shows an example.

e. Observe closely. Where is most of the colored, saltier water? What kind of water movement do you observe?

f. With your team, discuss: Do you think water is denser when the salinity is higher?

If you have time, you can combine the two experiments, thinking about how temperature and salinity together affect density.

Discuss what you observed.

a. For each experiment, which type of water sank because it had a higher density?

b. What do you think might be causing changing temperatures or salinity in the water of the ocean? Hint: Go back and read the paragraphs under *Temperature* and *Salinity* if you need ideas. Where in the ocean would you predict denser water sinking to the ocean floor?

c. Draw an arrow from *air temperature* to *ocean* on your *Ocean and Temperature System Diagram*. Label the arrow with what you just learned about how temperature affects the density and salinity of the ocean.

4. If both groups did not have a chance to do both activities, share your model, your results, and your additions to your system diagram with the other group.
5. Read *The Global Ocean Conveyor Belt* to find out how temperature and salinity work together to create vertical currents in Earth's ocean.

The Global Ocean Conveyor Belt

You learned in Part 2 that the ocean has many surface currents driven by wind. It also has a very important deep-water current that travels the entire globe. This current is called the **Global Ocean Conveyor Belt**. Water from the surface goes down deep in the ocean and travels from pole to pole and beyond. It takes around 1,000 years for one drop of water to move all the way through the current. Figure 4.4 shows the path of the Global Ocean Conveyor Belt. It may appear to be on the surface, but the cold currents are moving the water deep in the ocean.

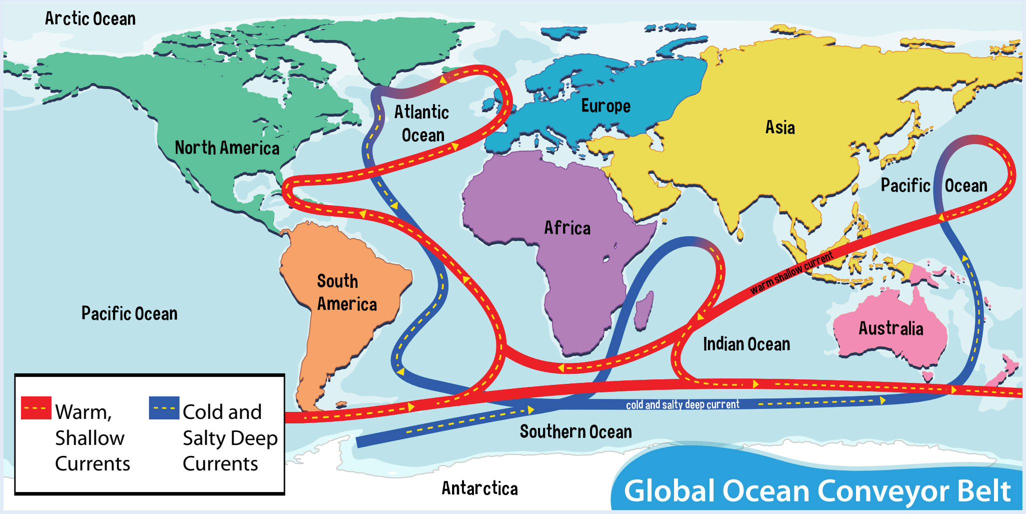

Figure 4.4: World map showing the Global Ocean Conveyor Belt ocean current.

Part 4 Task 1

This vertical deep-water current is driven by differences in density. Cold, salty, dense water is created when sea ice forms in the polar ocean near the North Pole. This dense water sinks, taking some of the heat from the sun and oxygen from the air with it. This helps organisms in the deep ocean survive.

The water comes up again, often thousands of kilometers away, in a process called **upwelling**. Upwelling water carries with it many nutrients that have fallen into the deep ocean. These nutrients help organisms near the ocean's surface thrive. The Global Ocean Conveyor Belt mixes heat, oxygen, and nutrients globally.

6. Add "Global Ocean Conveyor Belt" and "organisms" as elements your *Ocean and Temperature System Diagram*.
7. Draw and label arrows to connect the *Global Ocean Conveyor Belt* to other elements, such as the *polar ocean* and *organisms*. You may want to include that when the dense water sinks in the polar ocean, it takes heat and oxygen with it. When the deep water upwells, it brings nutrients with it. This mixing helps ocean organisms survive.
8. Read Marcin's thoughts. Are there any hopes or concerns you have about the Global Ocean Conveyor Belt? If so, add them to the *Concerns* circle on your *Ocean Identity Map*.

Marcin says . . .

The Global Ocean Conveyor Belt is extremely important in transporting oxygen. Without it, the bottom of the ocean would be almost dead, with only microbes. So we need it badly, and I hope it will continue to work even with warmer waters. It will be slower, though, and work much less efficiently than today.

Part 4 Task 1

Act: *How can we share the ocean's role in keeping Earth comfortable for us?*

The ocean's ability to regulate temperature is one of the major reasons Earth is **habitable**, or a place where people can live. This also means we are very dependent on the ocean's ability to keep our planet comfortable. How can we help the ocean system keep fulfilling this important role?

1. Break into four groups and assign each group one perspective: **social, environmental, economic,** or **ethical**.
2. Think about what you have learned about the ocean's role as a heat sink and redistributor. Why is this important from your group's perspective? For example:
   a. Social perspective: Why is this system important for human health, education, well-being, and social interactions?
   b. Environmental perspective: Why is this system important for the living and non-living things in the natural world?
   c. Economic perspective: Why is this system important for economies, jobs, and industry?
   d. Ethical perspective: In what way does this system help create a world that is fairer?
3. With your group, imagine an alien was considering a trip to Earth. What are the great things about Earth that are only possible because the ocean is regulating the planet's temperature?
4. Create a poster that shows how the ocean's temperature regulation makes Earth a better place to live from your perspective.
5. Share your posters with one another and with others outside your team.
6. Discuss with others how the ocean helps keep Earth a place where people can easily live and why it is important to help the ocean keep filling that role.
7. Take out your *Ocean Identity Map* and add any connections you have noticed between people and the ocean's role in regulating Earth's temperature.
8. Read Marcin's thoughts. Is there one thing he discusses that concerns you about Earth's changing temperature?

Marcin says . . .

Earth's temperature has varied a lot over millions of years. But the present-day richness of life evolved in relatively stable temperatures following the last Ice Age. The temperature and chemistry of the water and atmosphere have been a driving factor in the species that are currently on Earth. Humans are now changing the temperature and chemistry of the planet—and alterations in the living world will follow. Those processes are so complicated, they cannot be predicted precisely.

Certainly, if we care for the importance of the natural world and the conditions we know, we should slow down the changes in the physical world, to give the life on Earth time to adapt.

9. Take a moment for gratitude. Is there one thing in your life that you are particularly grateful for today that would not happen if the average temperature in your community was very different? Connect that thing to the ocean's role in regulating global temperature. If the ocean was a person, what words would you use to thank it for making that part of your life possible?

Part 4 Task 1

Task 2: How will a warming ocean affect people and the planet?

As the ocean warms, it may affect people and ocean systems in a wide variety of ways. In this task you will first ***discover*** how a warming ocean might affect your community. Then you will investigate to ***understand*** the impact of feedback loops on the system of the ocean and temperature. Finally, you will ***act*** to either try to slow the warming of the ocean or adapt to its impacts.

Discover: *How is my community vulnerable to impacts from a warming ocean?*

As we have discussed, humans are adding a lot of **greenhouse gases** to the atmosphere, often by burning fossil fuels. Greenhouse gases in the atmosphere, such as carbon dioxide, trap energy from the sun that reaches Earth. Increasing greenhouse gases means additional heat stays on Earth. The ocean has absorbed more than 90% of the additional warming that has occurred across Earth in recent decades. But as the ocean absorbs additional heat, it changes the ocean system. In this activity you will explore how these changes may affect you and others in your community.

1. Examine Figure 4.5, which shows a graph of changes in ocean heat energy since 1955. Energy in the form of heat is measured in zettajoules in this graph. A zettajoule is a huge measure of energy! To help you understand how big it is, all the energy people use globally for a whole year is around half a zettajoule.

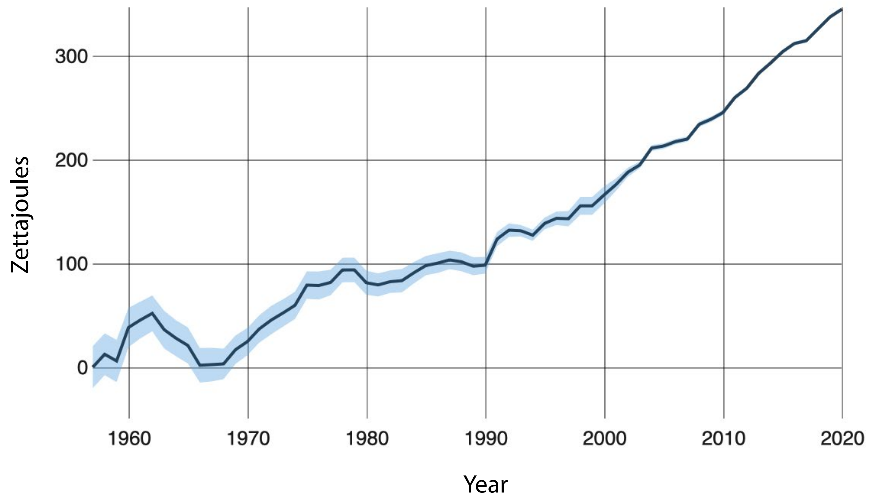

Figure 4.5: Heat energy in the ocean from 1955 to 2020[1].

2. Use Figure 4.5 to answer these questions with your team.
    a. What do you notice about the amount of heat energy in the ocean over time?
    b. What is your prediction about how the rise in heat energy is affecting the temperature of the ocean? Remember, as water absorbs heat, the temperature slowly goes up.
    c. Examine your prediction. Scientists measure the sea surface temperature at locations around the world. If you compare the global sea surface temperature in 2022 with the average for 1901 to 2000, 2022 was warmer by 0.67°C. In fact, the sea surface temperature has been warmer than the average of the 1900s every year since 1976[2]. Is this what you would have predicted?
3. Take out your *Ocean and Temperature System Diagram*. Draw a large rectangle as a system boundary that surrounds all your elements, such as the one shown in Figure 1.6.
4. Take out a new color of pen or a marker.
5. Add a new *Addition* arrow labeled "heat" to your diagram. This shows the additional heat the ocean is absorbing due to global warming.
6. With your new pen or marker draw a "+" sign next to any of the arrows where you think more heat in the system might mean a change in the relationship. For example, more heat in the system might raise *air temperature* and change its relationship to *people*.
7. Read *At the Smithsonian* to learn more about how Smithsonian researchers are working to help ocean organisms struggling with increased heat and temperature in ocean water.

At the Smithsonian

The bright coral you may be familiar with is the result of **symbiosis,** or a relationship between two species that benefits both. Healthy coral lives in symbiosis with algae. However, when the water around coral gets too hot, algae is pushed out

Part 4 Task 2

and the coral turns white or lighter, a process known as **coral bleaching**. Although bleached coral is not dead, it is very stressed and has difficulty surviving. As the ocean becomes a more difficult place for corals to live, is there a way to help them survive into the future? One research team at the Smithsonian Conservation Biology Institute is trying do just that, using freezing techniques to preserve corals for future generations.

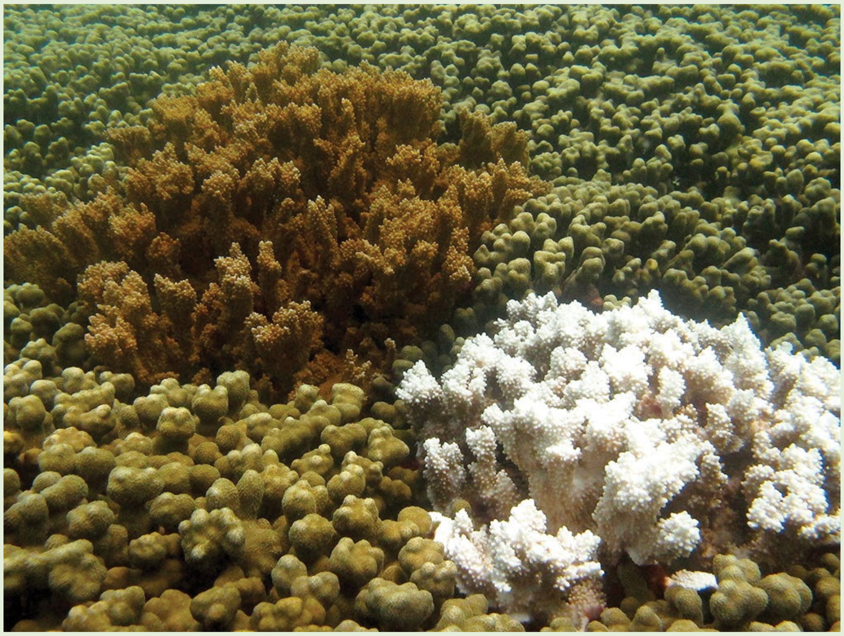

Figure 4.6: Example of bleached coral (white, right) amid unbleached coral.

Team member Claire Lager explains why this is important. "I had been working in monitoring of coral reefs and I felt like I was just watching the coral disappear. So when I joined this project, it was exciting to think we could actually do something to help save corals for **biodiversity**. Our team has been working to freeze coral larvae, the **symbiotic algae**, and one of our big projects now is to try to freeze a whole coral fragment. I am doing science still, but it now has a direct conservation aspect to it."

Fellow team member Dr. Mike Henley adds, "I wanted to do more than just say that everything was going wrong. I wanted to help. I was working at the Smithsonian National Zoo and we started thinking about zoos as living arks where species could survive while we found a way to combat climate change."

Part 4 Task 2

Figure 4.7: Mike Henley diving to study a coral reef ecosystem.

As water temperatures rise, so do the effects on the coral reef ecosystems. Dr. Mary Hagedorn leads the research team trying to conserve corals. She says, "When you have a warming event in the ocean, it can impact the corals for many years. We talk about an individual species, like coral, but sometimes we don't talk about all the other species that depend on it. It really is this web of life that gets destroyed, not just a coral that goes extinct or a fish that goes away. There is a compounded effect on biodiversity."

8. Think with your team, are there any other relationships you think might change with increased heat? For example, how do you think increased temperature might affect living things other than humans?
9. Follow the directions in *My Community and a Warming Ocean*.

My Community and a Warming Ocean

As the ocean absorbs heat and warms, there are many changes for people. Here are three concerns that affect many human communities.

1. **Sea level rise:** As water gets warmer, it takes up more space; this is called **thermal expansion**. If ice on land, such as a glacier, melts and that

Part 4 Task 2

water enters the ocean, there is more water in the ocean. As global heat increases, thermal expansion and land ice melt mean the sea level around the world is rising. This is a threat to many communities that live near the ocean.

2. **Extreme weather:** In a warming ocean more water evaporates into the air. This increasing amount of water vapor changes weather patterns. Extreme weather is becoming more common. Hurricanes and typhoons are becoming more powerful. Precipitation patterns are changing, with some places having long periods of drought. Drought is often linked to wildfires. Other places have increasing rain or snow, leading to flooding.
3. **Ocean ecosystem changes:** A warming ocean means a changing habitat for the living things of the ocean. Some animals, such as fish, may **migrate** to a new area to find temperatures that are more comfortable for them. Others, such as coral, may find it impossible to move quickly to new habitats. Organisms that cannot migrate easily may find it difficult to survive in a warming ocean. Migrating organisms may find themselves in new competition for habitats as species move. This may cause changes to fisheries and ocean ecosystems that are linked to tourism.

Community Investigation

a. With your team or a smaller group, pick one of the three warming ocean changes to investigate within your own community.
b. Decide how you will find out more about the changes that have happened and might happen in your community. For example:
   - Is there an expert or an organization in your community that might know more?
   - Is there information you could gather online or from a local source about changes that have already happened in your community, such as recent historical weather patterns?
   - Is there information you could gather about what might happen in the future, such as a map of potential sea level rise?
c. The *Ocean!* StoryMap has some resources to help you with this investigation.
d. Make notes so you can remember what you have learned.

e. Share what you have learned with the rest of your team and discuss: What are the biggest threats to our community from a warming ocean?

⚠ Emotional Safety Tip

Thinking about terrible things that might happen in the future can be scary and stressful. No bad or catastrophic outcomes are already decided. By understanding issues that concern you now, you can become part of the effort to prevent these outcomes. Scientists and others around the world are also working hard to prevent these types of outcomes.

10. Read Marcin's thoughts. Is there anything you didn't think about that might affect your community because of changing ocean temperatures?

Marcin says . . .

Changing ocean temperatures are changing many things about the species of the ocean. For example, the ocean food system is controlled by plankton and microorganisms. Plankton quickly react and grow as the ocean temperature rises. This changes the system. People sometimes only think of large things in the ocean, like whales and big fish, but these are just the tiny tip of the whole system.

***Understand**: What are the concerns about a warming ocean?*

Data shows us that the ocean is warming. But there is still some uncertainty about exactly what will happen as the ocean warms. It can also be difficult to know exactly when changes will happen. In complex systems like the ocean, there can be processes that either balance the system or make it unbalanced. These processes are called **feedback loops**. In this activity you will explore more about the feedback loops related to ice and the ocean.

1. Read *What Is a Feedback Loop?*

What Is a Feedback Loop?

Many systems have feedback loops. Think of the system of you, your behavior, and your friends as an example.

Imagine making a joke. Your friends laugh. You like making them laugh, so you are more likely to make jokes like that in future. If the response makes a thing happen more and more often, that is a **reinforcing feedback loop**.

What if this turned out another way? Imagine making your joke, but your friends don't think it's funny. You don't like that, so you are less likely to make similar jokes in the future. If the response regulates the system so it goes back to being more like it was before, that is a **balancing feedback loop**.

The same is true in natural systems. A reinforcing feedback loop means the changes to the system get bigger or more frequent over time. A balancing feedback loop helps regulate the system so it remains the same.

2. Examine your *Ocean and Temperature System Diagram*. Do you notice any places where there might be feedback loops? For example, *people* may burn fossil fuels, which changes the *atmosphere,* which changes the *air temperature,* which may make *people* burn more fossil fuels for air conditioning to keep cool. This is a reinforcing feedback loop. The change to the system become bigger over time.
3. Do the *Ice Feedback Loop Investigation*.

Ice Feedback Loop Investigation

You have probably realized that as temperatures rise, ice and snow tend to melt. But you may not have thought about a feedback loop related to the **albedo** of ice and snow. Albedo means how much light a material reflects. The word may be unfamiliar, but you probably know the concept. For example, if you are going outside on a sunny day, would you be cooler in a white shirt or a black shirt? Probably a white shirt, because a black shirt will absorb more heat energy from the sun. In this investigation you will explore how albedo relates to sea ice, snow, ice sheets, and glaciers.

a. Gather your materials. You will need:
   - 1 sheet of white paper (thick paper or cardstock works best)
   - 1 sheet of black or dark paper (thick paper or cardstock works best)
   - 10 to 20 ice cubes or 2 cupfuls of crushed ice or snow
   - A timer

b. Place both sheets of paper in the sunlight. Note: This investigation will only work if the air temperature is above freezing. If the outdoor air temperature is below freezing, try to do this indoors on a sunny windowsill.

c. Divide the ice evenly and place it in the same pattern on both pieces of paper. Figure 4.8 shows an example.

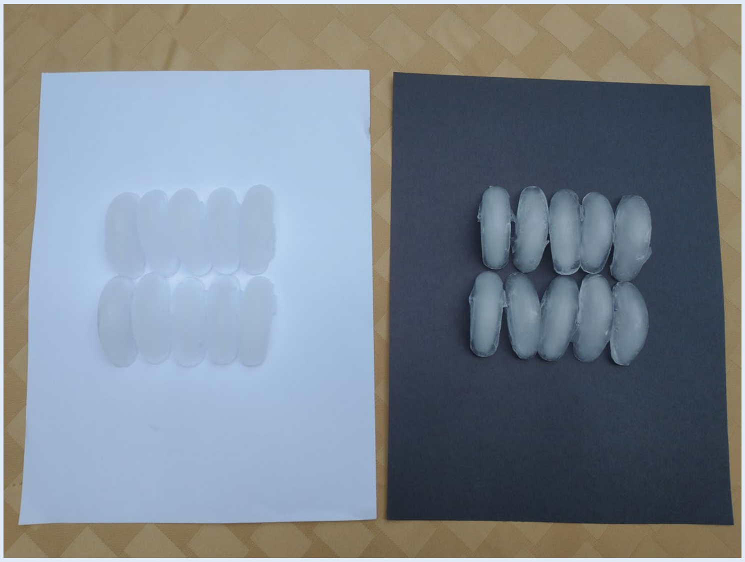

Figure 4.8: Example of the Ice Feedback Loop Investigation setup.

d. Start your timer.

e. Observe each piece of paper.

f. Note down how long it takes for all the ice to melt on each piece of paper.

Discuss and Apply

Discuss with your team:

a. Which sheet of paper had all the ice melt first?

b. Do you think the white paper or the black paper has a higher albedo? Which one absorbs more heat?

c. How does this relate to ice formation and melting near Earth's poles?
Try to rank this list from highest albedo (most reflection) to lowest (most absorption):

- Open ocean
- Newly fallen snow
- Dry soil
- Old (dirty) snow
- Snow-covered sea ice
- Melting snow

d. How could rising temperatures, ice and snow, and ocean water and the albedo of light versus dark together combine to make a reinforcing feedback loop?

After you have ranked the albedo, you can check your answers here. Newly fallen snow has the highest albedo and can reflect more than 90% of the solar radiation that hits it. Snow-covered sea ice reflects about 70%, old (dirty) snow about 50% to 60%, melting snow around 50%, dry soil 15% to 20%, and the open ocean around 8%.

Part 4 Task 2

4. Where do you think you could add details of the ice and albedo feedback loop to your *Ocean and Temperature System Diagram*? If you would like, add additional elements and arrows to show that feedback loop.
5. Examine the + signs on your system diagram and think about changes you can think of caused by increased heat in the system.
6. Read about Marcin's experience in the Baltic Sea. Is what he describes similar to what you thought might happen because of an increase in heat?

Marcin says . . .

The Baltic Sea, which I study, used to be very cold; now it's much warmer. It's relatively shallow and there's no ice now, so there's a lot of sunlight and the whole system is working probably twice as fast as before. The Baltic Sea is becoming very strongly **stratified,** which means the light fresh water sits on the top, and the heavy salty water is down below. In the past we had ice, but now it is often not cold enough to create ice anymore. That means the water at the top does not get cool enough to sink, and so it stays on the surface. Oxygen only comes to the bottom during this mixing as the cool water sinks. Instead, the bottom layer is slowly getting deoxygenated, which means fewer things can live there. All of these changes affect the fish and other living things that are in the Baltic Sea. People who fish are struggling more and more to get a good catch.

7. Read *Ocean Slowdown*.

Ocean Slowdown

You learned about the Global Ocean Conveyor Belt and added it to your *Ocean and Temperature System Diagram*. Examine that system within a system carefully. Do you notice anything that might mean the system would not work as well at higher temperatures and as the ice albedo reinforcing feedback loop occurs?

Climbing ocean temperatures means less sea ice formation. Combined with fresh water runoff because of melting glaciers, the result is that water on the surface at the poles is warmer, less salty, and therefore less dense. Since increased density drives the Global Ocean Conveyor Belt, the current is slowing down. Examine Figure 4.9 showing the way the Global Ocean Conveyor Belt moves. What do you think would change if the current slowed or stopped?

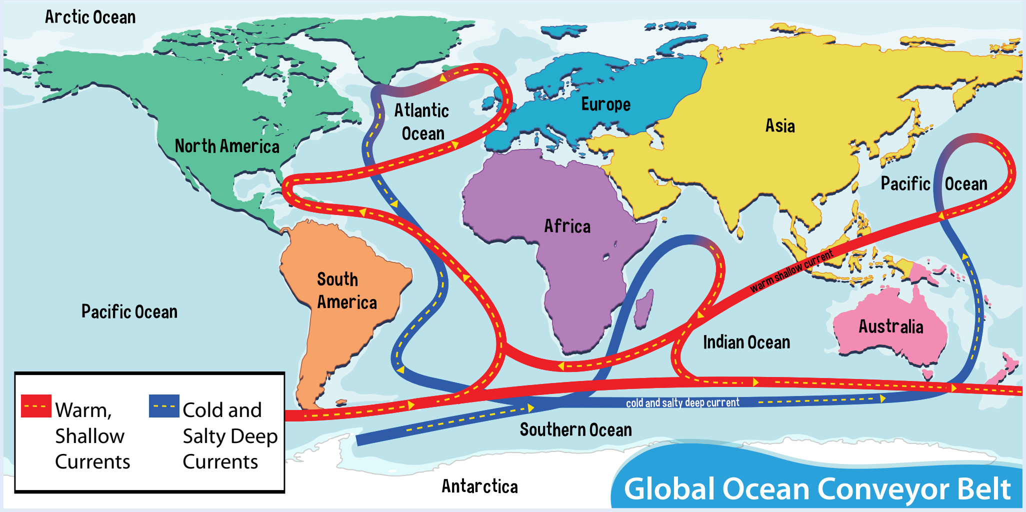

Figure 4.9: Map of the Global Ocean Conveyor Belt.

Part 4 Task 2

As you learned in Task 1, the Global Ocean Conveyor Belt is an important distributor of heat. Many scientists believe this conveyor belt may have stopped or slowed in the distant past, with dramatic consequences, including very sudden extreme cooling in some areas. How do you think the consequences might be different in different places?

The upwelling from the Global Ocean Conveyor Belt also mixes nutrients from the bottom of the ocean that are essential for ocean ecosystems. Places where upwelling happens often have a lot of fish.

If warm water sits on the top of the ocean and does not mix with the cold water toward the bottom, the water is said to be stratified. This is a problem. Cold water at the bottom has many nutrients needed by the organisms in the upper, sunlit ocean. The oxygen dissolved in the warm, upper layers of the ocean is needed by deep-water organisms. Often the warmer the ocean is, the more stratified it becomes. More stratified water is challenging for organisms.

8. Examine your _Ocean and Temperature System Diagram_ and discuss with your team the concerns you have about the impact of increasing heat on the ocean. Be sure to consider:
    a. Impacts of changes to ocean temperature on people and other living things
    b. Impacts of changes to the Global Ocean Conveyor Belt
9. Add your concerns to the *Concerns* circle on your _Ocean Identity Map_.

Act: *What will we do about the warming of the ocean?*

There is a lot to be concerned about related to a warming ocean. But catastrophic consequences are not inevitable. The sooner we start to act, the more effective those actions can be. Each of us can make choices that can make a difference to the warming of the ocean.

1. Read Marcin's thoughts about a changing ocean and temperature system.

Marcin says . . .

The world is changing rapidly. In some places the changes are dramatic. In other places, species are changing. This change might be good or bad, depending on your perspective. But it is not easily predictable. It is not simple. The system of the ocean works at its own speed, with its own logic. It is not built to serve people.

2. Take a moment to think quietly to yourself: How do you feel about the changes you learned about to the ocean and temperature system?

⚠ **Emotional Safety Tip**

Thinking about bad things that might happen in the future can be scary and stressful. Whatever you are feeling is okay. Just remember, no catastrophic outcomes are already decided. By understanding issues that concern you now, you can become part of the effort to prevent these outcomes. Scientists and others around the world are also working hard to prevent these types of outcomes.

3. Take out your *Ocean Identity Map*. What do you hope for the future of the ocean and its temperature? Add those to the *Hopes* circle.
4. Take out your *Personal Identity Map*. Examine it carefully. Is there anything on your identity map that shows how you like to express yourself and share your ideas? For example, do you like writing or dancing or talking with your friends?
5. Pick one way you feel comfortable expressing your ideas and feelings to others. If you are having trouble thinking of an idea, you can read *Expression Strategies*.

Expression Strategies

There are many ways to express yourself when communicating with others. Which ones will work best depends on the information you are trying to share, the way people around you are used to getting information, and your own preferences. Here are a few methods to consider.

Writing

Writing can take many forms: essays, pamphlets, news reports, fictional stories, poetry, social media posts, and many others. Some people feel most comfortable giving and receiving information in written form.

Storytelling

Sharing stories can be an important way to communicate ideas. Stories are sometimes shared through public speaking, recorded in a podcast or video, or presented dramatically on stage. Some people prefer to use stories to give or receive information.

Visual and Performance Art

There are many different art forms that can be used to share information and encourage others to consider new perspectives. Visual arts like painting, drawing, sculpture, printmaking, textiles, and photography, and performance arts like dance and music can be powerful ways of communicating. Some people feel most comfortable giving and receiving information shared through an artistic medium.

Digital Communication

Different forms of digital communication, such as memes, gifs, short videos, infographics, and other methods can be used to share information. Often these communications are posted on social media sites and can be easily shared with others. Some people prefer to use social media or other digital spaces to give and receive information.

Another Method

There may be another way you use to communicate with others, or you might combine some of the ways already listed.

6. If you would like, find others interested in the same method of expression. Some methods might only need one person, such as creating an individual piece of visual art or a meme. Others might need a number of people, such as creating a dance or play.
7. Take out your *Ocean and Temperature System Diagram* and examine it.
8. Think about what you might want to share with others about what you have learned about the system of ocean and temperature and the ways it is changing?
    a. Do you want to help people think about how to limit the changes to the ocean system due to heat?
    b. Do you want to help people think about ways your community might need to adapt to the changes to the ocean?
    c. Do you want to share specific *Hopes* or *Concerns* from your *Ocean Identity Map*?
9. By yourself or with your group, decide:
    d. What you want to share
    e. How you want to share it
    f. Who you want to share it with
10. Create your expression to help share your feelings and knowledge and help others think.
11. Share your expression with an audience.
12. Reflect together: How did your expression connect with your audience?
13. Save your *Ocean and Temperature System Diagram*. You will need it in Part

Congratulations!

You have finished Part 4.

Find out More!

For additional resources and activities, please visit the Ocean! StoryMap at bit.ly/OCEAN2030.

Part 4 Task 2

End Notes

1. NASA. "Ocean Heat Content Changes Since 1955 (NOAA)." Ocean Warming. Accessed December 7, 2023. https://climate.nasa.gov/vital-signs/ocean-warming.
2. National Centers for Environmental Information. "Climate at a Glance." Accessed December 7, 2023. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series.

Glossary

This glossary can help you understand words you may not know. You can add drawings, your own definitions, or anything else that will help. Add other words to the glossary if you would like.

Albedo: How much light a material reflects

Balancing feedback loop: When the response to a change regulates the system so it returns to normal

Biodiversity: The many different living things on Earth

Coral bleaching: When the water around coral gets too hot, algae is pushed out and the coral turns white or light colored

Density: How much mass is contained within a specific volume

Environmental: About the natural world

Economic: Concerned with money, income, or the use of wealth

Ethical: The fairness of something

Feedback loops: Processes that either balance a system or make it unbalanced

Global Ocean Conveyor Belt: An important deep-water current that spans the globe and transports surface waters into the deep ocean and deep waters to the surface

Greenhouse gases: Gases such as carbon dioxide and methane that cause the atmosphere to get warmer

Habitable: Suitable for people to live

Heat capacity: The amount of heat needed to change the temperature of an object by one degree

Heat sink: The ability to absorb a lot of energy with only minor changes in temperature

Migrate: Moving from one location to another

Reinforcing feedback loop: When the response to a change makes that change happen more powerfully or more often

Salinity: How much salt is dissolved in water

Social: The interaction of people in the community and their education, health, and well-being

Solar radiation: Energy from the sun

Stratified: A substance that has layers

Symbiosis: A relationship between two species that benefits both

Symbiotic algae: Algae that live with another living thing, such as a coral, and together they help each other

Thermal expansion: When water gets warmer, it takes up more space

Tropics: The area around Earth's equator

Upwelling: When deep water comes up to the surface

