# All mixed up: how can robots help us understand turbulence and mixing in the Arctic Ocean?

The Arctic Ocean is a unique environment that can tell us a lot about global climate change. **Professor Stephanie Waterman**, from the **University of British Columbia** in Canada, uses ocean-observing robots called ocean gliders to understand ocean turbulence and how it mixes heat and salt in this polar environment. Her work is part of a larger effort to learn more about the changes in the Arctic Ocean and their implications.

**Professor Stephanie Waterman**

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**Fields of research**
Arctic oceanography, ocean mixing and turbulence

**Research project**
Using a robotic ocean-observing platform to measure turbulence in the Arctic Ocean

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Talk like an ...

## Arctic oceanographer

**Ocean circulation** — the large-scale movement of water in the ocean, determined by wind, density and the Earth's motion around its axis, that transports heat, freshwater, nutrients and carbon both at and below the surface

**Ocean turbulence** — small-scale, intermittent and patchy movements of water in the ocean that irreversibly mix water properties like heat and salt

**Ocean acidification** — as the ocean absorbs more carbon dioxide from the atmosphere, its pH level is reduced, causing it to become more acidic

The Arctic Ocean is undergoing rapid change as the climate warms. Sea ice, which in the past covered most of its surface in both winter and summer, is shrinking significantly, allowing the ocean to absorb more heat from the sun. Freshwater from rivers, rain and melting glaciers is entering the Arctic Ocean at a growing rate, and, at the same time, its deep waters are heating up as warmer waters enter from the Atlantic and Pacific Oceans.

These changes are affecting how heat and freshwater are stored and transported inside the ocean, with important implications for Arctic Ocean ecosystems, the people who live in the Arctic region and global climate. Understanding the fate of the Arctic Ocean's increasing stores of heat and freshwater is key to understanding how the system will change in the future.

For much of her career, Professor Stephanie Waterman from the University of British Columbia has been working to improve our understanding of how the ocean mixes. "Ocean turbulence is responsible for the irreversible mixing of seawater," says Stephanie. "Quantifying how ocean turbulence mixes heat, salt, dissolved gases and nutrients is key to understanding how it works."

## Measuring ocean turbulence

Stephanie uses autonomous ocean-observing robots called ocean gliders to measure turbulence in the ocean. "We equip our gliders with specialised sensors that can make rapid and sensitive measurements of small fluctuations in ocean motion that give us information about ocean turbulence," she explains. "Our gliders can map these and other ocean properties over an extended area at a high level of detail, resulting in beautiful pictures of ocean structure."

Ocean gliders don't have motors; instead, they adjust their buoyancy to rise and sink through the water, using fixed wings to convert some of this vertical motion into horizontal motion. This type of propulsion requires minimal power, so gliders can collect data over


*Scientists and crew from the CCGS Louis S. St. Laurent deploying a turbulence-sensing ocean glider in the Beaufort Sea in summer 2024. © Kazu Tateyama*

long periods of time and large distances. Moving the glider in this way also reduces vibrations, making gliders extremely quiet platforms and allowing them to observe tiny fluctuations in ocean properties. "This is key to ensuring that we are measuring the turbulence of the ocean, rather than the motion of the glider," explains Stephanie. "It allows gliders to detect extremely low levels of turbulence, like those we often see inside the Arctic Ocean."

Stephanie's glider is pre-programmed to navigate to specified locations using an internal compass, surfacing at set times to transmit the collected data and receive updated instructions from Stephanie and her team back home via satellite communication. "The mission can be adapted in real-time based on what the glider is seeing or changing conditions, like storms or drifting sea ice," explains Stephanie.

## The Beaufort Gyre

The Beaufort Gyre is an enormous swirl of polar water that holds much of the freshwater released into the Arctic Ocean. "The freshwater stored in the Beaufort Gyre is periodically released into the North Atlantic Ocean, where it impacts important ocean processes," says Stephanie. "These processes form much of the Earth's deep ocean water and drive global ocean circulation that transports water and heat around the globe."

Every summer, researchers from the Joint Ocean Ice Study (JOIS) and Beaufort Gyre Observing System (BGOS) programme travel aboard a research vessel, the Canadian Coast Guard Ship (CCGS) *Louis S. St-Laurent*, on an expedition to collect water samples and make observations of ice and ocean properties in the gyre. They also deploy and maintain autonomous instruments that remain in the water and take samples year-round. For example, ice-tethered profilers are buoys that are anchored to, and drift with, the sea ice. Below the ice, a sensor travels up and down a wire to a depth of 750 metres multiple times a day making measurements of the water properties. The data recorded are then reported back to shore via satellites.

The JOIS/BGOS programme has been making these observations since 2003. "To understand how this important system works, and how and why it is changing, we require consistent and regular measurements of a variety of parameters at similar locations year-after-year," explains Stephanie. "The measurements taken by the JOIS/BGOS programme allow us to understand decades-long changes to the structure of the Beaufort Gyre. This understanding of how the system is changing on these timescales is critical in helping us better predict how it will change in the future."

In the summer of 2024, JOIS/BGOS scientists deployed Stephanie's glider at the beginning of their expedition and collected it at the end, several weeks later. During that time, the glider made near-continuous measurements of ocean turbulence within the gyre.

## What has Stephanie learnt about the Arctic Ocean?

"Our glider observations in the Beaufort Gyre give us important insights into how mixing in the Arctic Ocean differs from mixing in the lower-latitude oceans," explains Stephanie. In general, the Arctic Ocean is much less turbulent than other oceans. As a consequence, heat stored in the water column tends to remain at depth and not be transferred to shallower waters and the sea ice above. "However, the near-continuous observations of the glider allowed us to catch a small number of patchy and intermittent turbulent mixing events that are responsible for most of the mixing of heat and salt that we observe," continues Stephanie.

Stephanie's work is a small part of a much larger effort to document and understand climate change in this region. The JOIS/BGOS programme has observed and studied significant changes in all elements of the Beaufort Gyre system over the last two decades. "Significant sea ice losses have been accompanied by an intensification of the Beaufort Gyre circulation and a significant increase in both the heat and freshwater stored in the gyre," says Stephanie. "The programme has also documented changes in biological productivity, increases in ocean acidification and a marked decrease in dissolved oxygen."

## Communicating the impacts

Stephanie believes that communicating research findings to a wide variety of stakeholders is a vital part of her role as an environmental scientist. "Information about how the environment is changing is critical to people who live in the region and are dependent on the environment for their livelihood, safety and culture," explains Stephanie. "It is also critical to people everywhere, as changes in the Arctic region highlight the magnitude of humans' impact on the climate system and the urgency to act to address human-caused climate change."

# **About** *Arctic oceanography*

The oceans are vast, remote places, covering 70% of the Earth's surface and playing a critical role in our climate and weather systems. From crystal-blue surface waters down to the inky depths, they harbour a huge variety of interconnected physical, chemical and biological processes, about which there is still much to learn.

The Arctic Ocean's polar location makes it a uniquely interesting and challenging environment to study. In addition to the usual challenges of observing the ocean, including salt corrosion, high pressures and the impenetrable nature of seawater to many forms of remote communication, observing the Arctic Ocean presents its own challenges including sub-zero temperatures, endless winter nights, extreme remoteness and deserts of sea ice that need to be cracked open by ice-breaking ships.

Overcoming these challenges presents exciting opportunities for people working in Arctic oceanography. "Sustained, long-term observations require the dedication and effort of many people from many different fields," says Stephanie. Many choose to travel and work on location in the field, whereas others prefer to work in laboratories as technicians and analysts. Engineers are also needed to develop and improve instruments that can make measurements of ocean properties.

"Over the last two decades, there has been an explosion in the development of autonomous and robotic ocean observing platforms and the electronic sensors we equip them with," says Stephanie. "In the future, we must continue to innovate our ocean monitoring methods in order to understand how our climate system works and how it is changing. There will also be important opportunities to develop and use computer models of the ocean and Earth's climate system. These models are important tools which help us understand ocean processes and predict what may happen in the future."

## **Pathway from school to** *Arctic oceanography*

Build solid foundations in basic science by studying mathematics, physics, biology, chemistry and geography, before focusing on a specific area.

At university, you can complete an undergraduate degree in oceanography, but undergraduate degrees in physics, chemistry, biology, geology or environmental science can also be applied to oceanography at a later stage.

Studying engineering can be a great background for working on equipment design, repair and support.

You can also complete a lab technician course, and learn to apply this to oceanography.

## **Explore careers in** *Arctic oceanography*

Learn more about the work of Stephanie and her colleagues in the Department of Earth, Ocean and Atmospheric Science at the University of British Columbia: **www.eoas.ubc.ca/research**

"Volunteer in citizen science programmes to collect environmental data or participate in local clean-ups and environmental restoration efforts," says Stephanie. "Experience in the field will give you valuable skills."

The website of the Oceanography Society contains a number of career profiles with information about different roles in oceanography, and the paths people took to get there: **tos.org/career-profiles**

Stephanie says, "Be open-minded about the opportunities that present themselves. The Arctic is alluring, but there are exciting opportunities for important work oceanography field around the globe."

*The coast guard ship and research vessel CCGS Louis S. St. Laurent and its scientists and crew engaged in its annual expedition to study the changing Beaufort Gyre as part of the JOIS/BGOS programme. © Paul Macoun*

# **Meet** *Stephanie*

**As a teenager, I liked outdoor adventures, travelling, sailing and physics.** My first dream job idea was designing racing sailboats - this led me to learn about fluid mechanics. Later, a professor introduced me to physical oceanography, which combined my interests in fluid mechanics and understanding the natural world. The opportunity to be a field-going oceanographer presented opportunities for adventure and travelling the world.

**I love the challenge of figuring out how a complex, awe-inspiring system works,** often with only limited information. I enjoy having opportunities to travel to remote parts of this beautiful planet, and the privilege of working with so many passionate and creative colleagues.

**Highlights of my career have been successes in collecting new datasets** that are critical to pushing the boundaries of what we understand, such as high-density turbulence observations collected by a glider in the Beaufort Gyre!

**I've enjoyed working as part of a team in the field** to achieve diverse objectives under challenging conditions. I loved my times at sea, working on a research ship with a team of scientists and ship crew. Now, we execute glider missions as a distributed team on shore, but the camaraderie in the face of a challenge is similar in many ways.

**Mentoring the next generation of scientists has been very rewarding;** I am now in a position where I can help others achieve their goals, and this is very satisfying.

**I am very proud of the glider programme** our team has built over the last 10 years. There has been so much to learn and we have experienced many setbacks. Our successes are due to the efforts of many people who have worked hard and supported each other.

**Hard work, perseverance, teamwork, curiosity and creativity have been fundamental to a successful career.** I have several role models who are 'on-the-ground' scientists who have inspired me. They have a drive to really understand how things work and a commitment to collaboration and supporting others.

**To unwind,** I enjoy spending time outdoors, running in the woods and reading books with my children.

## **Stephanie's** *top tips*

1. Follow your passion and curiosity. Many young people I know are attracted to Earth and environmental sciences out of a duty to help address the many environmental issues we currently face; this is a valid motivator, but you also want to be able to find joy in what you do.

2. Be open-minded and unafraid to seize the opportunities that are presented to you; you never know where they will lead, and the opportunities of the future may be hard to predict.