Measuring fine-scale variability of carbonate chemistry over mesophotic reefs in Cuban waters using an integrated ROV-sensor system

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Introduction

Mesophotic coral reef ecosystems support abundant and diverse benthic and fish communities but are vulnerable to global climate change including warming and ocean acidification. Yet high-resolution spatial-temporal information of the environmental conditions, particularly carbonate chemistry parameters in much of these systems are still lacking due to the limitations of observation technology. During a recent cruise to Cuba mesophotic reefs (Figure 1), we use a SAMI pH and HydroC pCO_2 sensor along with a CTD mounted on a Remotely-Operated-Vehicle (ROV) to measure ambient CO2 system around the reefs. Here we present the preliminary results from a station on Bank of St. Antonio.

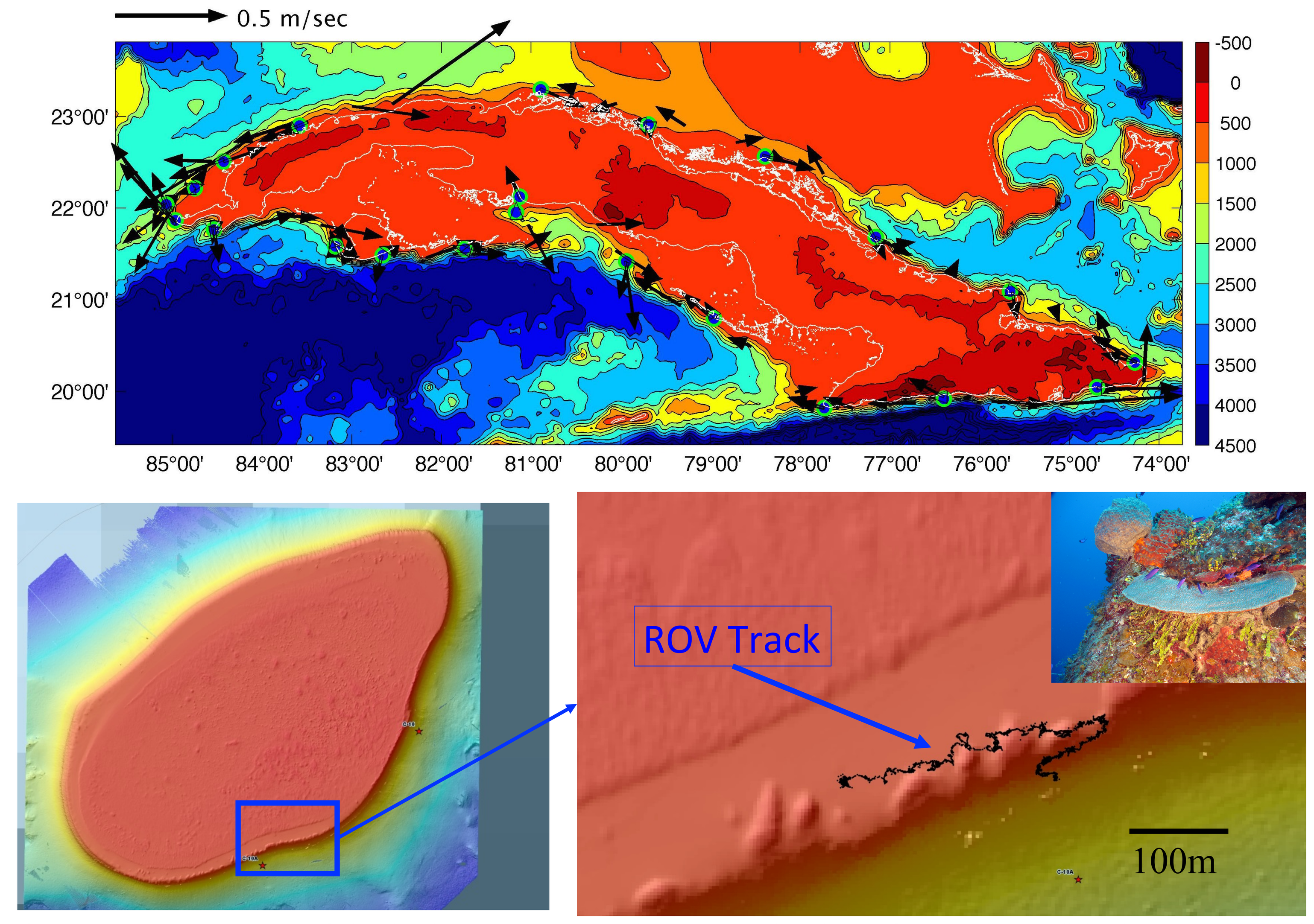
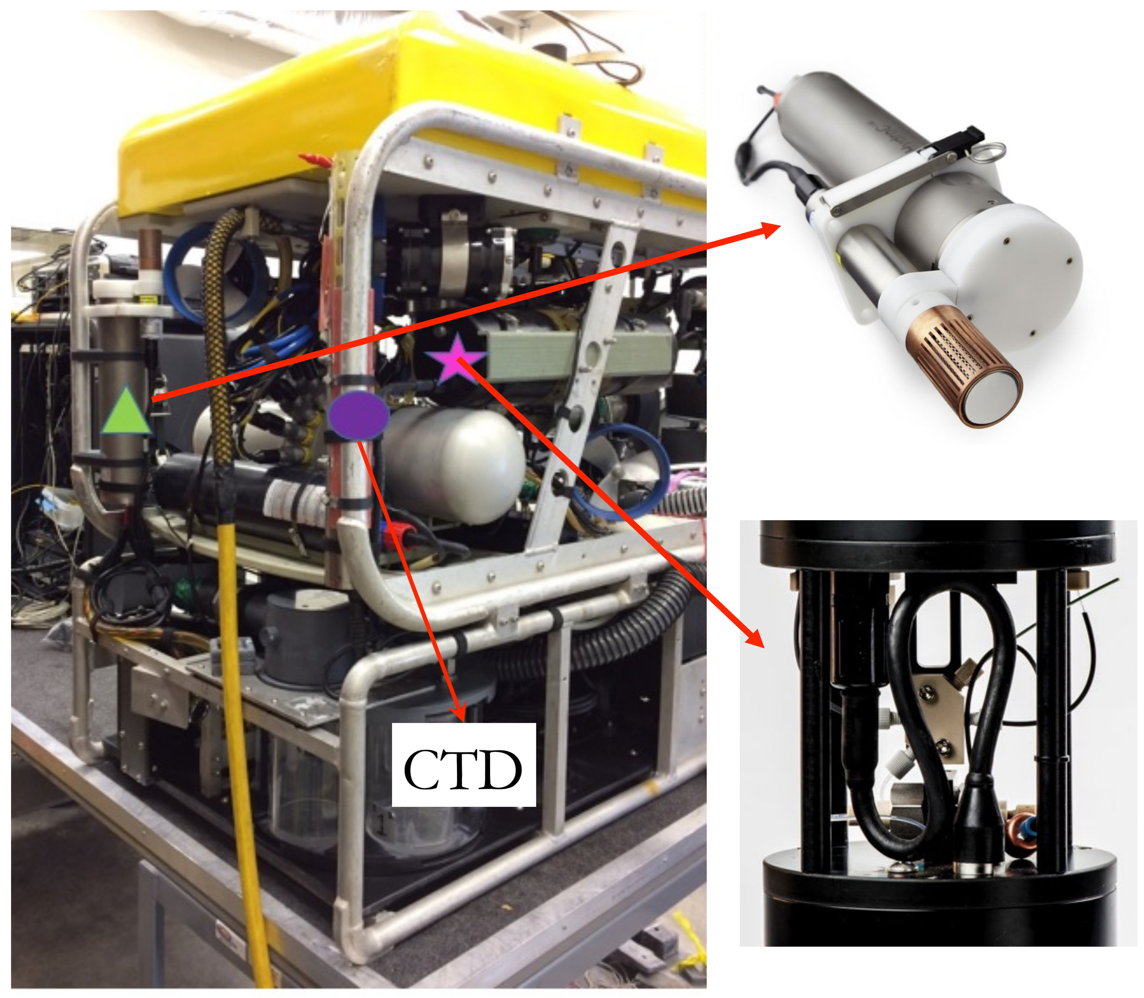


Figure 1. Top: A map of the bathymetry around Cuban Island, surface current (black arrows) and CTD stations (blue-green circles). Bottom left: Bank of St. Antonio. Bottom right: Southern Flank of the bank overlaid with a ROV track (black line). Inset shows an image taken with ROV HD camera.

Methods

A Seabird CTD, SAMI-pH, and HydroC pCO_2 were mounted on a Mohawk ROV, which flies ~1m above the bottom (Figure 2). The integrated system worked well except for a few dives when the pH sensor started before the vehicle was submerged. CTD casts were made once a day, mostly off the reefs to avoid complex reef banks, and water samples were collected to measure T, S, DIC, TA, and pH. Shipboard ADCPs measure current profiles down to 600m. Water samples were analyzed upon return to the lab. Both SAMI and HydroC sampled at 1 min. interval.



HydroC pCO_2 sensor
- High-precision optical analyzing NDIR system
- Standard calibration is 200 – 1000 µatm
- Op. depth 2,000 m
- Response time: 60 s
- Accuracy: ±1 % of reading

SAMI-pH sensor
- High accuracy fast response
- Accuracy: +/- 0.003 pH units
- Response time: 3 min.
- Salinity range: 25-40
- pH range: 7-9 units
- Long deployment (234 d)

Figure 2. Part of Mohawk ROV with sensors on (left) and the HydroC pCO2 (middle top) and SAMI-pH sensors (middle bottom, and their specifications (right).

Currents and water masses

Surface currents around the Cuban Island are dominated by the Caribbean Current, Florida Current and a small branch of Antiles Current in the Bahamas Channel (Figures 1 and 3). The water masses thus are dominated by subtropical North Atlantic waters around the entire island with deep thermocline. Subsurface chlorophyll maximum are prominent at most stations at 80-120m (Figure 3, right).

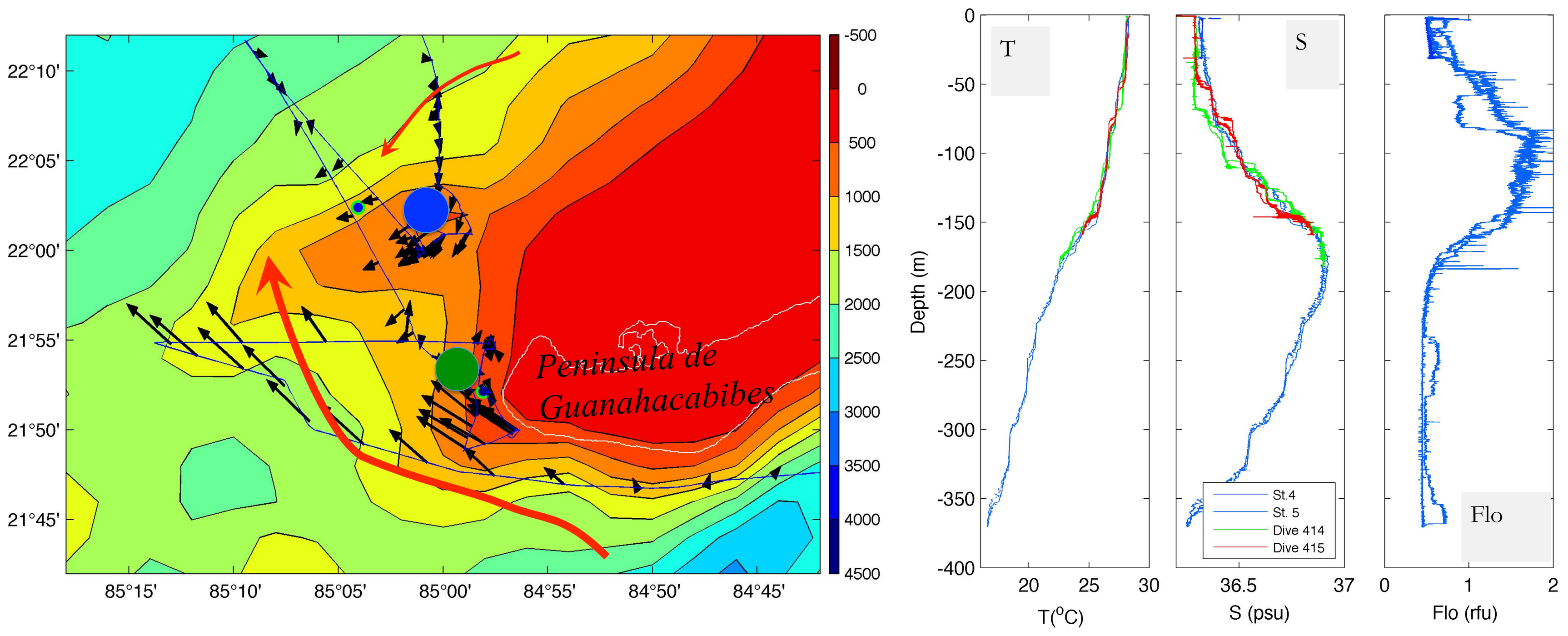


Figure 3. Left: Surface currents (black arrows) around Guanahacabibes Pennisula. Broad red arrows indicate the Caribbean Current getting very close to shore. The think red arrow indicates a moderate return flow along northwestern Cuban slope as part of an anti-cyclonic eddy. Blue and green dots indicate the CTD stations on Bank of St. Antonio and near the Cape, respectively. Right: Temperature (T), salinity (S) and fluorescence (Flo) measured by the shipboard and ROV CTDs at the two stations.

Along track data

Along track data, pH in particular, show significant spatial variations (Fig. 4). pCO_2 and temperature are strongly correlated at most of the stations, likely controlled by temperature but also local biological activity. pH distribution is patchy with a de-correlation scale (a distance beyond which two parameters are not correlated) of ~ 15-30 m, likely due to the patchy distributions of benthic communities, which include diverse corals, sponges and algae.

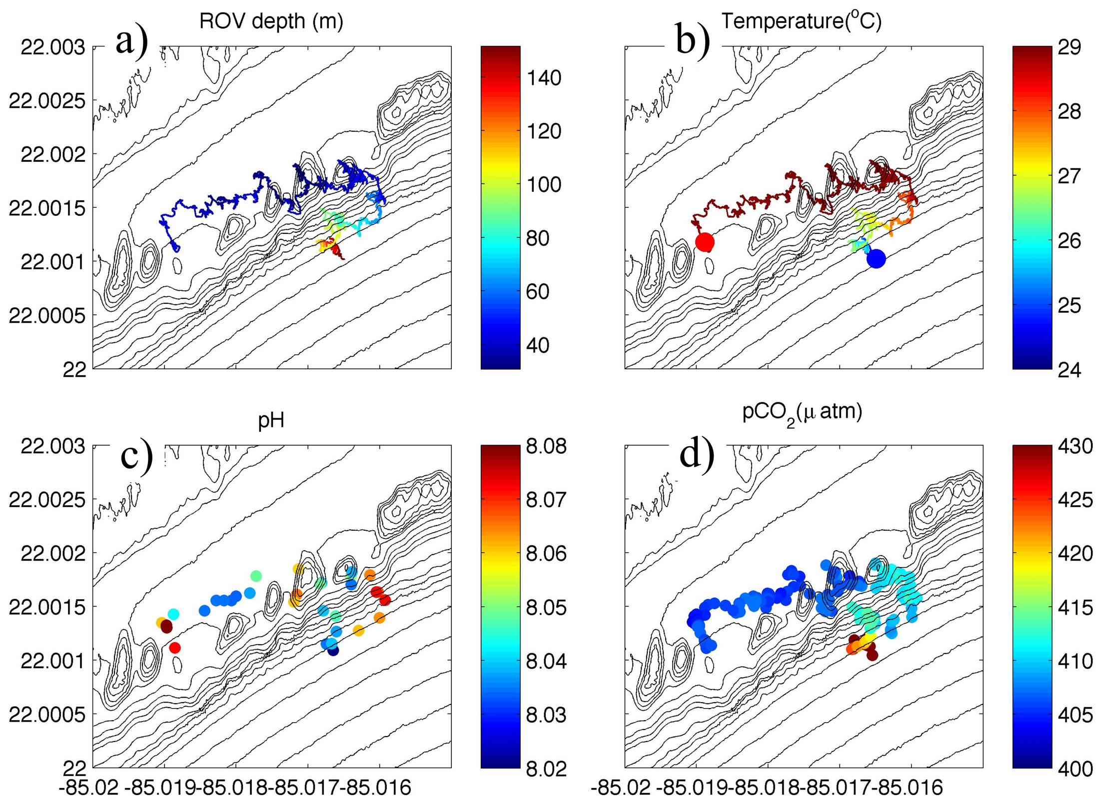


Figure 4. ROV depth (a) and observed temperature (b), pH (c) and pCO_2 (d). Blue and red dots in b) indicate the start and end points of the ROV. Black contours are bathymetry indicating a steep slope and several mounds about 10-15 m high along the ridge. pH and pCO_2 show clear but different spatial patterns.

Vertical profiles with bottle data

DIC, TA, and aragonite saturation state (Ω) were comupted based on the pH/pCO_2 sensor data, using the co2sys program (Van Heuven et al. 2011), which show strong distinct vertical zones as compared to the background measurements from the bottle samples (Fig. 5). DIC/TA variations at 30-50m depth reflect the pH patchiness on the ridge and back reefs. Ω was generally between 3-4.

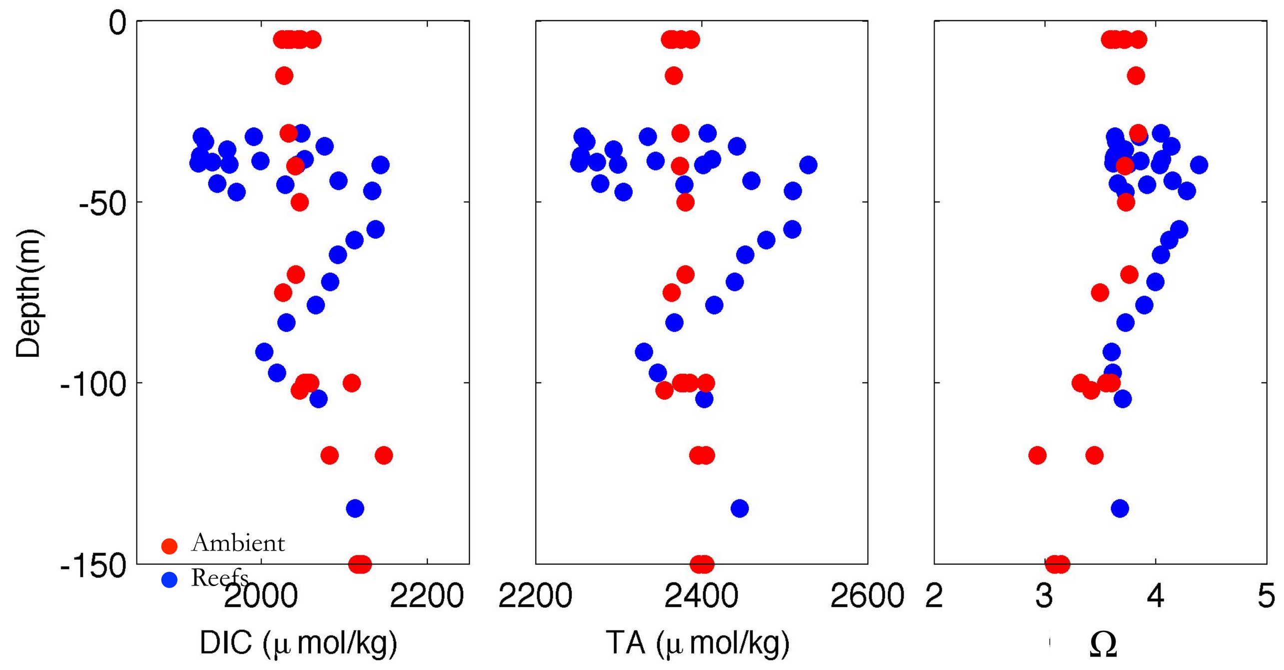


Figure 5. Computed DIC, TA and Ω from ROV-sensor data (blue dots) versus measurements (red dots) from bottle samples at the two stations (see Fig. 3, left). Note that the bottle samples were off the reefs, reflecting the ambient conditions.

Conclusions

Several sensors were integrated with a ROV and the integrated system was successfully deployed to survey >40 mesophotic reefs. The system was able to resolve fine-scale variations of CO_2 parameters due to relatively fast responses of the sensors, and the slow motion of ROV. Significant uncertainties, however, exist in pH data. A preliminary analysis of the sensor data indicates significant fine-scale spatial variability in pH, DIC and TA over the reef areas, likely due to local processes. Ω was within a healthy range.

Acknowledgements

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