

THE ROLE OF THE OCEAN IN OUR GLOBAL CLIMATE

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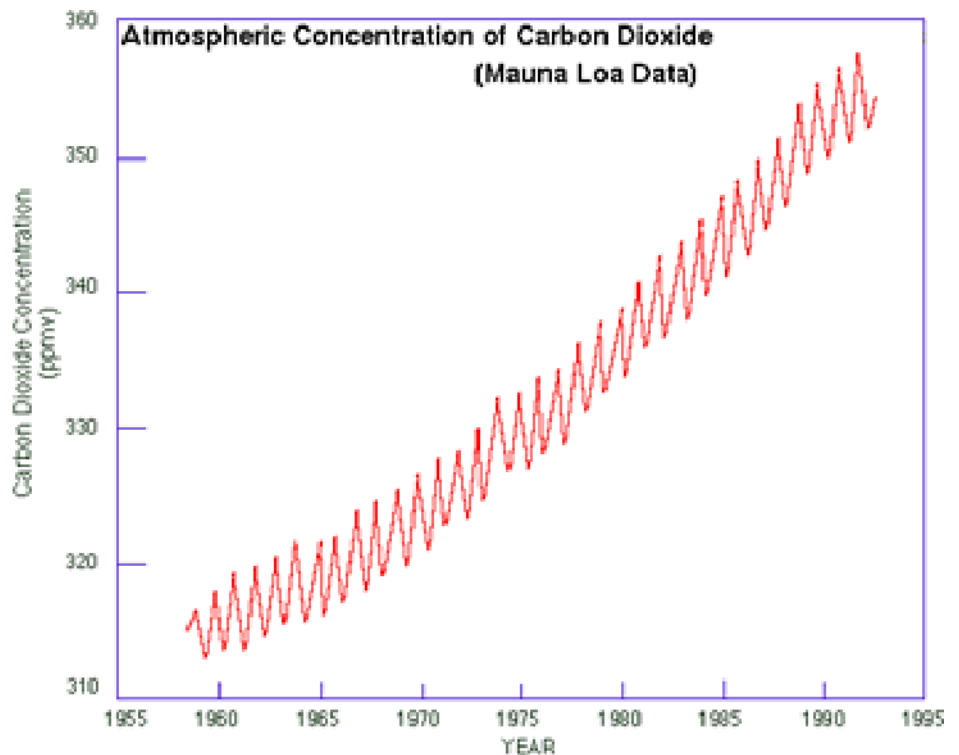
Ages and ages ago, man was motivated to learn more about the ocean because he needed to get his outrigger across a tidal inlet, or through some surf, or across an ocean. Through the centuries, navigation remained a driving force behind the desire to learn more about the sea and its swift and sometimes terrible currents. Other activities, such as fishing, national defense, and weather forecasting, have also turned our attention to the oceans over the years. But today, the big question for oceanographers is this: What role does the ocean play in Earth's changing climate? The answer to that question will help us predict how the Earth and its inhabitants will fare in the future. But the answer is not a simple one.

As You Read, Think About...

Why are scientists concerned about the increase in carbon dioxide levels?

What might be some of the effects of a warmer ocean?

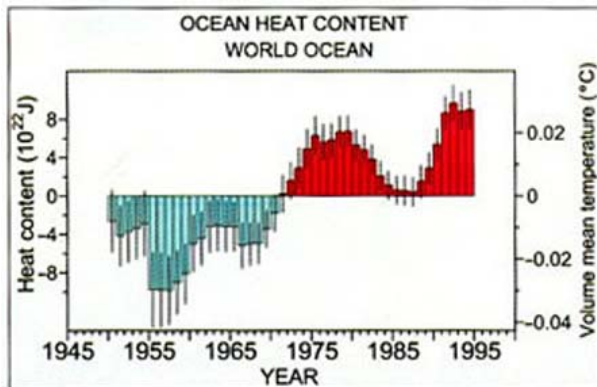
The amount of carbon dioxide in Earth's atmosphere has risen by approximately 30 percent since the Industrial Revolution. This rise is likely to affect climate because carbon dioxide and other gases absorb much of the radiation that is emitted by the Earth's surface. Instead of escaping into space, this energy warms the atmosphere near the Earth's surface, creating a greenhouse effect. The greenhouse effect has played an important role in our planetary history; without it, Earth would be approximately 30°C colder and could not support life as we know it. The recent rise in carbon dioxide levels, which comes mainly from the burning of fossil fuels, is expected to increase the greenhouse effect. In fact, many scientists believe that that the warming of the atmosphere we have seen over the past century is the result of this long-term increase in carbon dioxide.



Courtesy NOAA/NASA.

Oceans As A Heat Sink

Curiously, the warming we have seen in recent years is actually less than climate scientists would have predicted based on what they know about carbon dioxide and the atmosphere. Recent studies on ocean warming have shed some light on this mystery. The researchers found that all of the ocean basins have been warming since the middle of the 20th century, and that the oceans have been warming ten times more than the atmosphere and other parts of our earth system. Apparently, the ocean has been absorbing and storing some of the excess heat trapped by the atmosphere. These studies point us in two directions. First, we need to investigate how rising ocean temperatures will affect marine life and sea levels. Second, we need to understand how the ocean acts as a heat reservoir for our planet: how it absorbs heat, where it stores heat, and how it moves heat through the oceans and around the planet. We especially need to understand the rate at which the ocean can absorb and store heat so we can better predict future changes in atmospheric temperatures.



This plot shows how the temperature of North Atlantic waters has changed over the past 50 years. All water temperature readings above 3000 m were averaged for this time series. The y-axis shows the annual temperatures as anomalies; i.e., the 50-year average has been subtracted from the average for each year. Those years that were warmer than the 50-year average show a positive anomaly; cooler years show a negative anomaly. When looking at a plot with anomalies, it is easier to spot which data are unusual (e.g. warmer or cooler years) than those that reflect the average.

If we had no oceans, only land and air, it would be a lot easier to figure out how our climate works and how it is changing. That's because the land stores very little heat; what it gains during the day, it loses at night. Moreover, land loses its heat in the same place it gained it, making it fairly easy to trace how heat moves over the continents and large islands. But the ocean behaves differently. The ocean can store tremendous amounts of heat and release that heat thousands of kilometers away. To figure out how much heat the ocean can store we need to understand where the heat is gained and how it is distributed to other parts of the ocean. In other words, we need to understand about ocean currents, both surface currents and deep currents.

The Ocean Conveyor Belt

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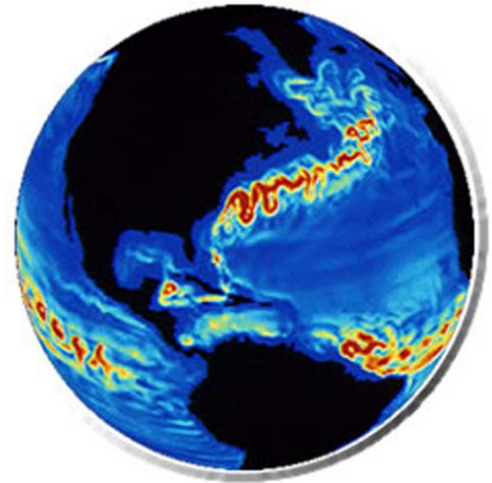
How does the ocean conveyor belt work?

Why do oceanographers measure levels of radioactivity in the ocean?

The currents of the deep ocean were largely a mystery until around 1800, when Count Rumford, an American-born scientist, examined the first temperature data from the deep ocean. Puzzled by the low temperatures found deep in the tropical ocean, Rumford theorized

that there was a system of currents running through the oceans of the world. He was right. Today we call this system of currents the ocean conveyor belt. It conveys waters from the surface to the deep ocean and circulates them around the globe. Why is this so important? The ocean gains heat at its surface, where it captures solar energy. One way it can spread this energy to the waters below the surface is by a process called diffusion, in which the surface waters gradually warm the waters below. Diffusion transfers heat very slowly; it would take thousands of years for any excess heat at the surface to reach the deep ocean. The global conveyor belt works much more quickly. When surface waters become denser than the waters beneath them, as happens at high latitudes where waters cool quickly, the surface waters sink. As they sink, they carry with them whatever properties they had at the surface, including heat. These dense waters then spread throughout the deep ocean, distributing that heat thousands of meters from the surface and thousands of kilometers from where it sank.

A dramatic example of the ocean conveyor belt in action comes from oceanographers' measurements of radioactive tracers in the North Atlantic Ocean. During the 1960s, both the United States and the Soviet Union conducted atomic bomb tests in the northern North Atlantic Ocean. The radioactive residue from the bombs, tritium and He_3 , was absorbed into the surface waters of the ocean. When the surface waters sank during wintertime cooling, they carried the tritium and He_3 to the ocean depths. Up until that time, the ocean was essentially free of these radioactive isotopes; now they provide scientists with a "fingerprint" for the waters that were recently at the surface. In the four decades since the bomb testing, oceanographers have traced these isotopes as they have moved southward into the rest of the North Atlantic Ocean. The tracers have moved relatively fast along the deep boundary currents in the North Atlantic Ocean, then have spread slowly into the ocean interior. It will take several more decades for the entire North Atlantic Ocean to have measurable amounts of these radioactive tracers. This is because deep ocean currents, especially those in the middle of the ocean, are sluggish compared to the swift surface currents. The surface Gulf Stream, for example, typically moves at a speed of about 100 km/day, while the deep interior currents move, on average, only 0.1 to 1 km/day. At these rates, filling a deep ocean basin takes tens to hundreds of years.



The speed of currents at the ocean surface simulated with a computer model. High speeds are in red, low in blue. Courtesy HPCC and the DOE CHAMMP (Computer Hardware, Advanced Mathematics, and Model Physics) Program.

Unanswered Questions

As You Read, Think About...

What two variables influence ocean conveyor belt movement?

Which unanswered question do you find most interesting?

Does heat move through the ocean in the same way and at the same relative speed as the radioactive tracers? We don't know. We do know that as global climate change continues, the excess heat absorbed by the ocean should sink with the surface waters at high latitudes and gradually fill the deep ocean basins with warmer water. Already we are beginning to see the heat changes in the deep ocean, but two things make it difficult to predict how that warming will progress. The first is the nature of deep ocean circulation. While oceanographers understand in general how the conveyor belt works, there is still much to learn about its many individual pathways through the oceans of the world. Will heat follow the same paths as the radioactive tracers? Will it move more quickly or more slowly? Will the heat itself affect the movement of the deep ocean currents? We don't know yet; there are years of mapping and measuring still to do.

The second complicating factor is salinity. As global climate change continues, land ice will melt and add fresh water to the ocean, decreasing the density of the surface waters. Remember that the ocean conveyor belt is a density-driven system: it gets moving when the dense surface waters at high latitudes sink to the ocean depths. If the surface waters become less salty, they may not sink as far or may stop sinking altogether. In fact, this has happened in Earth's past thousands of years ago. If the ocean conveyor belt no longer reaches the deep ocean basins, then the reservoir available for heat storage would be reduced. Oceanographers will need to study temperature and salinity changes carefully before they can devise a predictive model for ocean heat storage.

How our global climate will respond to the ever increasing amounts of carbon dioxide in our atmosphere depends on how much heat the ocean can store. Ocean heat storage in turn depends upon ocean currents—those deep and often mysterious waters that move slowly and silently around our planet. In the decades ahead, oceanographers hope to unravel more and more of the deep mysteries that these waters hold.