Ocean Circulation and the Butterfly Effect

Can swimming animals impact ocean circulation?

For the complete video with media resources, visit: http://www.nationalgeographic.org/media/ocean-circulation-and-butterfly-effect/

Partner

Learning how water is mixed by currents and other means is essential in understanding how heat energy, nutrients, and gases move between the Earth’s water bodies, landmasses, and atmosphere. The ocean has an interconnected current, a circulation system powered by wind, tides, the Earth’s rotation (Coriolis effect), the sun (solar energy), and water density differences. Ocean water circulation affects temperature extremes, local weather conditions, global climate patterns, and the cycling of gases and nutrients in marine ecosystems.

To better understand the impact ocean mixing and currents have on global climate and physical processes in the ocean, scientists create climate and circulation models. Scientific models are used to explain or predict a system that is hard to observe. Many factors must be considered when creating a scientific model. In the case of ocean mixing and circulation, winds, tides, and currents are the dominant forces considered. Some scientists argue that other, less-studied sources of mixing, including swimming animals at mid-water depths, should also be factored into the models to obtain more accurate predictions.
Dr. Kakani Katija is a scientist who studies the impact swimming animals have on ocean mixing and circulation. As a bioengineer, Katija applies engineering principles to the study of marine biology. She works with oceanographers to explore how the movement of fish, jellies, whales, and plankton mixes water under the surface of the ocean. She and her team want to show that small forces, like many swimming jellies, can add up to a large force resulting in ocean mixing. The idea that a small organism can have a large effect on a physical system is often referred to as the butterfly effect. If Katija’s theory is confirmed, it could change our understanding of ocean circulation and influence future global climate models.

Katija’s research includes field and lab studies, as well as new methods and technologies she has developed to help with her research. In one method, scuba divers use a camera and high-powered laser to illuminate and measure the movement of particles in the water around the moving animals. In another method, dye is released into the water around a swimming organism. The dye can be used to measure the direction and movement of water swirling around and dragging behind the animal. Data show that the amount of mixing depends on the animal’s size, shape, movement type and direction, and distance traveled. Results from these research methods indicate deeper, calmer waters can be mixed more easily with less energy input from the animal.

Many different forces and processes affect ocean mixing, both on the surface and at depth. Scientists hope to investigate the impact that biological processes, including swimming animals and the resulting butterfly effect, may have on ocean circulation. When combined, these forces and processes drive the ocean’s global circulation system, playing a key role in distributing heat energy, regulating weather and climate, and cycling vital nutrients and gases.

Questions

- What are some of the forces and physical processes scientists should consider
when creating and analyzing ocean circulation models?

Scientists should consider wind, waves, tides, the Earth’s rotation (Coriolis effect), the sun (solar energy), water density differences, surface and deep-water currents, and biogenic mixing.

- In addition to ocean mixing, what are some other ways bioengineers could contribute to the study of oceanography?

Bioengineers could contribute to creating more efficient underwater submersibles and remotely operated vehicles. They could play a role in the discovery and development of marine pharmaceuticals and biomedical applications.

- Ocean circulation is driven by density differences throughout the water column. What are the key physical factors that affect water density?

The key physical factors that affect water density are temperature, salinity, depth, and pressure.

Fast Facts

- Some estimates show that just 10% of the energy from surface waves and tides contributes to the mixing and circulation of deeper ocean layers.

- Edward Lorenz was an American who studied meteorology, mathematics, and chaos theory. In 1963 he developed his “butterfly effect” theory to help explain the unpredictable nature of weather due to small, local changes that could lead to large, wider-ranging effects. Lorenz explained his theory with an example: that a butterfly flapping its wings on one side of the world can cause major weather changes on the other.

- One of the technologies Dr. Kakani Katija’s team developed to study biogenic
ocean mixing in real time is SCUVA (self-contained underwater velocimetry apparatus). SCUVA enables a single scuba diver to collect digital measurements of animal-fluid interactions in the field.

Vocabulary

<table>
<thead>
<tr>
<th>Term</th>
<th>Part of Speech</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coriolis effect</td>
<td>noun</td>
<td>the result of Earth's rotation on weather patterns and ocean currents. The Coriolis effect makes storms swirl clockwise in the Southern hemisphere and counterclockwise in the Northern Hemisphere.</td>
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<tr>
<td>ocean circulation</td>
<td>noun</td>
<td>worldwide movement of water (currents) in the ocean.</td>
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<tr>
<td>plankton</td>
<td>plural noun</td>
<td>(singular: plankton) microscopic aquatic organisms.</td>
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<tr>
<td>solar energy</td>
<td>noun</td>
<td>radiation from the sun.</td>
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<tr>
<td>technology</td>
<td>noun</td>
<td>the science of using tools and complex machines to make human life easier or more profitable.</td>
</tr>
<tr>
<td>weather</td>
<td>noun</td>
<td>state of the atmosphere, including temperature, atmospheric pressure, wind, humidity, precipitation, and cloudiness.</td>
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</tbody>
</table>

Websites

- National Geographic: Real-World Geography—Dr. Kakani Katija
- National Geographic: Kakani Katija, Bioengineer
- National Geographic: Marine Mix
- National Geographic: Sea Animals Change Climate Via Flutters and Flaps
- National Oceanic and Atmospheric Administration: Education Resources—Ocean Currents

Funder

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