Gene Massion
Monterey Bay Aquarium Research Institute (MBARI)
Monitoring Reporting, and Verification for Marine Carbon Dioxide Removal Using Profiling Floats

A range of marine carbon dioxide removal (mCDR) systems are currently being proposed or in development to address the consequences of increasing acidification in the world's oceans. All of these systems will need a monitoring, reporting, and verification (MRV) system to assess the efficacy of the specific approach. Understanding the long-term impact on the health of the surrounding ecosystem is equally important. As yet, there is no generally accepted approach for mCDR MRV applications. This paper will describe one potential solution based on profiling float technology.

MBARI has developed and deployed a prototype coastal profiling float (CPF) system designed specifically to better understand the health of our ocean in coastal regions, or anywhere in the upper 350 meters of the world's oceans. The CPF platform supports the full suite of biogeochemical measurements defined by the Argo Biogeochemical community: salinity, temperature, depth, oxygen, pH, nitrate, chlorophyll, suspended particles, and down-welling radiation. In addition, dissolved inorganic compounds, $pCO_2$, and total alkalinity can be derived from these measurements. The CPF is autonomous, can anchor, and more importantly de-anchor, on the ocean bottom, or park at a user defined depth. The CPF profiles vertically from the bottom or the park depth up to the surface making measurements at user defined depths and reports the profile results back in near-real time via the IRIDIUM satellite network. Like many profiling floats, the CPF uses an energy efficient buoyancy engine to control vertical profiling speed and depth. The CPF buoyancy engine provides 3.5 liters of volume change (most profiling floats have < 1 liter of volume change) and accurate closed loop control of platform vertical velocity and depth. The CPF system also includes mission planning and operation tools for an array of floats and a data pipeline that provides processed and quality controlled data products. We have designed the CPF to be a flexible platform for a range of applications other than our primary research interests. In addition to the core BGC instruments, we have supported a range of other equipment including sediment traps, turbulence sensors, and acoustic modems.

Although the CPF system is not specifically targeting mCDR MRV, it has demonstrated many of the major and potentially riskiest elements of a cost effective mCDR MRV system. This paper will also address 2 additional elements that might be required for a CPF system specifically targeting mCDR MRV applications. The first is a non-drifting profiling float. In order to minimize energy consumption and achieve our mission life goals, the CPF only has control over vertical speed and depth. The CPF is free to drift horizontally driven by prevailing currents. In some scenarios, both in our future research needs and the needs of a mCDR MRV system, an array that combines drifting CPFs and CPFs fixed to the ocean bottom will be desirable. Unfortunately, fixed oceanographic moorings are generally expensive, vulnerable, difficult to deploy and recover, and have significant maintenance costs. Adding a profiling capability to a typical oceanographic mooring further exacerbates these problems. A somewhat novel winched profiling concept anchored to the ocean bottom and integrated into the CPF platform will be described that minimizes some of the aforementioned problems. The second element is addressing the practical challenge of evolving research technology like the CPF system across the so-called "tech transfer canyon of death" into cost-effective, scalable, robust operational systems generating relevant, defensible data products.