On 24 July 2015, C-MORE embarked on an ambitious open ocean expedition to conduct a comprehensive analysis of the diel patterns in phytoplankton physiology and biogeochemical cycling in the near-surface waters of the oligotrophic North Pacific Ocean (Figure 1). Diel patterns in ecology are particularly relevant in biological oceanographic research where the planktonic biomass turns over on timescales of days. While measurements over a diel period have been conducted on previous occasions, they are not generally regarded as a ‘tool’ to better understand key marine ecosystem processes such as productivity and export. Some of the difficulties include making sufficient measurements for repeated days and having analytical instrumentation with sufficient detection limits. In July 2015, C-MORE sought to reverse this situation by conducted the most highly coordinated diel study in the oligotrophic gyre.

To accomplish the research objectives, C-MORE took two research vessels the R/V Kilo Moana and the R/V Kaimikai O’Kanaloa out to sea with a total science party manifest of 46 people making this one of the largest expeditions hosted by C-MORE.

To aid the high-resolution temporal measurements, the seawater sampling was conducted using a Lagrangian approach which was facilitated by the deployment of two Surface Velocity Program (SVP) drifters (Figure 3). These free-drifting drogues have a small surface float attached to a
holey-sock centered at a depth of 15 m. The drifters were deployed close to the center of an anticyclonic eddy which was located to the north-east of Station ALOHA at the time of sampling. During the expedition the drifters remained within 500 meters of each other and drifted at a rate of 5-10 miles per day (Figure 4). The weather and sea state were perfect for conducting operations with light winds and calm seas. The water-column had a relatively shallow mixed layer depth during the first half of the cruise, between 15 and 30 m. It subsequently deepened due to increasing wind speed in the latter half of the cruise, causing some entrainment of seawater below the mixed layer into the surface waters.

Figures 3 and 4. On the left-hand side are the SVP drifters which were deployed to facilitate the Lagrangian sampling. On the right-hand side is the drift track of the drifters by the end of the expedition. The shipboard operations were conducted by both research vessels next to the drifters.

Figure 5. The stratified conditions were accompanied with a small accumulation of pigments and a large accumulation of dissolved oxygen beneath the base of the mixed layer. When the winds picked up in the latter half of the cruise, there was a small entrainment of these cells and O2 into the mixed layer, complicating the diel analysis.

One of the exciting discoveries concerned an abundant population of Crocosphaera watsonii which is a 2-4 µm sized unicellular coccoid cyanobacteria. Populations of Crocosphaera have low genomic diversity with only two phenotypes identified so far based on cell size and production of extracellular polysaccharides. Both phenotypes were present in the water-column in July-August 2015. Crocosphaera has the capability of full oxygenic photosynthesis, but also contains the nitrogenase enzyme and thereby reduce atmospheric dinitrogen (N2) to ammonium. It conducts the oxygen-sensitive N2 fixation process during the night-time (Figure 6) to avoid the deleterious effects of oxygen production during photosynthesis which allows it to rotate its
cellular iron inventory which is required by both nitrogenase and photosynthetic enzymes. Further adaptations to life in the tropics include comparatively high temperature growth optima. The cell size, its metabolic capacity for fixing carbon and nitrogen, its low iron requirement and high temperature optima would seemingly establish Crocosphaera as a key player in the oligotrophic marine ecosystem however a prominent role for this microorganism has so far not been established. The high abundance of cells in July-August 2015 allowed for simultaneous measurements of population dynamics; cell transcripts; rates of N2 fixation, and contribution to export in the context of water-column hydrography and biogeochemistry.

Figure 6. Rate measurements of N2 fixation during the expedition revealed the time when Crocosphaera is active during the night. Its narrow window of nitrogenase activity is strongly regulated over the diel period.