CASE STUDY 1.1:
Integration of dissolved CO_2 sensors into an autonomous vehicle for ocean monitoring: The Liquid Robotics Wave Glider®

SUMMARY

Accurate measurements of pCO_2 in the surface ocean are essential for determining the spatial and temporal distributions of ocean sources and sinks of anthropogenic CO_2. However, traditional methods of oceanographic data collection, such as research cruises and Ships of Opportunity Program (SOOPs), can be costly, time consuming, and labor intensive leading to a barrier in the quality and quantity of data collected.

The recent advancements in autonomous vehicles have helped to ease these burdens, specifically for measurements made with sensors. By integrating a suite of sensors onto an autonomous vehicle, oceanographers are able to collect more data in locations that may be difficult to reach by a vessel for longer periods of time. Additionally, the overall cost will be significantly lower than for repeated research cruises.

INTEGRATION ON A WAVE GLIDER

INTRODUCTION

Pro-Oceanus' CO_2-Pro CV and Mini TDGP sensors were integrated onto a Liquid Robotics Wave Glider® (The Boeing Company) and used to collect measurements of pCO_2 from the Scotian Shelf region during the spring bloom of 2022. The shelf, located off Canada's east coast, is an ideal location for studying carbon dynamics due to the variety of ecosystems encompassed in the region and that it is generally a CO_2 source because of a deep winter mixed layer. The track of the Wave Glider can be found in Morgan et al., 2025, and shows the three distinct regions that the glider collected measurements in during its deployment.

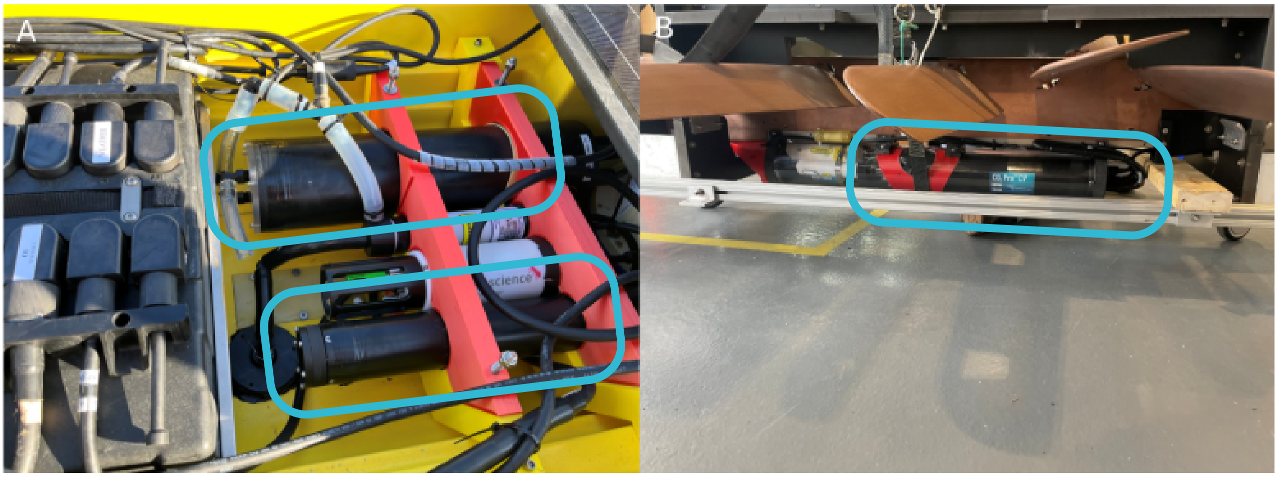

Figure 1: Images of the CO_2-Pro CV sensors and Mini TDGP sensors on the "float" (A) and "sub" (B) components of the Wave Glider. The "float" is made of foam-filled fiberglass and has an internal payload cavity where the sensors and other electronics are located as seen in (A). A pumped flow through system is required for most of the sensors on the "float" and the inlet for this pump is located approimately 15 cm below the waters surface. The "sub" is used primarily for propulsion of the Wave Glider and has several payload attachment points as well as six articulating fins which can be seen in (B).

CASE STUDY 1.1:

Integration of dissolved CO_2 sensors into an autonomous vehicle for ocean monitoring: The Liquid Robotics Wave Glider

The Pro-Oceanus sensors — in addition to sensors measuring pH, dissolved oxygen (DO), and conductivity, temperature, and depth (CTD) — were mounted in the “float”, the surface of the glider (~ 15 cm deep), and at 4 meters depth on the “sub” component of the glider. This allowed the researchers to calculate the air-sea fluxes for the different regions in which the Wave Glider was located. A detailed schematic showing the exact placement of the sensors on the glider can be found in Figure 2 (below).

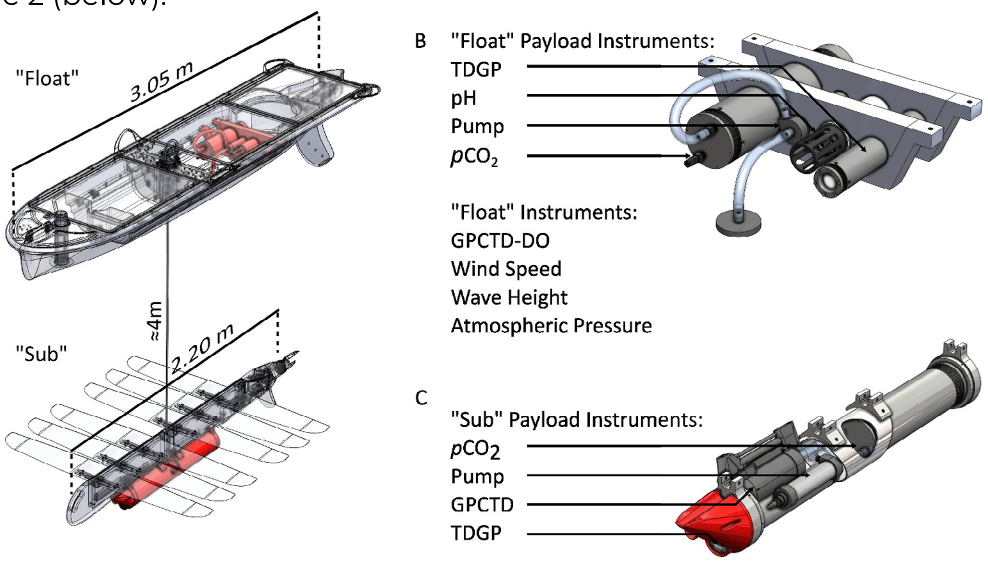

Figure 2: Diagram of the sensor placements on the “float” and “sub” of the Liquid Robotics Wave Glider®. Image from Morgan et al., 2025.

The combination of the measured mole fraction of CO_2 (xCO_2) from the CO_2-Pro CV and the in-situ gas pressure (P) measurement from the Mini TDGP allow for the calculation of pCO_2 using the following equation:

$$pCO_2 = xCO_2 \times P$$

The researchers note that while the CO_2-Pro CV does measure in-situ gas pressure, the measurements from the Mini TDGP are preferred as they have higher accuracy.

Using the pCO_2 calculated above, the temperature correction can then be calculated to “deconvolve the pCO_2 signals and remove the effects of thermal forcing” (Morgan et al., 2025). The air-sea CO_2 fluxes are also calculated using pCO_2 for either the “float” or “sub” value and the atmospheric value.

RESULTS

The researchers found a significant difference in the pCO_2 measured from the “float” versus the “sub” over the whole deployment period, with measurements from the “float” being higher on average. A temperature correction was then applied to the “sub” data and the values were separated by the three distinct regions. With these corrections, a significant difference was still observed between the “float” and “sub” pCO_2 values, suggesting that there is a gradient in the upper layer of the water column.

CASE STUDY 1.1:
Integration of dissolved CO_2 sensors into an autonomous vehicle for ocean monitoring: The Liquid Robotics Wave Glider

Clear diurnal cycles were observed in each of the three regions, see Figure 3 below modified from Morgan et al., 2025. However, the observed peak in the "High Productivity Region" contradicts the general trend of biological respiration at night, and thus the researchers postulate several reasons for why this could be, including: circulation patterns, photorespiration, tidal upwelling, and bloom dynamics. The researchers also discuss the potential for unspecified biological forcings to be the cause for the anomalously high peak. Using nitrate data from a SUNA nitrate sensor on a nearby Slocum Glider they tested their theory. Further details and an explanation of the methods can be found in Morgan et al., 2025.

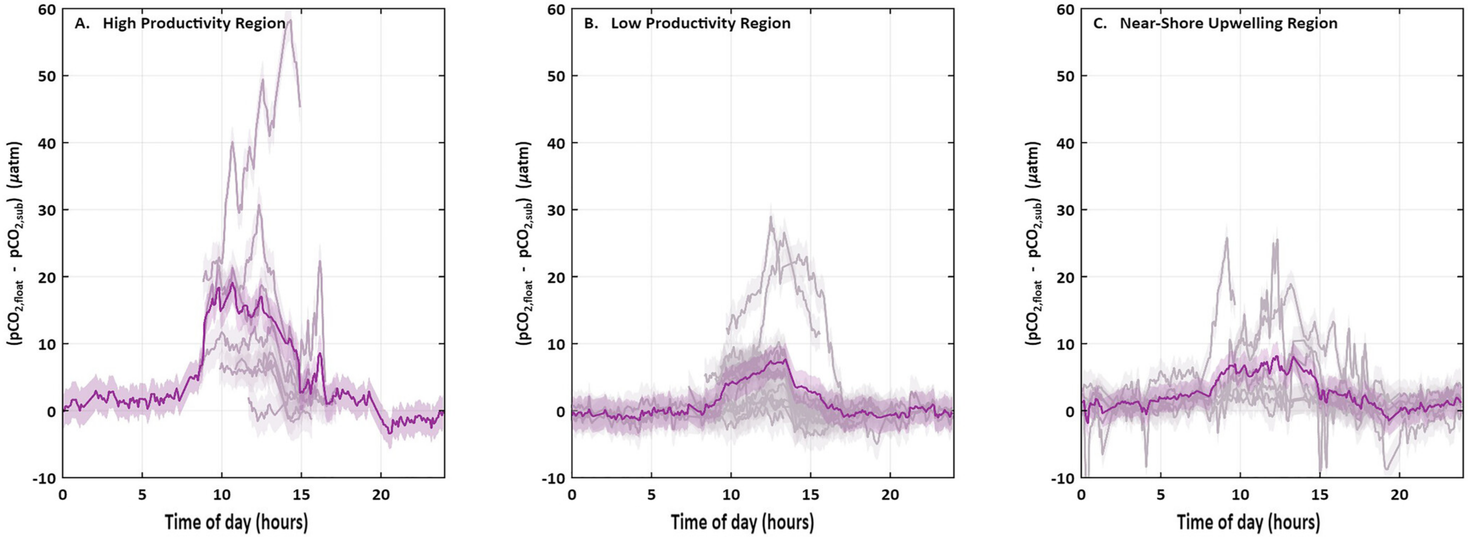

Figure 3: Daily cycles of pCO_2 from the Wave Glider. Light purple lines represent the difference between the "float" and "sub" measurement for a 24-hour period, and the dark purple line is the mean of the 24-hour cycles. Figure modified from Morgan et al., 2025.

Overall, the Pro-Oceanus sensors were able to be easily integrated into the Liquid Robotics Wave Glider® and used to collect measurements of pCO_2 along the Scotian Shelf. The CO_2-Pro CVs produced reliable and consistent data while remaining stable and sensitive enough to see vertical gradients in the near surface water, even when separated by only a few meters.

REFERENCES

Morgan, S., Wong, S., Byrne, T., Comeau, A., Ward, B., Barry, M., & Atamanchuk, D. (2025). Wave glider-based measurements and corrections of near-surface pCO_2 gradients in the coastal ocean. Global Biogeochemical Cycles, 39, e2024GB008396. https://doi.org/10.1029/2024GB008396.

PRO OCEANUS Dissolved Gas Sensors

80 Pleasant Street,
Bridgewater, Nova Scotia
Canada B4V 1N1

Phone +1-902-530-3550
sales@pro-oceanus.com
Pro-Oceanus.com