A glider at rest communicates turbulence measurements to its operator via a satellite or radio connection.

Oceans in Motion

by Arran Whiteford

Collecting data across the vast breadth and depth of our oceans poses an extraordinary challenge. Even massive international research networks can only skim the surface of the knowledge that the oceans hold. But as robotic technologies develop, so does our ability to study the oceans. The underwater glider is one such robot: an efficient autonomous submarine drone that cruises the water column, collecting data along the way.

EOAS oceanographer Prof. Stephanie Waterman and her group use ocean gliders to study physical ocean processes, particularly turbulence. Characterizing these processes is critical to understanding the larger ocean system, from melting sea ice to whale migration.

A glider is deployed off the CCGS Amundsen's "Science Barge" to measure turbulence in the Beaufort Sea.

MEASURING TURBULENCE

To sample the deep ocean, oceanographers typically string weighted sensors overboard and haul them back to the surface. The process is laborious and slow, and recovers only sparse, discrete measurements. In contrast, an ocean glider samples continuously, delivering a large number of measurements with excellent resolution in space and time. In a single 11-day Arctic mission, the glider recovered around 400,000 independent estimates of turbulent mixing rate, "the same order as all measurements of turbulence in the Arctic Ocean before," says Stephanie.

The glider traverses the ocean diagonally in a zig-zag profile. By enlarging or contracting a flexible bladder, the glider changes its buoyancy to sink or rise. Its wings direct this motion into a forward glide both as it dives and climbs through the water column. While underwater, the glider is entirely autonomous, acting on a pre-programmed mission plan. Between each dive, it surfaces to receive updated mission parameters and beam data back to base via a satellite link. At 1 kilometer per hour, the glider moves slowly but can travel up to thousands of kilometers in a single mission, zig-zagging as deep as 1000 meters. Its tranquil glide makes the drone a perfect low-noise platform for turbulence measurements, which are the focus of the EOAS glider group.

"Turbulence is the thing that you see when you pour milk into your coffee and watch the two liquids mix," explains Benjamin Scheifele, a PhD student in Stephanie's group. Tendrils of each liquid wrap around the other, swirling and intertwining to rapidly combine the milk and coffee into a single mixture. Benjamin looks at a similar process in a much bigger mug – the Arctic Ocean – with seawater as the coffee and ocean heat as the milk. "People are very interested in how quickly heat in warm subsurface water is transported to the surface and mixes with the cooler surface waters, and in whether or not that's a contributor to why we are losing so much sea ice." Turbulence plays a key role. If you can transport heat to the surface, you can melt a lot of sea ice.

A glider is well suited for turbulence research, where a large dataset of near-continuous measurements is ideal. "Turbulence is an intermittent, patchy, sporadic, chaotic process. You really can't just take one measurement. You have to take a whole sweep of measurements and talk about the distribution or the average," explains Stephanie. When turbulence levels are barely detectable and patchy – like in the Arctic Ocean – a large data set is even more important. Robust statistical characterizations of ocean turbulence are nearly impossible with traditional data collection techniques, but through the use of drones, Benjamin's research has already made significant progress in understanding turbulence in the Arctic Ocean.

PhD student Tara Howatt (left), technician Chris Payne (middle), and PhD student Benjamin Scheifele (right).

While the glider excelled in recording data from the Arctic Ocean, it struggled to dive and climb in the highly stratified environment. "The more stratified the water column is, the harder it becomes for the glider to travel," says Benjamin. Larger density changes in the water column mean that the glider must make greater changes to its own buoyancy, and surface layers of fresh water can even trap the glider underwater. "In the Arctic, we were working at the very limit of what the glider was capable of doing."

STUDYING WHALE HABITAT

The same glider was used by another PhD student in the group, Tara Howatt, as part of the Canada-wide Whales, Habitat and Listening Experiment (WHaLE) project, which pilots coordinated multi-glider missions on both the east and west coasts of Canada. The goal of the project is to better monitor whale locations and understand whale habitat so that shipping channels can minimize disturbance and mitigate vessel strikes.

To better predict the location of baleen whale feeding grounds, Tara studies the physical mechanisms that aggregate zooplankton. Using a range of data from multiple gliders in the project – conductivity, temperature, oxygen content, and pressure – Tara can identify local currents, upwelling, and downwelling. She compares these circulation features to zooplankton distributions mapped using a glider-mounted echo sounder to better understand the influence of ocean physics on zooplankton. Tara also plans to use her group's measurements to learn how turbulence impacts zooplankton. It is believed that limited turbulence can improve the chances of encountering prey and therefore increase feeding rates. Too much turbulence, on the other hand, can be disruptive.

Tara's glider missions have been exciting at times. One of the missions involved guiding the glider through a submarine canyon with powerful currents. Between each dive, Tara had to quickly learn and figure out the pattern of currents and where to direct the slow-moving glider. In these conditions, waypoints were "more of a guideline" and the glider would surface far away from where it was sent each dive. Good glider piloting therefore requires some intuition of the glider's path. Stephanie adds that "you often play games, trying to stay deep where the currents are weaker to try and break free."

Members of the EOAS glider group agree that the wealth of unique and interesting data that comes from a glider does not come for free. Gliders are at the forefront of technology, and so are complex to run and require active debugging. Benjamin says that the modern glider is "not always a user-friendly instrument. It requires a lot of work, a lot of understanding, a lot of problem solving skills. You really need to know what's going on behind the scenes." Collaboration and teamwork between technicians and scientists in the EOAS group and in the larger glider community is crucial to surmounting the challenges that come with the new technology.

A glider equipped with a hydrophone is deployed to listen for and identify whale songs.

As gliders become commonplace, the group hopes that these challenges will be worked out. "Hopefully, in 10 years, anyone will be able to take the instrument, put it in the water, tell it where to go, and simply push a start button," Benjamin shares. In the meantime, as the deep ocean remains largely unexplored, even limited technological advancements allow us to learn more about this "final frontier" than ever before.

For more information on Stephanie Waterman's research group, visit www.stephaniewaterman.ca/work.