DEVELOPMENT OF IN SITU RESPIROMETERS FOR OCEAN ACIDIFICATION STUDIES OS23A-1176

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Abstract

Studies of metabolic rates of deep-sea organisms are important components of research addressing the biological impacts of ocean acidification. These studies contribute to our understanding of the ocean carbon cycle by identifying the pathways and rates of organic carbon fluxes in ocean ecosystems. Oxygen consumption is expected to decrease in most animals in response to hypercapnic (high-CO_2) stress, due to disruption of internal acid/base balance. To perform these field and laboratory studies, a respirometry system utilizing a controller with a distributed architecture was developed. The architecture has allowed the system to be adapted to midwater and benthic respirometers. The distributed nature of the architecture allows the easy expansion of the respirometers as well as the integration of new sensors. An overview of the system and field results to date will be presented

System Description

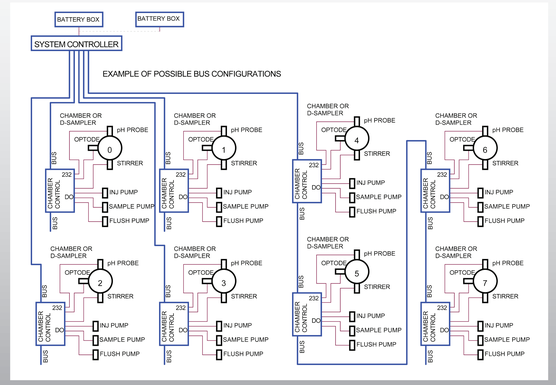
The development of a new control and data acquisition system for respirometry experiments was driven by the need to have a common system architecture that could be used on multiple respirometers. The system needed the flexibility to allow different experimental configurations for each respirometer, as well as for system expansion. A system based on distributed I/O rather than point to point I/O was developed to accomplish these goals.

There are two primary components of the system, the system controller and the chamber controllers, both of which are low power designs. The system controller's function is to execute software that is performing the experiment and to coordinate communications with the chamber controllers. Chamber controllers allow for control and communication with an individual respiration chamber.

The system controller can communicate with multiple chamber controllers over a serial communication bus. Up to seven serial busses are supported by the system controller. Each serial bus can support multiple chamber controllers. The system controller communicates with the chamber controllers using an industrial communication protocol called Modbus. Using Modbus the system controller can query any respiration chamber sensor or control any of the respiration chambers actuators (e.g. flushing and sampling pumps, stirring motors, reagent injectors).

The chamber controller provides the system controller with an interface to the sensors and actuators. When a chamber controller receives a Modbus command over the serial bus it performs the requested function and returns the result to the system controller.

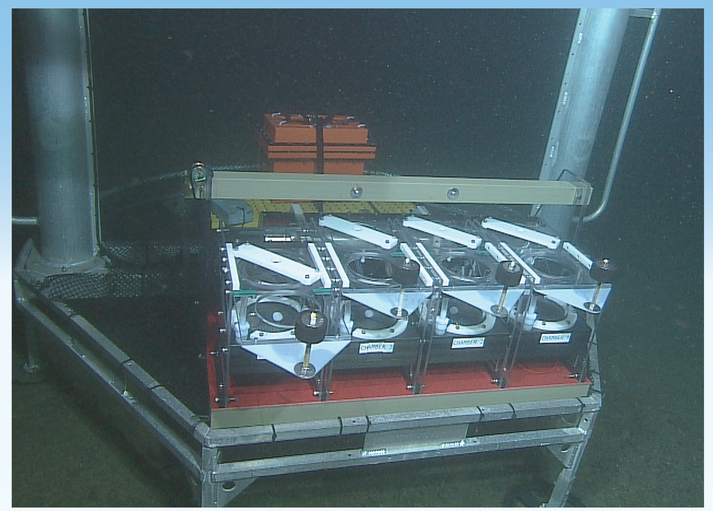
The choice of how many chamber controllers to put on a serial bus is dependant on the amount of data that is expected from the sensors and on the power requirements of the various actuators used by the respiration chamber. The system, however, provides for a great deal of flexibility when configuring a respirometer for deployment.



The diagram above is a system configuration for a typical benthic respirometer deployment. The configuration has eight respiration chambers with multiple serial instruments and actuators on each chamber.

MBARI Benthic Respirometer System Capabilities

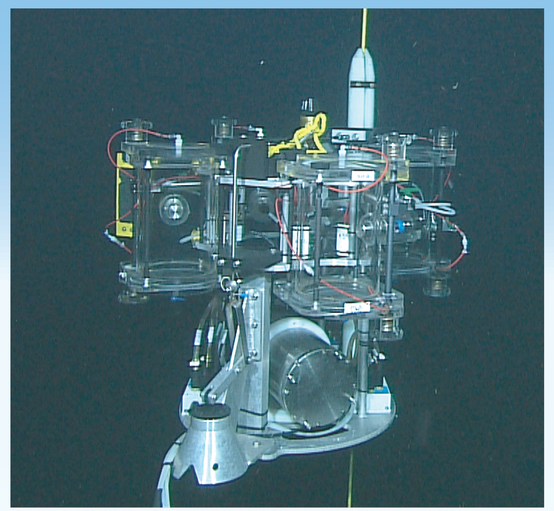
- In situ measurements of respiration rates on benthic deap-sea animals
- 8 chambers to allow for replication of treatment, controls and blanks
- Multiple injection of as many as 3 separate substances (e.g. CO_2 saturated seawater, antibiotics, etc.).
- Up to 3 fluid sample withdrawals from each chamber for pH, DIC, NO_3 etc.
- Flush the chambers at either a preset time or upon an O_2 threshold to avoid hypoxia and allow repeated respiration measurements.
- Quartz chambers and aluminum bases eliminate O_2 efflux from oxygen laden materials (e.g. plastics).



Monterey Bay CA, Sponge Ridge, 504 meters depth, November 11, 2009

MBARI Midwater Respirometer System Capabilities

- Measure the in situ O_2 consumption rates of individual meso & bathypelagic animals
- 6-8 chambers to allow for replication of treatment, controls and blanks
- Multiple injection of as many as 3 separate substances (e.g. CO_2 saturated seawater, antibiotics).
- Flush the indivdual chambers on either a preset interval or when a threshold is reached inside the chamber to replicate measurements of respiration rate.
- Deployable on subsurface mooring line at various depths.
- Quartz chambers to eliminate O_2 efflux from oxygen laden materials (e.g. plastics).



Monterey Bay CA, Midwater Respirometer Mooring, 800 meters depth, November 11, 2009

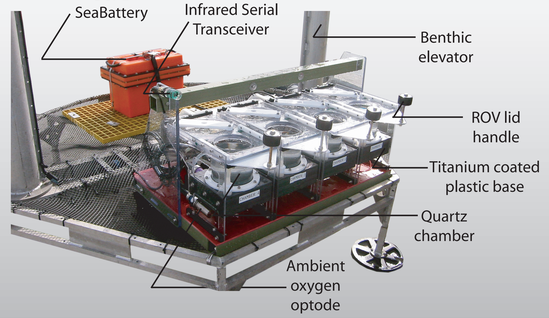
System Controller Features

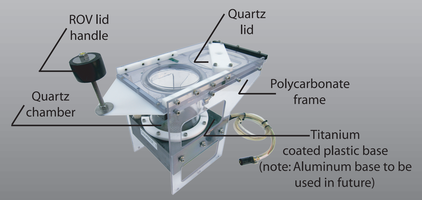
- Persistor CF2 CPU Core (http://www.persistor.com)
- 2-25 milliamp running
- Sub milliamp sleep current
- 7 RS-232/RS-485 ports with associated 12 volt power
- Isolation relays for all serial ports
- Relay switched power on all serial ports
- Modbus supported on all RS-485 ports
- RS-232 console port for configuration and data retrieval

Chamber Controller Features

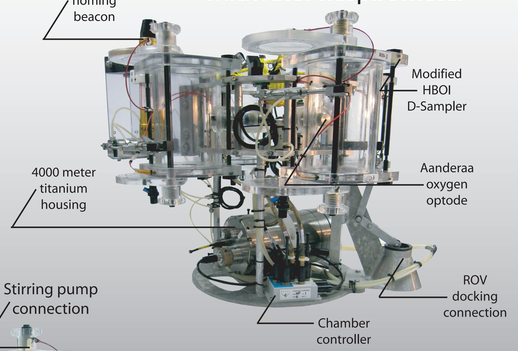
- PIC24 microcontroller
- Microamp sleep current
- 3 milliamp running current
- RS-485 Modbus interface port
- 3 RS-232 sensor interfaces with associated 12 volt power
- 12 volt instrument power sourced via high-side FET switch
- 8 low-side FET switched digital outputs for actuators
- Pressure tolerant potted electronics
- Serial bootloader to allow future firmware updates

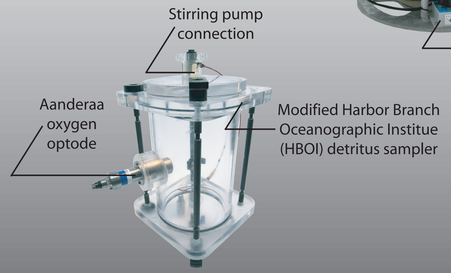
Benthic Respirometer



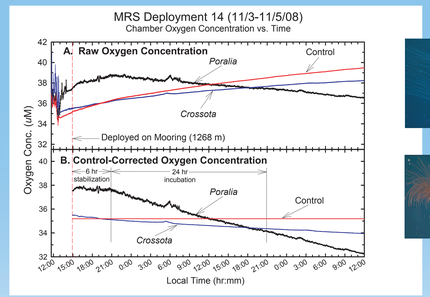


Midwater Respirometer





Midwater Sample Data

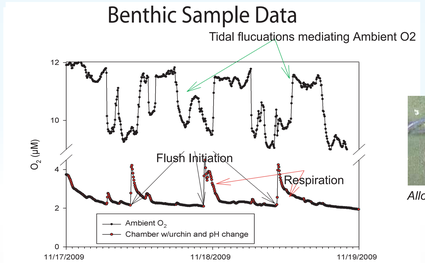


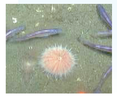
Poralia

Crossota

Oxygen consumption data collected for two bathypelagic medusa (*Poralia* sp. and *Crossota* sp.) and a blank (no animal) control sample during a November, 2008 MRS deployment at 1268 m. Increasing oxygen concentration over time, as seen in the control sample (A), is attributed to the diffusion of oxygen from the walls of the acrylic chambers and is assumed to be consistent in all sample chambers. A best fit regression is determined for the control sample oxygen data and then used to adjust the slopes of the sample curves to correct for this artifact (B). Following deployment, a six hour stabilization period was allowed prior to using the next 24 hours of measurements to later calculate oxygen consumption. The next generation of MRS will field chambers constructed specifically to minimize the oxygen diffusion problem.

Benthic Sample Data





Allocentrotus fragilis

The first deployment of our new Benthic Respirometer System occurred in November (11-19th) in the O_2 minimum zone (504m) in Monterey Bay. This engineering test was limited to 4 glass chambers, 2 were left empty to assess O_2 diffusion from the plastic, 2 had an urchin (*Allocentrotus fragilis* sp.) placed in the chambers. Of the two chambers with animals, Chamber 1 was injected with approximately 15 mls of CO_2 saturated filtered seawater to cause a 0.5 unit decrease in pH. Every 12 hours we flushed the chambers with ambient seawater and re-injected with CO_2 saturated seawater. We present some of these data above. Each point (5 minute interval) on the respective plots represents a reading from the Aanderaa optodes.

Conclusion

In just a handful of deployments the new system architecture has already reduced the effort required to maintain, modify, and deploy MBARI's multiple respirometer systems. In 2010 modifications will be made to the system controller software to allow for more complicated experiments to be performed. In future respirometer deployments the new system architecture will allow larger data sets to be collected with each system deployment. Efforts will also be made to further reduce the overall energy requirements of the system. The new system will unburden the science users from the details of maintaining and deploying the respirometer systems and allow them to focus on experiments.

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