NH1410 Cruise Report

Eastern Tropical North Pacific
Oxygen Minimum Zone Microbial Biogeochemistry Expedition 2 -
Autonomous Float Sampling for N Loss
(OMZoMBiE 2 - Floats)

Vessel: *R/V New Horizon*
Dates: May 10-June 8, 2014
Port of departure/return: San Diego, CA

Contents

I. Objectives

The broad objective of this cruise was to characterize microbial nitrogen and sulfur cycling in the anoxic oxygen minimum zone (OMZ) of the Eastern Tropical North Pacific (ETNP). Specific emphasis was placed on key steps of dissimilatory nitrogen metabolisms contributing to fixed nitrogen loss (e.g., anammox, denitrification), and autotrophic sulfur oxidation. Meeting this broad objective involved an overall assessment of OMZ microbial diversity, gene content, and metabolic activity across gradients of oxygen and substrate (e.g., inorganic nitrogen) availability and between particle-associated and free-living microniches, as well as detailed descriptions of water column chemistry using a novel autonomous float platform for measuring nitrogen loss (via N_2 production) *in situ*. This cruise builds upon prior work initiated in the study area in June 2013 during cruise OMZoMBiE 1 (NH1315).

Table 1. Science party.

Participant	PI/Lab	Role	Institution
Frank Stewart	Stewart	Chief Sci	Georgia Tech
Josh Parris	Stewart	Grad	Georgia Tech
Cory Padilla	Stewart	Grad	Georgia Tech
Mark Altabet	Altabet	PI	U Mass-Dartmouth
Anne Bourbonnais	Altabet	Postdoc	U Mass-Dartmouth
Haibei Hu	Altabet	Grad	U Mass-Dartmouth
Anne Cruz	Altabet	Tech	U Mass-Dartmouth
Eric D'Asaro (onshore-support, floats ops)	D'Asaro	PI	U Washington
Craig McNeil	McNeil	PI	U Washington
Andrew Reed	McNeil	Grad	U Washington
Bo Thamdrup	Thamdrup	PI	U. Southern Denmark
Laura Bristow	Thamdrup	Postdoc	U. Southern Denmark
Martin Hernandez-Ayon	Hernandez-Ayon	PI	U Autonoma de Baja, Mexico
Orión Lopez	Hernandez-Ayon	Grad	U Autonoma de Baja, Mexico
Gadiel Alarcon	Ulloa, Osvaldo	Scientist	U. Concepcion, Chile
Montserrat Aldunate	Ulloa, Osvaldo	Postdoc	U. Concepcion, Chile
Emilio Garcia-Robledo	Revsbech, Niels Peter	Postdoc	Aarhus U, Denmark
Meghan Donohue	NA	ResTech	Scripps Inst. Oceanography
Josh Manger	NA	ResTech	Scripps Inst. Oceanography

Cruise NH1410 was funded through NSF BIO OCE grants to PIs Stewart (1151698) and Altabet (1154741). In total, the cruise combined the efforts and expertise of 16 science party participants (not including ResTechs), representing 8 laboratories (PIs) from 7 universities and 4 countries (Table 1). This collaboration utilized an integrated sampling approach involving ship-based and autonomous (float) profiling of environmental variables (oxygen, inorganic nitrogen and carbon concentrations, N_2 production), bottle and microcosm incubations for measuring metabolic rates, and biomass collections for molecular analyses (metagenomics, metatranscriptomics, single-cell genomics). A key component of this project involved the testing and application of two autonomous floats (APL GasFloats) equipped with gas tension devices to measure biogenic N_2 production in OMZs (Project 1154741, Altabet). Rosette-based water sampling and chemical profiling were directly coupled to float operations to calibrate autonomous measurements and to enable time-series Lagrangian sampling within a water mass in the OMZ. In addition, this cruise enabled further testing of a novel Rosette-based sampler for the *in situ* preservation of microbial biomass samples for gene expression analysis (Stewart group). Additional details regarding sampling and cruise operations can be found below.

II. Study site - ETNP OMZ

Encompassing ~12×10^6 km^2 of shelf and off-shelf waters, the ETNP OMZ south of Baja California is the largest of the major permanent oxygen minimum zones (41% of total OMZ area) (Paulmier and Ruiz-Pino 2009). Dissolved O_2 falls to near or below the detection limit (<100 nM) at mid-water depths (~150-750m) throughout the region (Karstensen et al. 2008). This oxygen depletion significantly alters the pelagic ecosystem, resulting in a microbially dominated community driven by anaerobic metabolisms with major contributions to marine biogeochemical cycling, including key reductive processes driving the loss of bioavailable nitrogen (i.e., N_2 and N_2O production by denitrification and anammox). Surprisingly, while the ETNP OMZ has been the focus of extensive oceanographic research, this region is under-explored from a microbiological and molecular perspective. Recent studies have begun to characterize the distribution and activity of a subset of functional taxonomic groups in the ETNP OMZ (Beman et al. 2012, 2013, Podlaska et al. 2012, Beman and Carolan 2013). However, the overall diversity of taxa and metabolisms and the contributions of these metabolisms to bulk ecosystem properties, including carbon flux and N_2 loss to the atmosphere, remain largely unknown for this OMZ.

Intensive microbial biogeochemical studies in other major OMZ regions have revealed a taxonomically diverse microbial and viral community with the potential for unexpected and cryptic metabolisms (Thamdrup et al. 2006, Stevens and Ulloa 2008, Canfield et al. 2010, Cassman et al. 2012, Wright et al. 2012, Ulloa et al. 2012). For example, experimental and molecular evidence from seasonal OMZs and from the permanent OMZ of the Eastern Tropical South Pacific (ETSP) has identified an abundant and active pelagic community of dissimilatory sulfur-metabolizing bacteria with important links to nitrogen loss processes and carbon cycling (Walsh et al. 2009, Canfield et al. 2010). However, it remains unclear how environmental conditions (e.g., oxygen, nitrogen gradients), and their fluctuation over variable spatial and temporal scales, structure the diversity, activity, and ecological significance of most microbial groups in OMZs. This cruise was organized around cross-disciplinary collaborations merging physical and biological oceanography, isotope biogeochemistry, microbiology, and genomics, thereby facilitating a comprehensive description of ETNP OMZ biogeochemistry and microbiology. Our expectation is that this work will enhance a broader understanding of how oxygen gradients structure pelagic microbial ecosystems and therefore affect elemental fluxes between the ocean and atmosphere. This work will also help advance the development of new techniques and instrumentation for studying microbial biogeochemistry in low-oxygen waters.

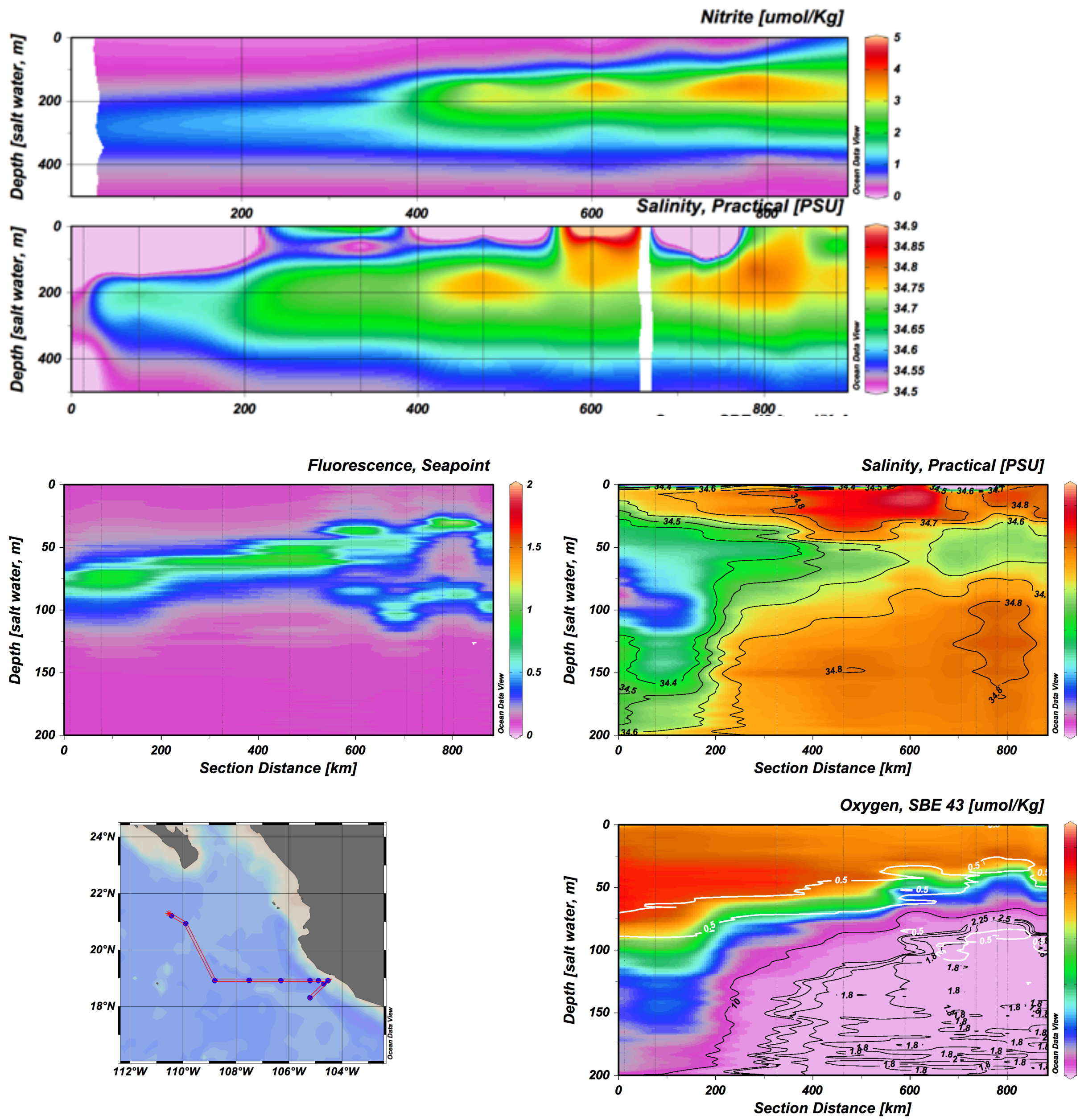


Figure 1. Profiles of nitrite, salinity, fluorescence, and dissolved oxygen in the upper water column of the study area west of Manzanillo in June 2013 (OMZoMBiE cruise, NH1315). The upper plots highlight a relationship between nitrite and salinity.

Table 2. Station locations.

Station*	Lat N**	Long W**	Station*	Lat N**	Long W**
Test station	32 37.239	117 29.838	11F-03	20 42.800	107 52.444
Soledad (#1)	25 11.939	112 42.113	11F-04	20 44.726	107 53.997
Float dunk test	23 36.590	111 06.003	11F-05	20 43.846	107 55.195
4T	18 53.873	106 17.977	12F-01	20 44.971	107 57.116
F1	18 59.927	106 59.968	12F-02	20 47.877	107 54.354
F2	19 19.979	107 00.042	12F-03	20 49.735	107 56.254
F3	19 40.291	107 00.057	12F-04	20 49.029	107 55.441
F4	20 00.062	107 00.037	12F-05	20 50.989	107 56.992
F5	20 19.965	107 00.000	13F-01	20 52.963	107 58.268
F6	20 39.907	107 00.199	13F-02	20 53.295	107 57.338
F7	21 00.104	107 00.089	13F-03	20 53.570	107 58.254
6T	18 54.001	104 54.040	13F-04	20 53.337	107 58.165
7T	18 12.023	104 12.160	13F-05	20 53.990	107 58.270
8T	18 11.885	104 53.804	13F-06	20 54.122	107 54.767
9T	18 11.998	105 12.006	13F-07	20 55.755	108 00.063
10T	18 12.047	106 17.797	13F-08	20 55.420	108 00.135
11T	18 12.077	107 29.955	14F-01	20 57.351	108 00.670
2T	18 54.072	108 48.015	14F-02	20 57.707	108 00.490
3T	18 54.201	107 29.922	14F-03	20 56.972	107 58.153
3Ta	18 54.475	107 19.488	14F-04	20 56.857	107 58.014
9F-01	20 33.354	107 46.060	14F-05	20 57.169	107 58.260
9F-02	20 33.120	107 46.536	14F-06	21 00.092	108 00.321
10F-01	20 36.723	107 49.214	14F-07	20 59.792	107 59.755
10F-02	20 37.279	107 50.527	14F-08	20 59.954	108 00.005
10F-03	20 39.655	107 51.567	15F-01	20 52.70	107 42.48
10F-04	20 40.321	107 51.742	ES (eddy)	21 45.029	110 50.946
10F-05	20 40.198	107 49.448	BS-01	28 21.900	115 51.719
11F-01	20 42.766	107 51.791	BS-02	29 50.417	116 30.989
11F-02	20 41.176	107 51.591			

*Stations named to maintain consistency with CTD log files (see 'Operations log')
**Lat/Long are coordinates for initial CTD/PPS deployment at each station

III. Sampling strategy and cruise operations

A primary goal for NH1410 cruise operations was to balance N-sensing float operations with ship-based water sampling for chemical measurements and experiments. To meet this goal, the cruise was structured into three primary phases (Figure 2, Table 2).

- **Phase 1** (May 10-19) involved transit south from San Diego, test deployments of instrumentation, CTD surveying to identify float deployment sites, and ARGO and APL float deployment. Phase 1 also included water sampling for experimentation at a process station (4T) located on a transect line previously sampled in June 2013 (Cruise NH1315) and at Soledad Basin, a silled basin on the western continental shelf off Baja (~25° 6.0N, 112° 42.0W) that experiences persistent anoxia (Van Geen et al. 2003). Prior to float deployment, a CTD-based survey was conducted along a S-N transect (19° to 21°N, 107°W) to assess water column oxygen and nutrient conditions and identify deployment sites. Based on survey results, APL floats were deployed in the vicinity of 20°N, 107°W on May 17th.

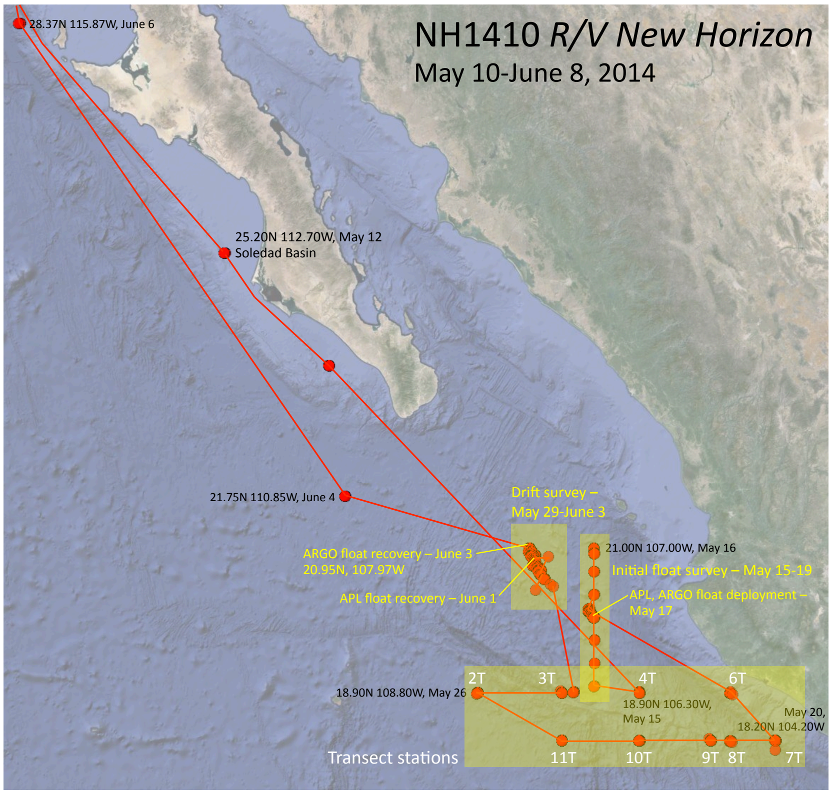


Figure 2. NH1410 cruise track showing key stations for float operations or water sampling (red circles) and associated waypoints. The cruise departed from and returned to the Scripps Nimitz Marine Facility, San Diego.

- **Phase 2** (May 19-27) involved extensive water sampling along two west-east transects spanning an off-slope-to-shelf gradient within the OMZ (stations 2T-11T; Figure 2). Biogeochemical and molecular analyses in the OMZ off Peru recently confirmed a stark contrast in microbial activity between offshore and coastal (shelf) sites, with the latter exhibiting substantially higher rates of key OMZ nitrogen transformations (Kalvelage et al. 2013). These elevated rates were linked to an overall greater level of primary production and organic matter influx at coastal sites. Sampling in the ETNP in June 2013 identified similar variability along our ETNP transects, with the transition from deeper waters to slope/shelf sites (from ~110°W to 104°W) accompanied by oxycline shoaling, a mid-depth (~200-500m) salinity increase, and an enhanced secondary fluorescence peak in the upper OMZ. Our sampling strategy was designed to capture similar gradients in 2014. At stations 2T-11T (excluding station 5T, which was not sampled), water was collected via either rosette or pump-profiling system (PPS; property of collaborator O. Ulloa, U. Concepcion) and either preserved for chemical or molecular analysis at home institutions or used for shipboard measurements of nutrients, dissolved oxygen, and dissolved inorganic carbon (DIC) concentrations, bottle incubations to quantify rates of nitrogen metabolism, respiration, and O_2, and mesocosm experiments to examine community gene expression. Sampling required ~12-24 hours per station.

- **Phase 3** (May 27-June 8) involved a return to float-based operations and sampling, and return transit to San Diego. Notably, intensive water sampling was conducted from May 28 to June 3 along the track of the drifting APL floats. Sampling sites during this "drift survey" were determined based on float positions, thereby allowing repeat sampling of the same water mass over multiple diel cycles. (Floats were recovered on June 1; the survey continued along the projected float track until the morning of June 3) Samples for measurements of biochemical rates, nutrient concentrations, and community gene expression during the survey were collected primarily from the primary and secondary chlorophyll layers and lower oxycline (all within the photic zone), and intermittently from the OMZ nitrite maximum (below the photic zone). Operations after the drift survey involved rosette sampling at two sites in non-OMZ waters north of the study area (June 4,6; Figure 2).

IV. Group Summaries

Detailed summaries of sampling activities are provided below, listed according to PI/group. A list of station names and locations is provided in Table 2 at the end of the document, along with a summary of PPS deployments and the Operations Log for the cruise (Appendix A and B).

i. Microbial community genomics and function - Stewart

Team members: Cory Padilla (grad student), Josh Parris (grad student), Frank Stewart (PI)

Cruise objectives: The Stewart lab explores how oxygen concentrations affect the structure and function of marine microbial communities. The first major objective of this research is to characterize the genomic basis and biogeochemical properties of coupled microbial sulfur and nitrogen cycles in oxygen-depleted marine waters. This work involves sampling at two physiochemically distinct low oxygen regions, the permanently anoxic oxygen minimum zone (OMZ) of the ETNP (this cruise, and cruise NH1315 in 2013) and the seasonally hypoxic zone of the Gulf of Mexico (2012, 2015). To help contextualize sulfur cycling relative to other community biogeochemical and ecological processes, a secondary objective is to conduct an overall assessment of OMZ microbial (prokaryote and eukaryote) and viral diversity and metabolism across gradients of oxygen and substrate (e.g., inorganic sulfur and nitrogen) availability and between particle-associated and free-living microniches. A substantial component of this secondary objective involves participation by collaborators, with a focus on linkages between OMZ sulfur cycling and key steps of dissimilatory nitrogen metabolism (e.g., nitrification, anammox, denitrification) and carbon metabolism (e.g., dark carbon fixation).

Cruise tasks:

1) *DNA/RNA sampling*. We collected samples for metagenomic, metatranscriptomic, and single-cell genomic analyses of OMZ bacterioplankton biomass over depth gradients at coastal and

offshore sites in the ETNP OMZ. Coupled community DNA/RNA samples were collected from an average of 4-12 depths targeting key water column features: the oxic photic zone, oxycline (upper), OMZ interface, secondary chlorophyll maximum, nitrite/salinity maximum, and anoxic OMZ core. Depth profile samples for metagenomics (DNA) only were collected at a subset of stations. At most stations (transect and survey), DNA/RNA sampling was coupled to collections by the Thamdrup lab, either for experimental measurements of biogeochemical rates (anammox, denitrification, N_2O production, and methane production/consumption), experiments, or chemical measurements (e.g., methane concentration). At three sites (float survey, 3T, 7T), DNA/RNA collections were coupled to high-resolution sampling for anammox rate measurements across the oxycline, interface, and upper OMZ (Thamdrup lab). In most instances, DNA/RNA samples were collected across two or three size classes (0.2-1.6 µm, 1.6-30 µm, > 30 µm) to assess compositional and metabolic differences between free-living and particle-associated OMZ bacterioplankton. Filter volumes for all DNA/RNA samples were recorded to enable downstream quantitative-PCR counts of individual microbial taxa or target functional genes. At four sites (2T, 3T, 9T, F14), size fractionated microbial samples were collected from bathypelagic depths beneath the OMZ (2300-3000 m) in coordination with the Altabet lab.

2) *Methane sampling*. In collaboration with the Thamdrup lab and the Girguis lab (Harvard), we collected samples to A) quantify methane concentration and production measurements across the OMZ, B) measure microbial gene transcription in response to methane addition, and C) enrich for nitrite-dependent methanotrophs related to NC10 bacteria. This work was motivated by metagenomic and metatranscriptomic sequences from the 2013 ETNP cruise suggesting the presence and transcriptional activity of microorganisms mediating both the production (methanogens) and consumption (methanotrophs) of methane in the OMZ, notably at core anoxic depths at station 6T. These sequences include a subset matching the NC10 clade, a group of methanotrophic bacteria that putatively oxidize methane aerobically under anoxic conditions using oxygen liberated from the dismutation of nitric oxide. Sampling for methane concentration (objective A) and turnover is described below (Thamdrup lab). To meet objective B, microbial gene expression in response to methane was measured at three sites (8T,10T, F14) using microcosm (bottle) experiments. For each experiment, OMZ water (~300 m, OMZ core) was collected and used for anaerobic incubations in glass bottles. Seawater was purged of residual oxygen and amended with nitrite (15 µM), followed by a pulse of methane gas (1 min). The bottles were incubated for 15 hrs under *in situ* temperatures, without light, and with a continual feed of helium/CO_2 gas into the bottle headspace. Samples for analysis of community RNA and methane concentration were collected at the end of each experiment. Experiments were run in collaboration with the Thamdrup lab. To meet objective C, enrichments for nitrite-dependent NC10 bacteria were initiated using core OMZ water from two stations (6T, 8T). A total of 32 enrichment treatments were initiated at each site, encompassing variation in cell abundance (filter-concentrated vs. non-concentrated cells), and inorganic nitrogen source (nitrite vs. nitrate) and concentration (ambient, 10, 100, or 1000 µM nitrite or nitrate).

3) *In situ RNA preservation*. We deployed and tested a recently developed instrument for the *in situ* collection and preservation of microbial biomass for RNA analysis. The sampler is designed for mounting on a standard Rosette and actuated by bottle triggering. Upon triggering, seawater is pumped through a collection filter for 25 min, followed by pumping of RNA preservative to saturate the filter. The goal is to stabilize RNA *in situ*, thereby minimizing changes in the total

transcript pool that may arise due to collection and transport to the surface (i.e., in response to changes in oxygen). The sampler was deployed successfully on three casts to the OMZ core at station 8T. *In situ* preserved samples will be compared to control samples collected via Niskin bottle and processed through standard filtration and preservation methods aboard ship. This objective is part of a collaboration with the Girguis lab.

4) *Size-fractionation filter experiments*. We ran three experiments to test how measurements of microbial community composition vary depending on the volume of water passed through a filter. Filter clogging may rapidly change the composition of the retained biomass. I.e., small cells pass through a filter early during filtration, but may eventually be retained as the volume of water passed through a filter increases. Quantifying this bias is critical for accurately characterizing microbial communities within different filter size fractions or microhabitats (e.g., free-living vs. particle-associated communities). These experiments tested a range of water volumes and three filters types (0.2 µm Sterivex, 1.6 µm GF/A disc, and 30 µm nylon disc filters).

5) *Diel gene expression*. Samples for analysis of microbial community gene expression over a day-night cycle were collected four times per day (0700, 1200, 1800, 2300 hrs) from 3-4 target depths during the 5-day APL float drift study (29 May – 1 June). Samples for total RNA analysis were collected from the primary and secondary chlorophyll maxima (~40 and 90 m, respectively) and upper OMZ interface (~70 m) at each timepoint. RNA from the nitrite/salinity maximum (125-150 m), which occurred below the photic zone, was sampled at only the beginning, middle, and end of the survey. DNA for community composition analysis was sampled at the same three timepoints. All samples were collected via rosette or PPS deployments as close to the actual or predicted positions of the drifting APL floats as possible. Coupled with measurements of water column chemistry and biogeochemical rates, these RNA samples will enable one of the first Lagrangian surveys of microbial community metabolism within a dynamic OMZ water mass.

6) *Other*. Samples to initiate enrichment cultures of OMZ microbes for use in microbial fuel cells (Girguis lab) were collected from the core of the OMZ at station F9. Samples for analysis of community transcription in response to light gradients were collected to complement incubation experiments by E. Garcia-Robledo (Station F13).

ii. N isotope chemistry - Altabet

Team Members: Mark A. Altabet (PI), Annie Bourbonnais (postdoc), Anne Cruze (summer intern), Happy Hu (grad student)

Background**:**

Nitrogen isotope and N_2/Ar biogeochemistry of the ETNP suboxic zone: a Lagrangian experiment

Nitrogen (N) is an essential and often limiting macronutrient for primary producers in the surface ocean. It is therefore an important modulator of the marine biological pump and of the ocean's capacity to sequester atmospheric CO_2, a greenhouse gas, in its interior (Falkowski, 1997). The availability of bio-available N in marine environments is regulated by the balance between N sources, mainly from N_2 fixation, and N loss by denitrification and anaerobic ammonium oxidation (anammox), both of which occur under hypoxic conditions ([O_2] <10 μM) and convert dissolved inorganic N to gaseous N_2. Although they represent only 0.1% of total oceanic volume, OMZ's host the largest portion of total marine N-loss (up to 400 Tg/yr; Codispoti, 2007) and dominate the ocean N isotope budget through co-generation of ^{15}N and ^{18}O enriched NO_3^- (Cline and Kaplan 1975; Voss et al., 2001; Sigman et al. 2005) and ^{15}N depleted N_2.

The most direct geochemical measure of N-loss is to measure the accumulation of biogenic N_2. However, even in the most active oceanic N-loss settings this is a small signal on top of a large background of atmospherically derived N_2. This has traditionally been overcome by very precise mass spec measurements of the ratio of N_2 to inert Ar gas on samples brought back to the laboratory. A novel approach is to precisely measure total dissolved gas pressure use gas tension devices (GTD) which in the absence of O_2 is almost entirely due to N_2 gas.

Stable isotope measurements are another useful tool to study N-cycle transformations in marine environments. Both NO_3^- assimilation and denitrification increase NO_3^- $\delta^{15}N$ (with $\delta = [(R_{sample}/R_{standard})-1] \times 1000$, where R represents the ratio of ^{15}N to ^{14}N) as a consequence of kinetic N-isotope fractionation (e.g. Cline and Kaplan, 1975; and reference therein). The isotope enrichment factor (ε_{den}) associated with microbial denitrification is high, with most recent estimates from both laboratory experiments and natural environments clustering between 20 and 25‰ (Brandes et al., 1998; Voss et al., 2001; Granger et al., 2008). The measurement of coupled NO_3^- N and O isotope ratios has the potential to disentangle NO_3^- consumption and production processes in environments where they occur simultaneously (Sigman et al., 2005; Casciotti and McIlvin, 2007; Bourbonnais et al., 2009; 2012). In addition, the unusual inverse fractionation effect for NO_2^- oxidation (Casciotti et al. 2009, $\varepsilon \sim$ -14 to -20‰) represents a potentially powerful approach to help distinguish processes controlling both the NO_3^- $\delta^{18}O$:$\delta^{15}N$ relationship and the production of biogenic N_2. For denitrification, $\delta^{15}NO_2^-$ would be a function of the difference in ε values for NO_3^- and NO_2^- reduction. Since they are similar in magnitude (Bryan et al., 1983), $\delta^{15}NO_2^-$ should be similar to $\delta^{15}NO_3^-$. However if NO_2^- oxidation is a significant fraction of these fluxes, $\delta^{15}NO_2^-$ is lower, as observed in the ETNP consistent with either extensive cycling between NO_3^- and NO_2^- and/or important fluxes to NO_3^- via oxidation of low $\delta^{15}N$ NH_4^+.

The large isotopic and isotopomer signatures associated with N_2O production and consumption yield important source/sink information (Yoshinari et al 1997; McIlvin and Casciotti 2010). In addition to bulk $\delta^{15}N$ and $\delta^{18}O$, the asymmetry of the N_2O molecule permits distinguishing the N isotopic composition of the central (α) and end (β) position N atom (^{15}N site preference (SP) is defined as $\delta^{15}N^{\alpha}$ - $\delta^{15}N^{\beta}$) (Yoshida and Toyoda 2000), which is distinct for N_2O resulting from nitrification or denitrification, and thus potentially allow to differentiate between these different processes.

<u>Cruise objectives and tasks</u>**:**

Our main goal during the research cruise NH1410 was to collect discrete and continuous samples to calibrate two Lagrangian (#77 and #78) and one Argo floats first deployed at 19 59.936°N and 107 00.059°W, on the southern edge of a cyclonic eddy (see McNeil section. These, for the first time, were equipped with GTD sensors for the purpose of measuring biogenic N_2 production in OMZ's. The floats were recovered about 3 weeks later at 20 33.342°N and 107 46.065°W. In addition to samples to be returned to the laboratory, we also made for the first time high precision N_2/Ar measurements at sea using a quadrupole mass spectrometer on discrete samples collected by CTD as well as continuous samples obtained using a pump profiler system (PPS). Samples were also collected along hydrographic sections (stations 1T-11T (except station 5T)). The following analysis were (will be) performed:

1) *Nutrient concentrations*. 15 to 125 mL of seawater was frozen for nitrate (NO_3^-) and phosphate (PO_4^{3-}) analysis on-shore. Nitrite (NO_2^-) was analyzed on-board using a NO_2^- autoanalyzer. Continuous NO_2^- profiles were collected at stations 2T, 3T, 6T, 7T, 8T, 10T, 11T and F10 and F11 using the PPS.

2) *Dissolved inorganic N (DIN) isotopes*. NO_3^- and NO_2^- for $\delta^{15}N$ and $\delta^{18}O$ analysis were collected at all regular and float stations. In addition, at two stations (2T and 9F), ~60 samples for both NO_3^- and NO_2^- isotopes were collected using the PPS for high-resolution profiles. NO_3^- isotope samples were collected in 125 mL HDPE bottles acidified with HCl and sulfamic acid to remove NO_2^- prior to NO_3^- analysis. NO_2^- isotope samples were collected in 125 HDPE bottles and preserved at pH 12 (with NaOH) to avoid O isotope exchange with water.

3) *N_2/Ar & $\delta^{15}N_2$*. Discrete samples were collected at all regular and float stations in 60 mL glass bottles as described in Charoenpong et al. (2014) and preserved with 0.5 mL of 25% HCl. Discrete samples as well as continuous profiles (from the PPS) were also analyzed for N_2/Ar using a shipboard mass spectrometer (Pfeiffer Vacuum). In addition, at station F9, ~60 discrete samples were collected using the PPS for high-resolution $\delta^{15}N$-N_2 profiles.

4) *N_2O $\delta^{15}N$ and $\delta^{18}O$ and ^{15}N site preference*. Samples were collected at all regular stations and float station F9 in 125 mL glass bottles as described in Charoenpong et al. (2014) and preserved with 1 mL of 25% HCl.

5) *Near-surface POM $\delta^{15}N$*. Surface seawater from the underway system was filtered through 47 mm GF/F filters at all stations as well as during transit. At stations 3T (cast 07), 8T (cast 08), 9T (cast 04), 10T (cast 05), 11T (cast 07), 11F (cast 04), 12F (cast 04), 13F (cast 08), 15F (cast 01), and ES (cast 01), seawater in the first 200 m depth from Niskin bottles were also filtered through 47 mm GF/F filters.

iii. Float operations - McNeil and D'Asaro

Team members**:** Andrew Reed (grad student), Happy Hu (grad student from Altabet Lab), Eric D'Asaro (PI), Mark Altabet (PI) and Craig McNeil (PI)

Cruise objectives: The primary technical objective was to test and validate a new in situ method to measure dissolved gaseous N_2 production rates associated with de-nitrification processes in Oxygen Minimum Zone (OMZ) using a gas tension device mounted on a profiling float. The gas tension device was customized for use in the deep anoxic waters of the OMZ and uses a gas permeable Teflon membrane matrix interface and a precise pressure sensor to measure the total dissolved air pressure, or gas tension. Since the waters are anoxic in the OMZ, gas tension signal is primarily the sum of the partial pressure of N_2 gas, or pN_2, and water vapor. We measured vertical profiles of excess N_2 gas and temporal changes in N_2 along isopycnal surfaces. The overarching scientific motivation is to test the hypothesis that denitrification processes in deeper offshore waters are stimulated by the rain-down of organic matter from productive near-surface eddies originating from the continental shelf (e.g. by coastal upwelling).

Cruise tasks:

1) *APL GasFloats*. We deployed and recovered two APL Gasfloats (serial numbers #77 and #78), each equipped with a custom gas tension device to measure N_2 gas, a WetLabs FLNTU fluorometer for Chl and backscattering at 550 nm and 700 nm for suspended and particulate matter, dissolved oxygen using Aanderaa optode and a SBE-43 O_2 sensors, and a Satlantic SUNA sensor for nitrate and (hopefully) nitrite concentrations. We first surveyed the targeted region from 19 ^{o}N to 21 ^{o}N (station F1 through F7) at 107 ^{o}W, identified from satellite imagery to have high Chl levels. Based on the analysis of the survey data, with valuable contributions provided by Emilio Garcia-Robledo using the STOX sensor, we decided to deploy Float #77 early in the morning of 05/17/2014 in an offshore jet between two eddies located near 20 ^{o}N and 107 ^{o}W at station F8 (same coordinates as station F4). See Figure 3 for locations.

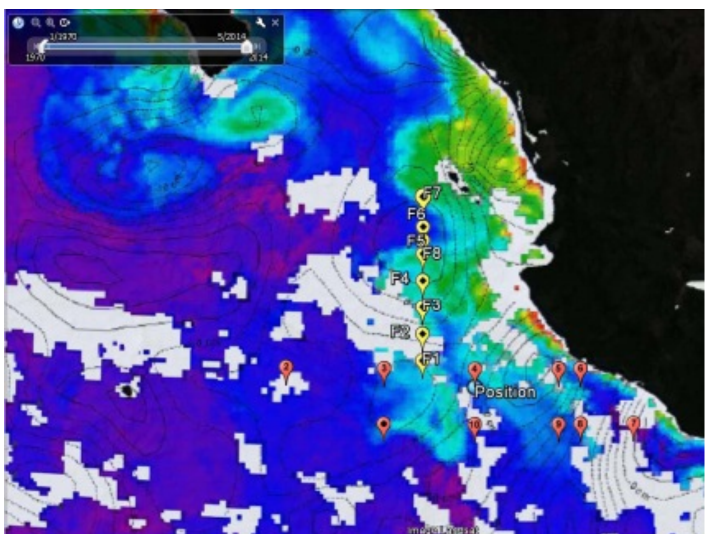


Figure 3. Location of pre-float deployment surveys F1 to F7 and deployment location F8 (yellow markers). Also shown are the main CTD transect stations (red markers).

We deployed Float #78 that same evening nearby Float #77 along with a custom Apex ARGO GasFloat. All three floats drifted northwest. We performed a time series CTD cast at the floats for sensor calibration purposes, coordinating sampling with Altabet's group who samples dissolved gases for mass-spectrometric analysis. The CTD sampling sequence was as follows: 1) float surfaced, 2) ship repositioned to within a few hundred meters of the float, 3) float was commanded to sink, and 4) a CTD was performed while the float was sinking to continue its mission. Just prior to vacating the float deployment region on 05/20/2014 to begin the main CTD surveys (see Figure 3, red markers), Float #77 was recovered due to a potential communications problem (post analysis suggested the float was fine). After returning to the float region, Float #77 was re-deployed on the evening of 05/28/2014 nearby Float #78. Over the next 5 days the ship followed Float #78, performing several hydrocasts per day at its predicted location as part of a Lagrangian Drift Study (Figure 4). One goal of the Drift Study was to compare the float measured denitrification rates with those rates and processes identified by other investigators. Each day a morning hydrocast was performed in coordination with Altabet's group for comparison with the float sensors. Both floats were recovered 06/01/2014 and performed very well (Figure 5).

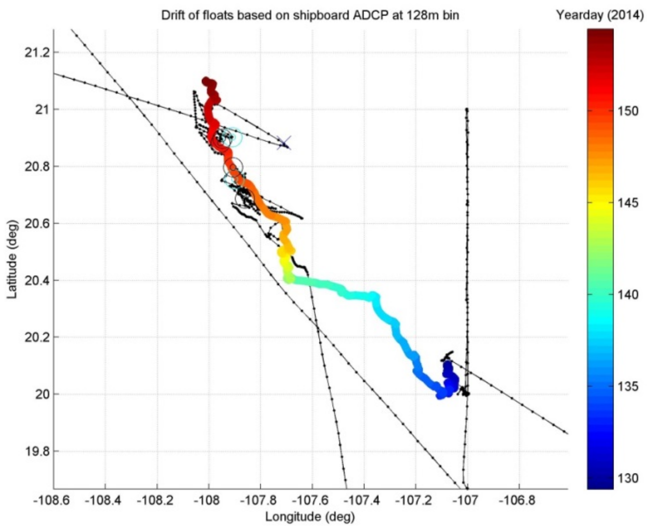


Figure 4. Drift track of Float #78 predicted using shipboard ADCP data

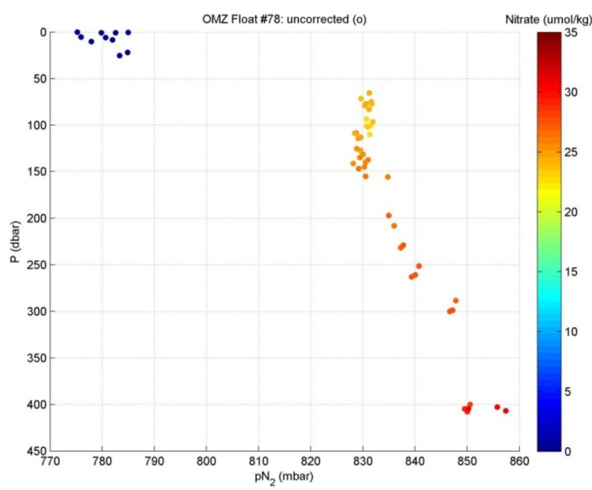


Figure 5. Partial pressure of dissolved nitrogen gas (pN_2) measured by Floats #77 and #78, and colored by SUNA measured nitrate concentration. Based on shipboard nitrite measurements (courtesy of Annie Bourbonnais in Altabet's group) we expected the excess N_2 to peak at around 125m depth.

2) *Underway sampling and PPS*. Various dissolved gas sensors were plumbed into the ship's seawater supply to the main lab from the bow. This same supply was switched to the PPS seawater supply when the PPS was in operation. The sensors were: 1) Aanderaa optode for dissolved O_2 and sea water temperature – importantly, this record also allows calculation of the warming of the seawater supply from the PPS which was observed to warm by up to 12 ^{o}C as shown in Figure 6; 2) a Pro-Oceanus Systems Inc. underway Gas Tension Device (GTD) for total dissolved air pressure; 3) an NDIR based Pro-Oceanus Systems, Inc. pCO_2 sensor; and 4) a Satlantic Inc. ISUS for nitrate (and hopefully nitrite).

Post-processing of the data collected using seawater supplied by the PPS must include a delay due to the transit time of water from the PPS intake to arrival at the main lab sensors, an additional delay due to the response time of the sensor and/or sampling system (e.g., nitrite analyzer) and any warming effects. Warming effects are significant, up to 12 ^{o}C, and significantly affect dissolved gas saturation levels. Of constant concern during the cruise was the ISUS sensor. To date we have confirmed that the newly calibrated sensor has a significant nearly linear drift of approximately 1 uM per day. Accounting for this drift, the underway measurements appear reasonable, however the measurements made on the PPS show peculiar features. An example profile is shown in Figure 7, which shows a decrease in nitrate concentration with depth and very large differences in the upcast and downcast surface measurements, neither of which are expected. Post-cruise analysis of discrete samples taken by Altabet's group will be performed to assess data quality.

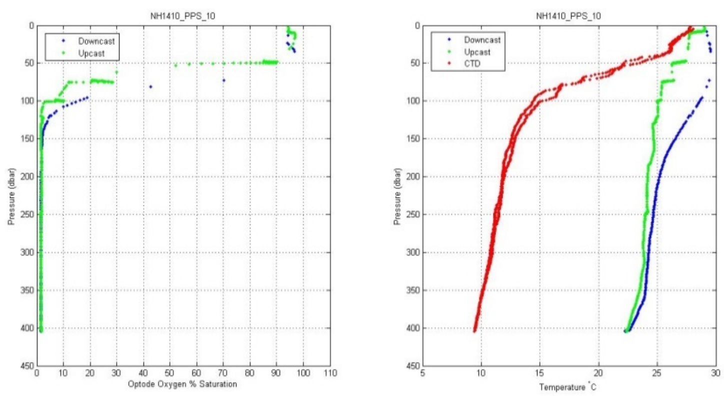


Figure 6. Optode data from the PPS cast NH1410-PPS-10, showing: a) oxygen saturation levels and b) seawater temperatures at the PPS CTD intake and optode. Upcast and downcasts are separated.

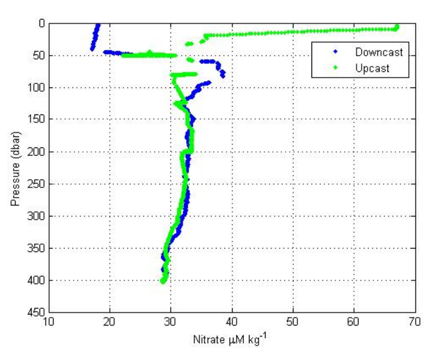


Figure 7. Nitrate concentration measured by the ISUS sensor during PPS cast NH1410-PPS-10. We do not understand why some PPS casts show decreasing nitrate concentration with depth, nor do we understand the often very large difference between downcast and upcast near surface measurements. Further analysis required.

3) Winkler DO measurements. Nearly 200 Winkler titrations on samples taken from the rosette CTD, the PPS, and the ship's seawater supply to calibrate various dissolved oxygen sensors on the ship, PPS and floats. An example is shown in Figure 8. The sample depths were chose to provide a large measurement range and to target specific water masses identified by TS analysis. The titration kit (amperometric detection system from Langdon Enterprises Inc., following the LDEO design) used 0.01 N KIO_3 standard purchased from MKS Japan. Repeatability of Japanese standards was excellent: ±0.13% (N=8). We are extremely grateful to Hapai 'Happy' Hu for performing this task aboard and also assisting with ISUS and SUNA dilution calibrations.

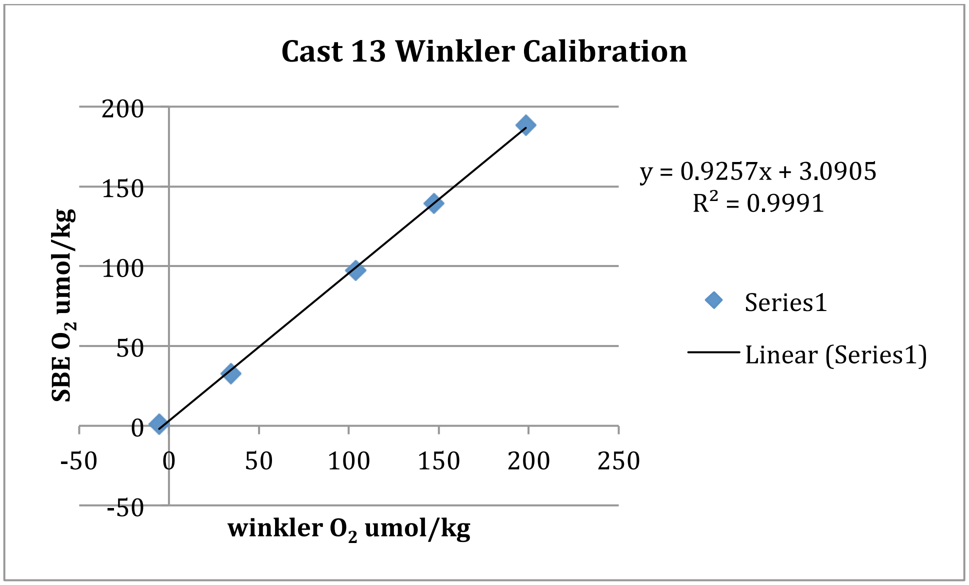


Figure 8. Example Winkler calibration of SBE43 on rosette CTD.

We were unable to modify the amperometric detection method to eliminate the well known 'nitrite interference' in anoxic OMZ waters. We tried adding sodium azide to the pickling reagents however it produced a clear interference with the KIO_3 standard, which we could not explain. So we decided to not measure Winklers in anoxic waters and focused on calibrating the other in situ oxygen sensors to concentrations above approximately 30 µmol/kg. True determination of anoxia needs to be determined by the STOX sensor.

4) *Argo GasFloat.* We deployed a profiling Apex Argo-type float (s/n 7049) along with Float #78 and recovered it early morning on 06/03/2014 eastward of the drift track of Float #78. The Argo float had the same membrane interface as Floats #77 and #78 but was unpumped, making it a very slow response sensor. The float performed well, even though it was difficult with the long response time to make many equilibrated gas tension measurements. Vertical profile measurements are shown in Figure 9.

5) *GTD on CTD.* We attempted to install a GTD onto the SBE911CTD early on in the cruise but found the power consumption of the GTD to be too large for the CTD system. The outflow of the CTD's secondary salinity cell pump was used to flush the GTD's Teflon membrane interface,

but the reduced flow caused the response time of the GTD to increase significantly. It is uncertain if the data can be deconvolved to provide reasonable gas tension profiles. The GTD had to be removed for deep casts (>500 m depth). After it was confirmed that the floats were working well and collecting gas tension profiles we stopped mounting the GTD on the CTD.

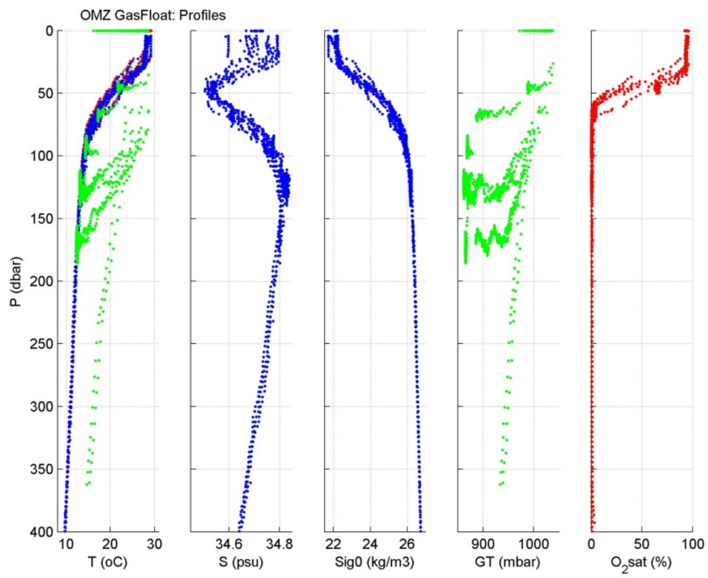


Figure 9. Argo float profiles of temperature (T), salinity (S), potential density (Sig0), gas tension (GT) and optode oxygen saturation (O_2sat).

iv. Rates and pathways of microbial N transformation - Thamdrup

Team members: Laura A. Bristow (postdoc), Bo Thamdrup (PI)

Cruise objectives: Our main goal was to investigate the rates and pathways of microbial nitrogen transformation in the OMZ as a function of the environmental characteristics. We had a particular focus on the effect of oxygen on both aerobic and anaerobic processes, as well as on potential interactions of nitrogen and methane cycling. Our general approach was to quantify transformation rates in experimental incubations using stable isotope tracers (^{15}N, ^{13}C, ^{18}O).

Cruise tasks:

1) *N metabolism rates -- high resolution*. We investigated the vertical distribution of nitrogen transformation rates at high vertical resolution across the upper oxic-anoxic interface of the OMZ and into the core. This was done at Stations 3T, 4F, and 7T, representing a shoreward gradient. At twelve depths at each station, we performed anoxic incubation of water amended with ^{15}N-labeled nitrate, nitrite, or ammonium, which will allow us to determine rates of nitrate reduction, denitrification, anammox, ammonium mineralization, ammonium oxidation, and nitrite oxidation. Potential oxygen contamination was monitored in a subset of the experiments by means of highly sensitive optode sensors. Incubations at selected depths using labeling of both nitrate and nitrite, and of nitrite with addition of acetylene, were included to study a suggested direct reduction of nitrate to N_2, bypassing the nitrite pool, and the nitrite oxidation associated with carbon fixation by anammox bacteria, respectively. The sampling of the water

column was coordinated with sampling for DNA/RNA analysis by the Stewart lab.

2) *Anammox rates - low resolution*. We extended the regional coverage of anammox rate determinations, included in item #1, by further incubations amended with ^{15}N-labeled ammonium at five depths at each of Stations 2T, 6T, 8T, and 11T. The sampling of the water column was coordinated with sampling for DNA/RNA analysis by the Stewart lab. Through a combination of these datasets we wish to obtain a detailed understanding of population dynamics and ecophysiology of anammox bacteria.

3) *N rates - Lagrangean sampling*. We further performed a 5-day temporal analysis of nitrate reduction, denitrification, and anammox in the same water mass (Lagrangean sampling, Stations 9F-13F) to analyze the dynamics of these processes in waters underlying a plume of surface chlorophyll, using incubations as in Item 1. This sampling was directed by the position of floats (McNeil lab), with floats providing in situ estimates of N2 accumulation and nitrate/nitrite dynamics. Sampling was further coordinated with sampling for DNA/RNA analysis by the Stewart lab

4) *N_2O formation.* We investigated the pathways of N_2O formation in three experiments with water from the oxycline (Station 8T), the secondary chlorophyll maximum (Station 4T), and the secondary nitrite maximum (Station 9F), respectively. Each time experimental treatments included addition of ^{15}N ammonium, ^{15}N nitrate, ^{18}O water, or ^{18}O oxygen, and incubation at fixed oxygen levels ranging from anoxia to 15 µM, which, in combination, will reveal the relative importance of nitrifiers and denitrifiers in N_2O accumulation. The sampling of the water column was coordinated with sampling for DNA/RNA analysis by the Stewart lab.

Figure 10. Rosette sampling for bottle incubations.

5) *Nitrite-dependent methane cycling*. We investigated the potential for methane cycling and it's coupling to nitrate and nitrite reduction at five depths in the OMZ core at Stations 6, 8, and 10. For this we employed anoxic incubations with ^{13}C bicarbonate for methanogenesis (Stns 6T and 8T only), ^{13}C methane and ^{15}N nitrate or nitrite for methane oxidation. We further included a

treatment with $^{15}N/^{18}O$ nitrite and acetylene specifically targeting oxygen production by bacteria related to candidate species Methylomirabilis oxyfera of the NC10 environmental clade. These experiments were accompanied by water column profiling for methane, DIC and their C isotope composition in collaboration with the Stewart lab and the Girguis lab at Harvard University, and by sampling for DNA/RNA analysis and enrichment for methanotrophs by the Stewart lab. In addition unaltered samples for potential rate determinations of methanogenesis and methane oxidation using radioisotopes were collected from Stations 6T and 8T for the Girguis lab.

6) *N transformation - quadrupole MS*. In a collaboration with the Altabet lab we tested the potential for shipboard analyses of ^{15}N transformations by quadrupole MS. Incubations of OMZ core water with ^{15}N nitrite were sampled both for onboard analysis and analysis at SDU. Preliminary evaluation of onboard results showed the production of ^{15}N N_2. Such onboard analysis will be useful, e.g., to guide sampling and identify activity hotspots in the future.

7) *C and N assimilation*. In a second collaboration with the Altabet lab, we performed an incubation of OMZ core water (station 14F, 93 m) with ^{15}N ammonium and ^{13}C bicarbonate to evaluate the potential for analyzing carbon and nitrogen assimilation by specific groups of microbes sorted by flow cytometry. These incubations were further sampled for ammonium mineralization rates and anammox activity.

8) *In situ sampling*. We attempted to obtain water samples for process measurements from the OMZ core without any oxygen contamination, by deployment of an *in situ* glass ampoule sampler. All conventional sampling techniques, including the Niskin bottles and pump profiling system used on the cruise, are associated with small but possibly critical oxygen contaminations, when used in the anoxic OMZ core. However, repeated deployments of the pump and attempts of troubleshooting were unsuccessful.

v. Picocyanobacteria in the OMZ - Ulloa

Team members: Montserrat Aldunate (grad student), Gadiel Alarcón (senior tech), Osvaldo Ulloa (PI, not on cruise).

Cruise objectives:
The main goal of our group is gain new understanding of the role of picocyanobacteria in mediating nutrient cycling and energy flow in marine OMZs, and of the genetic and phenotypic characteristics of OMZ Prochlorococcus.

Cruise tasks:

1) *$^{13}HCO_3^-$ + $^{15}NO_3^-$ experiments.* Carbon fixation and nitrate assimilation

We performed five experiments collecting water from the DCM using the rosette or PPS.

Stations: 4T, F8, 7T, 3T, 12F.

For each experiment, we filled 10 bottles:

T0:

2 bottles for carbon and nitrogen isotopic fractionation
2 bottles for RNA (qPCR)

Tf (after 12 hours):

3 bottles in dark for carbon and nitrogen isotopic fractionation + RNA(qPCR).
3 bottles exposed to blue light for carbon and nitrogen fractionation + RNA(qPCR).

2) *^{13}Glucose + $^{15}NO_3^-$ experiments*. Glucose intake and nitrate assimilation

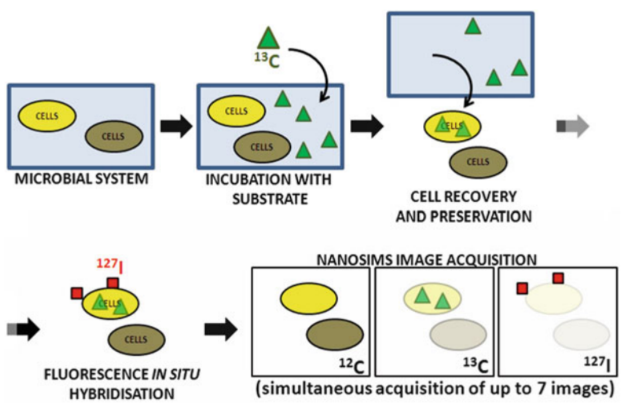
Stations: F8, 8T, 14F

Potential glucose intake by metagenomic data from ETSP: The same method that above, but using ^{13}Glucose + $^{15}NO_3^-$

3) *nanoSIMS $^{13}HCO_3^-$ + $^{15}NO_3^-$ experiments*. Carbon fixation and nitrate assimilation.

Station: 10T

The objective of nanoSIMS and nanoSIMS/FISH is follow, in 4 different times, the isotopic markers ($^{13}HCO_3^-$ + $^{15}NO_3^-$) and identified by CARD-FISH which populations are doing carbon fixation and nitrate assimilation.



Chew *et al*., 2014)

We did the following:

We fill 10 bottles:

T0: sampling without incubation.

2 bottles for carbon and nitrogen isotopic fractionation
2 bottles for RNA (qPCR of key genes).
20 ml for nanoSIMS and 20 ml for nanoSIMS/FISH.

T1, T2 and T3:

Dark

Bottle 5	vol (ml)	Bottle 6	vol (ml)	Bottle 7	vol (ml)
Rates (C+N)	530	Rates	530	Rates	530
RNA	530	RNA	530	RNA	530
nanoSIMS	20	nanoSIMS	20	nanoSIMS	20
nanoSIMS/FISH	20	nanoSIMS/FISH	20	nanoSIMS/FISH	20
Total	1100	Total	1100	Total	1100

Light

Bottle 8		Bottle 9		Bottle 10	
Rates	530	Rates	530	Rates	530
RNA	530	RNA	530	RNA	530
nanoSIMS	20	nanoSIMS	20	nanoSIMS	20
nanoSIMS/FISH	20	nanoSIMS/FISH	20	nanoSIMS/FISH	20
Total	1100	Total	1100	Total	1100

T1= 3 hrs	T2 = 6 hrs	T3 = 12 hrs

4) *nanoSIMS ^{13}Glucose + $^{15}NO_3^-$ experiments.* Glucose intake and nitrate assimilation.

Station: 10F

The same method that above, but amending with ^{13}Glucose + $^{15}NO_3^-$

5) *$^{13}HCO_3^-$ + $^{15}NO_3$ incubations for cell sorting.* Carbon fixation and nitrate assimilation.

Isotopic fractionation from a single population (cell sorting) in natural communities from DCM and after incubation of this community with $^{13}HCO_3^-$ + $^{15}NO_3$

Station: 9T

T0: Concentration of cells for cell sorting without incubation.

Tf (12 hrs): Concentration of cells for cell sorting after incubation in light/dark of 6 bottles with $^{13}HCO_3^-$ + $^{15}NO_3$

Aditional tasks:

- For all these experiments seawater was collected for: Flow Cytometry, DNA, RNA, HPLC and Single Cell Genomics samples.
- Discrete sampling from PPS downcast:

1) Nutrients and flow cytometry (Station 10T; Cast NH14_PPS_9): Discrete samples were taken every 30 seconds between 0-150 m depth. We did a total of 61 samples estimating one sampling every 3 m depth.

2) Flow cytometry: Discrete samples were taken every 1 min between 0-150 m depth, estimating 1 sample every 4 m depth.

Station-Cast	Samples number
3T – NH14_PPS_12	42
10F - NH14_PPS_14	42
12F - NH14_PPS_16	45

- Sampling and reading for ammonium concentration (attached file: "NH1410 – Ammonium")

vi. O_2 distributions and DCM microbial activity - Revsbech

Team members: Emilio Garcia-Robledo (postdoc), Niels Peter Revsbech (PI, not on cruise)

Cruise objectives: The broad goal was to characterize the oxygen distribution along the OMZ, the metabolism of the microbial community of the depth chlorophyll maximum (DCM) and the regulation of metabolic processes at low oxygen concentrations.

Cruise tasks:

1) *In situ STOX measurements*. I connected an in situ STOX unit to the CTD for the accurate measurements of low oxygen concentrations and the determination of the real Anoxic Core in the OMZ. The oxygen sensor of the CTD use to have an offset of 1µM, however oxygen concentrations at nanomolar concentrations have been show to inhibit some anaerobic processes and cannot be resolved with the common CTD sensor. The unit was connected to the data collection of the CTD so an Oxygen profile will be available from each CTD cast of the cruise (with some exceptions). Another in situ STOX unit was connected to the CTD of the PPS. Thus, a high resolution oxygen concentration profile will be also available for each PPS cast.

2) *Oxygen metabolism at the DCM*. The accumulation of Prochlorococcus at the DCM implies a net growth of this population at this depth. The DCM use to be located just below the oxycline, in complete anoxic conditions or with very low oxygen concentrations (< 0.5 µM) and at very low light conditions (about 0.1% of surface irradiance). The main focus of my lab incubations was to simulate the natural conditions occurring at the DCM and measure the net metabolism of the community at oxygen concentrations below 0.5µM. For that purpose, dark incubation and 3 light intensities were used (10, 20 and 40 µE m-2 s-1), using a blue light with a spectrum similar to in situ conditions. The evolution of the low oxygen concentration was followed for a period of 12 hours inside the all glass incubation bottles to obtain net rates (net community production and respiration in darkness).

3) *Carbon fixation rates at DCM*. parallel to the oxygen metabolism measurements, 13C-HCO3 was injected to each incubation bottle in order to measure the net carbon fixation rate and correlate it with the measurements of oxygen.

4) *Effect of light in the nitrogen cycling at DCM.* primary production, considered as an in situ production of organic compounds and oxygen, could have an effect on both aerobic and anaerobic processes of the N cycling. In order to measure a possible effect, 15N-NH4 or 15N-NO2 were injected to the incubation bottles as described for O2 metabolism. After 12-15 hours of incubations, samples for the later analysis of 15N gases were collected.

5) *Other*. Samples for analysis of community transcription in response to light gradients were collected by Stewart's group to complement incubation experiments (Station F13).

vii. DIC chemistry - Hernandez-Ayon

Team members: Orion Norzagaray (grad student) and Martin Hernandez-Ayon (PI).

Cruise objectives: The broad goal of our group is determine the distribution and concentration of dissolved inorganic carbon (DIC) in the OMZ. These data will be analyzed in relationship to oxygen and nutrient gradients to better understand the carbon cycle in this region.

Cruise tasks:

1) *DIC/pH sampling*. We collected discrete samples for DIC and pH over depth gradients at coastal and offshore sites in the ETNP OMZ. At each station, general water column parameters were collected via vertical depth surveys using standard oceanographic equipment (CTD-rosette at most stations). Seawater collections for DIC and pH samples were done by rosette casts to discrete depths covering the low-oxygen zones from an average of 12 depths targeting key water column features: the oxic photic zone, oxycline (upper), OMZ interface, secondary chlorophyll maximum, nitrite/salinity maximum, and anoxic OMZ core. In some stations deep profiles were collected. Almost all samples were analyzed aboard ship using an infrared CO_2 analyzer and a potentiometric pH system with controlled temperature. In addition, a subset of water samples will be returned to Mexico (Universidad Autónoma de Baja California) for further analysis. In total, we obtained 28 profiles with ~350 measurements.

2) *PPS profile sampling (400 m)*. High-resolution DIC profiles were measured using samples collected every 6 m during the downcast of the PPS. These samples were obtained by connecting the PPS outlet directly to an auto-DIC-analyzer. The PPS pumped at a rate of ~2.7 l min−1 about 4m min-1 and had a pump-to-deck time of 240 s and a pump-to-DIC analyzer time of 320 s. In addition, during the downcast of the PPS, we collected discrete samples every 1.5 minutes (~3 m) for analysis of both DIC and pH. A total of 10 PPS profiles were measured during the cruise, consisting of 596 DIC measurements and 496 pH measurements.

3) *Float drift monitoring*. We sampled for DIC and pH during the float drift study from May 28 to June 1. Samples were collected during three PPS deployments (with high-resolution measurements; May 28, 29, 31) and one CTD-Rosette deployment (June 1), with sampling sites

as close to the actual or predicted positions of the drifting APL floats as possible. Collections for DIC and pH samples averaged 37 samples per profile by PPS, plus an additional 28 discrete depths/samples targeting key water column features: the oxic photic zone, oxycline (upper), OMZ interface, secondary chlorophyll maximum, nitrite/salinity maximum, anoxic OMZ core, and deep water from beneath the OMZ. All samples were analyzed aboard ship.

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Appendix A - NH1410 Operations log

(modified from bridge record file '1410 - STEWART - VOYAGE CALCULATOR 3-0.xls')

Station	Date	Time*	Lat N	Long W	Operation	Rosette / PPS CTD log file ID or *comments
San Diego	10-May	0900	32 42.35	117 14.16		
test	10-May	1143	32 37.239	117 29.838	PPS deployed	* test of rosette CTD, and PPS CTD and pump; CTD pump and communication problems (resolved)
test	10-May	1154	32 37.239	117 29.840	PPS recovered	
test	10-May	1233	32 37.545	117 29.877	CTD deployed	
test	10-May	1245	32 37.746	117 29.867	CTD @ 35m, malfunction	
test	10-May	1254	32 37.773	117 29.889	CTD recovered	
test	10-May	1347	32 38.002	117 31.131	CTD deployed	
test	10-May	1350	32 38.040	117 31.159	CTD @ 10m, malfunction	
test	10-May	1357	32 38.054	117 31.164	CTD recovered	
test	10-May	1410	32 38.098	117 31.275	PPS deployed	
test	10-May	1415	32 38.112	117 31.311	PPS @ 50m	
test	10-May	1420	32 38.124	117 31.352	PPS recovered	
test	10-May	1515	32 38.188	117 32.156	CTD deployed	
test	10-May	1520	32 38.195	117 32.258	CTD @ 10m, malfunction	
test	10-May	1536	32 38.194	117 32.292	CTD recovered	
Soledad	12-May	2245	25 11.939	112 42.113	CTD deployed	NH1410_01_01
Soledad	12-May	2258	25 11.853	112 42.287	CTD @ 520m	
Soledad	12-May	2355	25 11.553	112 42.995	CTD recovered	
dunk test	13-May	1326	23 36.590	111 06.003	Float 77 deployed	* float test; no problems
dunk test	13-May	1337	23 36.590	111 06.003	Float 77 recovered	
dunk test	13-May	1400	23 36.564	111 05.919	Float 78 deployed	
dunk test	13-May	1406	23 36.556	111 05.887	Float 78 recovered	
4T	15-May	0600	18 53.873	106 17.977	CTD deployed	NH1410_04_01
4T	15-May	0632	18 53.933	106 17.982	CTD @ 1200m	
4T	15-May	0735	18 53.936	106 17.823	CTD on deck	
4T	15-May	1007	18 54.794	106 18.417	PPS Instrument deployed	NH14_PPS_01F
4T	15-May	1012	18 54.785	106 18.427	PPS Instrument recovered	
4T	15-May	1016	18 54.771	106 18.418	PPS Instrument deployed	
4T	15-May	1054	18 54.632	106 18.250	PPS Instrument recovered	
4T	15-May	1205	18 53.856	106 18.004	CTD deployed	NH1410_04_02
4T	15-May	1222	18 53.840	106 17.966	CTD @ 400m	
4T	15-May	1316	18 53.800	106 18.068	CTD recovered	

4T	15-May	1558	18 53.977	106 17.974	PPS deployed	
4T	15-May	1610	18 53.977	106 17.974	PPS on deck	
4T	15-May	1620	18 53.965	106 17.961	CTD deployed	NH1410_04_03
4T	15-May	1634	18 54.019	106 18.125	CTD @ 150m	
4T	15-May	1703	18 53.999	106 18.252	CTD on deck	
4T	15-May	1738	18 53.976	106 17.959	PPS deployed	
4T	15-May	1830	18 53.614	106 18.217	PPS on deck	
F1	15-May	2340	18 59.927	106 59.968	CTD deployed	NH1410_05_01, *begin float survey; 19N-21N, 107W (stations F1-F7, 20nm apart)
F1	15-May	2358	18 59.810	107 00.113	CTD @ 500m	
F1	16-May	0040	18 59.603	107 00.477	CTD on deck	
F2	16-May	0303	19 19.979	107 00.042	CTD deployed	NH1410_06_01FALBd
F2	16-May	0317	19 19.995	107 00.000	CTD @ 500m	
F2	16-May	0355	19 20.003	107 00.035	CTD on deck	
F3	16-May	0602	19 40.291	107 00.057	CTD deployed	NH1410_07_01
F3	16-May	0616	19 40.223	107 00.038	CTD @ 500m	
F3	16-May	0656	19 39.995	107 00.080	CTD on deck	
F4	16-May	0900	20 00.062	107 00.037	CTD deployed	NH1410_08_01
F4	16-May	0919	20 00.214	107 00.122	CTD @ 500m	
F4	16-May	1003	20 00.486	107 00.411	CTD on deck	
F5	16-May	1205	20 19.965	107 00.000	CTD deployed	NH1410_09_01
F5	16-May	1222	20 20.018	107 00.158	CTD @ 500m	
F5	16-May	1308	20 19.712	107 00.231	CTD on deck	
F6	16-May	1522	20 39.907	107 00.199	CTD deployed	NH1410_10_01FALBd
F6	16-May	1537	20 39.903	107 00.201	CTD @ 500m	
F6	16-May	1628	20 40.020	107 00.000	CTD on deck	
F7	16-May	1832	21 00.104	107 00.089	CTD deployed	NH1410_11_01
F7	16-May	1850	21 00.077	107 00.210	CTD @ 500m	
F7	16-May	1954	20 59.780	107 00.219	CTD on deck	
F4	17-May	0218	19 59.932	107 00.059	CTD deployed	NH1410_12_01
F4	17-May	0236	19 59.834	107 00.137	CTD @ 500m	
F4	17-May	0317	19 59.671	107 00.408	CTD on deck	
F4	17-May	0525	19 59.980	107 00.008	APL Float #77 deployed	
F4	17-May	0806	19 59.880	107 00.136	CTD deployed	NH1410_13_01
F4	17-May	0822	19 59.885	107 00.250	CTD @ 500m	
F4	17-May	0858	19 59.920	107 00.554	CTD recovered	
F4	17-May	1157	19 59.925	107 00.963	ARGO launched, recovered	* dunk test
F4	17-May	1339	20 01.308	107 00.996	FLOAT #78 deployed	
F4	17-May	1401	20 01.130	107 00.903	CTD deployed	NH1410_14_01
F4	17-May	1419	20 01.104	107 01.141	CTD @ 500m	
F4	17-May	1506	20 01.026	107 01.719	CTD on deck	

F4	17-May	2107	20 02.399	107 02.597	CTD deployed	NH1410_15_01
F4	17-May	2125	20 02.418	107 02.625	CTD @ 500m	
F4	17-May	2217	20 02.661	107 02.511	CTD on deck	
F4	17-May	2228	20 02.642	107 02.563	ARGO float deployed	
F4	18-May	0119	20 03.784	107 02.777	CTD deployed	NH1410_16_01
F4	18-May	0137	20 03.654	107 02.847	CTD @ 500m	
F4	18-May	0213	20 03.367	107 02.930	CTD on deck	
F4	18-May	0415	20 03.605	107 03.027	CTD deployed	NH1410_17_01
F4	18-May	0418	20 03.566	107 03.019	CTD @ 200m	
F4	18-May	0449	20 03.383	107 02.973	CTD on deck	
F4	18-May	0741	20 04.507	107 04.521	CTD deployed	NH1410_18_01
F4	18-May	0759	20 04.622	107 04.599	CTD @ 500m	
F4	18-May	0849	20 04.863	107 04.728	CTD on deck	
F4	18-May	0930	20 04.965	107 04.977	CTD deployed	NH1410_19_01
F4	18-May	0942	20 04.959	107 05.056	CTD @ 250m	
F4	18-May	1010	20 04.946	107 05.104	CTD on deck	
F4	18-May	1105	20 04.975	107 05.344	CTD deployed	NH1410_20_01
F4	18-May	1115	20 05.005	107 05.399	CTD @ 150m	
F4	18-May	1143	20 05.072	107 05.398	CTD on deck	
F4	18-May	1301	20 05.710	107 04.485	CTD deployed	NH1410_21_01
F4	18-May	1318	20 05.713	107 04.435	CTD @ 500m	
F4	18-May	1406	20 05.543	107 04.239	CTD on deck	
F4	18-May	1532	20 05.825	107 04.637	CTD deployed	NH1410_22_01
F4	18-May	1548	20 05.913	107 04.560	CTD @ 400m	
F4	18-May	1558	20 06.183	107 04.259	CTD on deck	
F4	18-May	1900	20 07.157	107 05.947	CTD deployed	NH1410_23_01
F4	18-May	1919	20 07.117	107 05.873	CTD @ 500m	
F4	18-May	2010	20 07.137	107 05.653	CTD on deck	
F4	19-May	0045	20 07.699	107 04.802	CTD deployed	NH1410_24_01
F4	19-May	0103	20 07.663	107 04.674	CTD @ 500m	
F4	19-May	0149	20 07.581	107 04.329	CTD on deck	
F4	19-May	~0200			APL Float #77 recovered	*communication failure; recovery not logged by bridge
6T	19-May	1704	18 54.001	104 54.040	CTD deployed	NH1410_6T_01
6T	19-May	1720	18 54.025	104 54.439	CTD @ 300m	
6T	19-May	1753	18 54.025	104 54.439	CTD on deck	
6T	19-May	1805	18 54.001	104 54.412	PPS deployed	NH14_PPS_02
6T	20-May	0303	18 52.236	104 51.793	PPS on deck	
6T	20-May	0336	18 53.995	104 54.013	CTD deployed	NH1410_6T_02
6T	20-May	0412	18 53.995	104 53.980	CTD @ 1200m	
6T	20-May	0502	18 54.030	104 53.953	CTD on deck	
6T	20-May	0619	18 54.027	104 54.076	Deploy PPS	NH14_PPS_03
6T	20-May	1207	18 54.692	104 54.020	PPS on deck	

7T	20-May	1810	18 12.023	104 12.160	CTD deployed	NH1410_6T_03, *mislabeled as NH1410_6T_03 in CTD files; should be NH1410_7T_01
7T	20-May	1821	18 12.148	104 12.336	CTD @ 250m	
7T	20-May	1859	18 12.110	104 12.221	CTD on deck	
7T	20-May	1950	18 12.017	104 11.891	CTD deployed	NH1410_7T_02
7T	20-May	2002	18 11.985	104 11.824	CTD @ 150m	
7T	20-May	2028	18 11.965	104 11.881	CTD on deck	
7T	20-May	2138	8 11.939	104 12.182	PPS deployed	NH14_PPS_04
7T	21-May	0758	18 03.932	104 12.606	PPS recovered	
7T	21-May	0826	18 12.053	104 12.155	CTD deployed	NH1410_7T_03
7T	21-May	0857	18 11.989	104 12.282	CTD @ 1200m	
7T	21-May	0946	18 12.270	104 12.730	CTD on deck	
7T	21-May	1059	18 11.982	104 11.988	CTD deployed	NH1410_7T_04
7T	21-May	1116	18 11.917	104 12.079	CTD @ 400m	
7T	21-May	1151	18 11.834	104 12.110	CTD on deck	
7T	21-May	1315	18 12.081	104 11.990	CTD deployed	NH1410_7T_05
7T	21-May	1330	18 12.140	104 12.120	CTD @ 300m	
7T	21-May	1349	18 12.201	104 12.210	CTD on deck	
7T	21-May	1423	18 12.462	104 12.326	CTD deployed	NH1410_7T_06
7T	21-May	1437	18 12.500	104 12.380	CTD @ 150m	
7T	21-May	1503	18 12.524	104 12.455	CTD on deck	
8T	21-May	1917	18 11.885	104 53.804	CTD deployed	NH1410_8T_01
8T	21-May	1934	18 11.858	104 53.703	CTD @ 300m	
8T	21-May	1952	18 11.870	104.53.802	CTD on deck	
8T	21-May	2002	18 11.904	104 53.913	PPS deployed	NH14_PPS_05 and 06
8T	22-May	0702	18 10.858	104 52.235	PPS on deck	
8T	22-May	0757	18 11.936	104 53.847	CTD deployed	NH1410_8T_02
8T	22-May	0830	`18 12.085	104 53.549	CTD @ 1200m	
8T	22-May	0919	18 11.883	104 53.083	CTD on deck	
8T	22-May	1111	18 11.968	104 54.163	CTD deployed	NH1410_8T_03
8T	22-May	1128	18 11.966	104 53.986	CTD @ 500m	
8T	22-May	1219	18 11.788	104 53.644	CTD on deck	
8T	22-May	1244	18 11.911	104 53.905	CTD deployed	NH1410_8T_04
8T	22-May	1258	18 11.854	104 54.065	CTD @ 500m	
8T	22-May	1344	18 11.834	104 54.411	CTD on deck	
8T	22-May	1401	18 11.981	104 53.836	CTD deployed	NH1410_8T_05
8T	22-May	1419	18 11.880	104 53.990	CTD @ 500m	
8T	22-May	1504	18 11.427	104 54.350	CTD on deck	
8T	22-May	1525	18 11.976	104 53.913	CTD deployed	NH1410_8T_06
8T	22-May	1539	18 11.791	104 53.958	CTD @ 300m	
8T	22-May	1612	18 11.316	104 53.957	CTD on deck	
8T	22-May	1756	18 11.959	104 53.926	CTD deployed	NH1410_8T_07

8T	22-May	1808	18 11.878	104 53.986	CTD @ 200m	
8T	22-May	1833	18 11.629	104 53.973	CTD on deck	
8T	22-May	2002	18 12.016	104 53.669	CTD deployed	NH1410_8T_08
8T	22-May	2020	18 11.856	104 53.600	CTD @ 120m	
8T	22-May	2041	18 11.888	104 53.582	CTD on deck	
9T	22-May	2304	18 11.998	105 12.006	PPS deployed	NH14_PPS_07
9T	23-May	0650	18 13.510	105 13.628	PPS on deck	
9T	23-May	0712	18 12.037	105 12.064	CTD deployed	NH1410_9T_01
9T	23-May	0745	18 12.029	105 12.020	CTD @ 1200m	
9T	23-May	0830	18 12.099	105 11.990	CTD on deck	
9T	23-May	1024	18 12.348	105 12.232	CTD deployed	NH1410_9T_02
9T	23-May	1052	18 12.459	105 12.270	CTD @ 1200m	
9T	23-May	1148	18 12.801	105 12.226	CTD on deck	
9T	23-May	1309	18 11.842	105 11.955	CTD deployed	NH1410_9T_03
9T	23-May	1403	18 11.945	105 12.196	CTD at 2800m	
9T	23-May	1516	18 11.790	105 12.039	CTD on deck	
9T	23-May	1626	18 12.142	105 12.000	CTD deployed	NH1410_9T_04
9T	23-May	1641	18 12.073	105 11.955	CTD @ 300m	
9T	23-May	1715	18 12.053	105 11.686	CTD on deck	
10T	24-May	0026	18 12.047	106 17.797	PPS deployed	NH14_PPS_08,08b, and 09, * PPS did not come out of water between casts
10T	24-May	0914	18 12.009	106 17.795	PPS recovered	
10T	24-May	0927	18 11.969	106 17.901	CTD deployed	NH1410_10T_01
10T	24-May	0955	18 11.925	106 18.135	CTD @ 1200m	
10T	24-May	1038	18 11.960	106 18.481	CTD on deck	
10T	24-May	1130	18 12.025	106 18.654	CTD deployed	NH1410_10T_02
10T	24-May	1148	18 11.999	106 18.699	CTD @ 200m	
10T	24-May	1237	18 11.762	106 18.831	CTD on deck	
10T	24-May	1259	18 12.031	106 18.007	CTD deployed	NH1410_10T_03
10T	24-May	1314	18 11.986	106 18.015	CTD @ 300m	
10T	24-May	1333	18 12.007	106 17.980	CTD on deck	
10T	24-May	1402	18 11.850	106 18.119	CTD deployed	NH1410_10T_04
10T	24-May	1420	18 11.971	106 18.090	CTD @ 300m	
10T	24-May	1446	18 12.000	106 18.083	CTD on deck	
10T	24-May	2059	18 12.031	106 18.129	CTD deployed	NH1410_10T_05
10T	24-May	2114	18 12.123	106 18.193	CTD @ 300m	
10T	24-May	2141	18 12.269	106 18.263	CTD recovered	
11T	25-May	0528	18 12.077	107 29.955	CTD deployed	NH1410_11T_01
11T	25-May	0547	18 12.080	107 29.895	CTD @ 200m	
11T	25-May	0618	18 12.071	107 29.841	CTD on deck	
11T	25-May	0643	18 12.020	107 29.985	PPS deployed	NH14_PPS_10
11T	25-May	1311	18 12.504	107 29.907	PPS on deck	
11T	25-May	1330	18 11.995	107 29.937	CTD deployed	NH1410_11T_02

11T	25-May	1357	18 11.996	107 29.890	CTD @ 1200m	
11T	25-May	1435	18 11.993	107 30.136	CTD on deck	
11T	25-May	1535	18 12.010	107 29.970	CTD deployed	NH1410_11T_03
11T	25-May	1550	18 11.976	107 29.997	CTD @ 200m	
11T	25-May	1620	18 11.955	107 30.048	CTD on deck	
11T	25-May	1649	18 12.071	107 29.967	CTD deployed	NH1410_11T_04
11T	25-May	1704	18 12.167	107 30.015	CTD @ 200m	
11T	25-May	1732	18 12.294	107 30.033	CTD on deck	
11T	25-May	1832	18 11.951	107 29.939	CTD deployed	NH1410_11T_05, *in situ RNA sampler (failed)
11T	25-May	1849	18 11.971	107 29.941	CTD @ 500m	
11T	25-May	1933	18 11.993	107 29.919	CTD on deck	
11T	25-May	1958	18 11.922	107 29.892	CTD deployed	NH1410_11T_06, *in situ RNA sampler (failed)
11T	25-May	2013	18 11.889	107 29.857	CTD @ 500m	
11T	25-May	2100	18 11.813	107 29.773	CTD on deck	
11T	25-May	2112	18 11.810	107 29.801	CTD deployed	NH1410_11T_07
11T	25-May	2117	18 11.787	107 29.883	CTD @ 150m	
11T	25-May	2148	18 11.790	107 29.920	CTD on deck	
2T	26-May	0648	18 54.072	108 48.015	CTD deployed	NH1410_2T_01
2T	26-May	0710	18 54.130	108 47.995	CTD @ 200m	
2T	26-May	0745	18 54.269	108 47.925	CTD on deck	
2T	26-May	0800	18 53.991	108 48.018	PPS deployed	NH14_PPS_11
2T	26-May	1010	18 54.067	108 48.353	PPS @ 400m	
2T	26-May	1407	18 53.167	108 49.096	PPS on deck	
2T	26-May	1430	18 54.010	108 48.049	CTD deployed	NH1410_2T_02
2T	26-May	1455	18 54.020	108 48.141	CTD @ 1200m	
2T	26-May	1540	18 54.089	108 48.190	CTD on deck	
2T	26-May	1638	18 53.910	108 48.040	CTD deployed	NH1410_2T_03
2T	26-May	1653	18 53.969	108 48.060	CTD @300m	
2T	26-May	1718	18 54.130	108 48.147	CTD on deck	
2T	26-May	1753	18 54.120	108 48.036	CTD deployed	NH1410_2T_04
2T	26-May	1844	18 54.093	108 48.093	CTD @ 2302m	
2T	26-May	1955	18 54.037	108 48.216	CTD on deck	
2T	26-May	2048	18 54.072	108 48.012	CTD deployed	NH1410_2T_05
2T	26-May	2101	18 54.128	108 48.085	CTD @ 300m	
2T	26-May	2130	18 54.254	108 48.203	CTD on deck	
3T	27-May	0538	18 54.201	107 29.922	CTD deployed	NH1410_3T_01
3T	27-May	0550	18 54.228	107 29.844	CTD @ 200m	
3T	27-May	0610	18 54.042	107 29.828	CTD on deck	
3T	27-May	0622	18 54.042	107 29.785	PPS deployed	NH14_PPS_12
3T	27-May	1320	18 55.679	107 31.715	PPS on deck	
3T	27-May	1350	18 54.049	107 30.084	CTD deployed	NH1410_3T_02

3T	27-May	1405	18 54.050	107 30.083	CTD @ 300m	
3T	27-May	1428	18 54.062	107 30.081	CTD on deck	
3T	27-May	1530	18 54.103	107 30.027	CTD deployed	NH1410_3T_03
3T	27-May	1542	18 54.319	107 30.035	CTD @ 150m	
3T	27-May	1608	18 54.039	107 29.954	CTD on deck	
3T	27-May	1700	18 54.002	107 29.999	CTD deployed	NH1410_3T_04
3T	27-May	1728	18 54.027	107 30.012	CTD @ 1200m	
3T	27-May	1811	18 54.027	107 30.043	CTD on deck	
3T	27-May	1912	18 53.988	107 30.003	CTD deployed	NH1410_3T_05
3T	27-May	1926	18 54.019	107 30.024	CTD @ 300m	
3T	27-May	1954	18 53.909	107 30.013	CTD recovered	
3Ta	27-May	2116	18 54.475	107 19.488	CTD deployed	NH1410_3T_06, *in deep water trough ~8nm E of stn 3
3Ta	27-May	2216	18 54.503	107 19.340	CTD @ 3000m	
3Ta	27-May	2330	18 54.523	107 19.018	CTD recovered	
3Ta	27-May	0033	18 54.988	107 19.131	CTD deployed	NH1410_3T_07
3Ta	27-May	0044	18 54.994	107 19.044	CTD @ 150m	
3Ta	27-May	0101	18 54.997	107 18.907	CTD on deck	
8F-01	28-May	1202	20 26.674	107 37.776	PPS deployed	NH14_PPS_13
8F-02	28-May	1912	20 28.876	107 40.668	PPS on deck	
	28-May	2017	20 33.133	107 46.155	APL Float #77 deployed	*start of float drift survey + diel RNA collections
9F-01	28-May	2040	20 33.354	107 46.060	CTD deployed	NH1410_9F_01
9F-01	28-May	2059	20 33.448	107 46.017	CTD @ 500m	
9F-01	28-May	2139	20 33.704	107 45.742	CTD recovered	
9F-02	29-May	0709	20 33.120	107 46.536	CTD deployed	NH1410_9F_02
9F-02	29-May	0724	20 33.187	107 46.576	CTD @ 200m	
9F-02	29-May	0753	20 33.429	107 46.30	CTD on deck	
10F-01	29-May	0835	20 36.723	107 49.214	CTD deployed	NH1410_10F_01
10F-01	29-May	0850	20 36.819	107 49.477	CTD @ 400m	
10F-01	29-May	0940	20 37.215	107 50.060	CTD on deck	
10F-02	29-May	1014	20 37.279	107 50.527	PPS deployed	NH14_PPS_14 and 15, *PPS did not come out of water between casts
10F-02	29-May	1726	20 23.489	107 54.347	PPS on deck	
10F-03	29-May	1810	20 39.655	107 51.567	CTD deployed	NH1410_10F_03
10F-03	29-May	1822	20 39.781	107 51.584	CTD @ 400m	
10F-03	29-May	1844	20 39.830	107 51.556	CTD on deck	
10F-04	29-May	1950	20 40.321	107 51.742	CTD deployed	NH1410_10F_04
10F-04	29-May	2002	20 40.500	107 51.769	CTD @ 150m	
10F-04	29-May	2025	20 41.063	107 51.743	CTD on deck	
10F-05	29-May	2300	20 40.198	107 49.448	CTD deployed	NH1410_10F_05
10F-05	29-May	2308	20 40.457	107 49.417	CTD @ 150m	
10F-05	29-May	2321	20 40.789	107 49.364	CTD on deck	

11F-01	30-May	0705	20 42.766	107 51.791	CTD deployed	NH1410_11F_01
11F-01	30-May	0727	20 43.006	107 51.392	CTD @ 200m	
11F-01	30-May	0751	20 43.240	107 50.982	CTD on deck	
11F-02	30-May	0845	20 41.176	107 51.591	CTD deployed	NH1410_11F_02
11F-02	30-May	0925	20 40.874	107 50.985	CTD on deck	
	30-May	1432	20 42.560	107 53.230	CTD deployed	file missing
	30-May	1503	20 43.273	107 53.035	CTD @ 400m	
	30-May	1544	20 43.969	107 52.815	CTD on deck	
11F-03	30-May	1803	20 42.800	107 52.444	CTD deployed	NH1410_11F-03
11F-03	30-May	1814	20 42.767	107 52.409	CTD @ 150m	
11F-03	30-May	1830	20 42.733	107 52.314	CTD on deck	
11F-04	30-May	2005	20 44.726	107 53.997	CTD deployed	NH1410_11F-04
11F-04	30-May	2023	20 44.737	107 54.008	CTD @ 400m	
11F-04	30-May	2052	20 44.730	107 53.930	CTD on deck	
11F-05	30-May	2308	20 43.846	107 55.195	CTD deployed	NH1410_11F-05
11F-05	30-May	2318	20 43.831	107 55.179	CTD @ 120m	
11F-05	30-May	2331	20 43.881	107 55.115	CTD on deck	
12F-01	31-May	0704	20 44.971	107 57.116	CTD deployed	NH1410_12F-01
12F-01	31-May	0718	20 44.979	107 57.133	CTD @ 200m	
12F-01	31-May	0743	20 45.097	107 57.085	CTD on deck	
12F-02	31-May	0830	20 47.877	107 54.354	CTD deployed	NH1410_12F-02
12F-02	31-May	0850	20 47.976	107 54.483	CTD @ 400m	
12F-02	31-May	0928	20 48.102	107 54.295	CTD on deck	
12F-02	31-May	1005	20 48.164	107 54.418	PPS deployed	NH14_PPS_16 and 17, *PPS did not come out of water between casts
12F-02	31-May	1656	20 50.670	107 55.326	PPS on deck	
12F-03	31-May	1800	20 49.735	107 56.254	CTD deployed	NH1410_12F-03
12F-03	31-May	1809	20 49.821	107 56.200	CTD @ 150m	
12F-03	31-May	1823	20 49.935	107 56.107	CTD on deck	
12F-04	31-May	1957	20 49.029	107 55.441	CTD deployed	NH1410_12F-04
12F-04	31-May	2012	20 49.044	107 55.290	CTD @ 400m	
12F-04	31-May	2046	20 49.412	107 55.056	CTD on deck	
12F-05	31-May	2307	20 50.989	107 56.992	CTD deployed	NH1410_12F-05
12F-05	31-May	2315	20 50.910	107 56.933	CTD @ 120m	
12F-05	31-May	2327	20 50.867	107 56.848	CTD on deck	
13F-01	1-Jun	0700	20 52.963	107 58.268	CTD deployed	NH1410_13F-01
13F-01	1-Jun	0721	20 52.963	107 58.268	CTD @ 200m	
13F-01	1-Jun	0746	20 53.021	107 58.278	CTD on deck	
13F-02	1-Jun	0824	20 53.295	107 57.338	CTD deployed	NH1410_13F-02
13F-02	1-Jun	0841	20 53.311	107 57.461	CTD @ 400m	
13F-02	1-Jun	0919	20 53.350	107 57.742	CTD on deck	
13F-03	1-Jun	1020	20 53.570	107 58.254	CTD deployed	NH1410_13F-03
13F-03	1-Jun	1036	20 53.568	107 58.437	CTD @ 400m	

13F-03	1-Jun	1108	20 53.622	107 58.794	CTD on deck	
13F-04	1-Jun	1223	20 53.337	107 58.165	CTD deployed	NH1410_13F-04
13F-04	1-Jun	1230	20 53.400	107 58.220	CTD @ 150m	
13F-04	1-Jun	1246	20 53.470	107 58.467	CTD on deck	
13F-05	1-Jun	1310	20 53.990	107 58.270	CTD deployed	NH1410_13F-05
13F-05	1-Jun	1337	20 53.902	107 58.492	CTD @ 1200m	
13F-05	1-Jun	1416	20 54.068	107 58.820	CTD on deck	
	1-Jun	~500			APL Float #78 recovered	*not logged by bridge
	1-Jun	1525	20 53.771	107 57.211	CTD deployed	file missing
	1-Jun	1533	20 53.799	107 57.211	CTD @ 30m	
	1-Jun	1542	20 53.899	107 57.205	CTD on deck	
	1-Jun	1805	20 54.294	107 54.649	APL Float #77 recovered	
13F-06	1-Jun	1814	20 54.122	107 54.767	CTD deployed	NH1410_13F_06
13F-06	1-Jun	1823	20 54.088	107 54.803	CTD @ 150m	
13F-06	1-Jun	1839	20 54.045	107 54.930	CTD on deck	
13F-07	1-Jun	2303	20 55.755	108 00.063	CTD deployed	NH1410_13F_07
13F-07	1-Jun	2312	20 55.698	108 00.112	CTD @ 100m	
13F-07	1-Jun	2326	20 55.567	108 00.135	CTD on deck	
13F-08	1-Jun	2340	20 55.420	108 00.135	CTD deployed	NH1410_13F_08
13F-08	1-Jun	2348	20 55.355	108 00.035	CTD @ 120m	
13F-08	2-Jun	0007	20 55.277	107 59.901	CTD on deck	
14F-01	2-Jun	0706	20 57.351	108 00.670	CTD deployed	NH1410_14F_01
14F-01	2-Jun	0715	20 57.299	108 00.767	CTD @ 200m	
14F-01	2-Jun	0737	20 57.199	108 00.861	CTD on deck	
14F-02	2-Jun	0815	20 57.707	108 00.490	CTD deployed	NH1410_14F_02
14F-02	2-Jun	0827	20 57.759	108 00.497	CTD @ 400m	
14F-02	2-Jun	0904	20 57.946	108 00.554	CTD on deck	
14F-03	2-Jun	1200	20 56.972	107 58.153	CTD deployed	NH1410_14F_03
14F-03	2-Jun	1208	20 56.979	107 58.102	CTD @ 150m	
14F-03	2-Jun	1221	20 56.960	107 57.936	CTD on deck	
14F-03	2-Jun	1234	20 56.894	107 58.071	CTD deployed	file missing
14F-03	2-Jun	1237	20 56.891	107 58.057	CTD on deck (closed bottle)	
14F-04	2-Jun	1239	20 56.857	107 58.014	CTD deployed	NH1410_14F_04
14F-04	2-Jun	1243	20 56.806	107 58.012	CTD @ 90m	
14F-04	2-Jun	1249	20 56.750	107 58.063	CTD on deck	
14F-05	2-Jun	1304	20 57.169	107 58.260	CTD deployed	NH1410_14F_05
14F-05	2-Jun	1331	20 56.997	107 58.256	CTD @ 1000m	
14F-05	2-Jun	1412	20 56.826	107 58.143	CTD on deck	
14F-06	2-Jun	1805	21 00.092	108 00.321	CTD deployed	NH1410_14F_06
14F-06	2-Jun	1816	21 00.114	108 00.347	CTD @ 300m	
14F-06	2-Jun	1838	21 00.236	108 00.429	CTD on deck	
14F-07	2-Jun	1909	20 59.792	107 59.755	CTD deployed	NH1410_14F_07

14F-07	2-Jun	2000	20 59.893	107 59.892	CTD @ 2600m	
14F-07	2-Jun	2104	20 59.293	107 59.718	CTD on deck	
14F-08	2-Jun	2302	20 59.954	108 00.005	CTD deployed	NH1410_14F_08
14F-08	2-Jun	2316	20 59.835	107 59.951	CTD @ 300m	
14F-08	2-Jun	2333	20 59.694	107 59.883	CTD on deck	*end of float drift survey
15F-01	3-Jun	0436	20 52.70	107 42.48	CTD deployed	NH1410_15F_01
	3-Jun	~0700			ARGO float recovered	*not logged by bridge
ES	4-Jun	0059	21 45.029	110 50.946	CTD deployed	NH1410_ES_01, *ES = eddy station
ES	4-Jun	0126	21 45.129	110 50.776	CTD @ 1000m	
ES	4-Jun	0207	21 45.066	110 50.928	CTD on deck	
BS1	6-Jun	0816	28 21.900	115 51.719	CTD deployed	NH1410_BS_01
BS1	6-Jun	0902	28 21.732	115 52.455	CTD @ 2000m	
BS1	6-Jun	1008	28 21.730	115 53.444	CTD on deck	
BS2	6-Jun	2304	29 50.417	116 30.989	CTD deployed	NH1410_BS_02
BS2	6-Jun	2335	29 50.000	116 31.260	CTD @ 1500m	
BS2	6-Jun	0023	29 49.446	116 31.880	CTD on deck	
San Diego	10-May	0800	32 42.35	117 14.16	San Diego	

* local time; add 7 for UTC time

Appendix B - PPS operations (Ulloa lab)

May 15. 18:10 hrs PPS/CTD deployment (output rate 4 scans/sec). **NH14_PPS_01.hex**

Test of communication and deployment.

May 19. 18:10 hrs PPS/CTD deployment (output rate 4 scans/sec). **NH14_PPS_02.hex**

Station 6T

Lat. 18° 54.135 N FINISH 18° 52.263 N

Long. 104° 54.131 W FINISH 104° 51.844 W

Time. 01:10 UTC FINISH

Speed 10 Hz

Downcast time 00:58:30

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig group). Depth 400 m.

Note. High winds and undercurrent make hard to match the desired depth

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
5	02:51	29.79	34.117	194.2	1,2,4
20	02:30	29.78	34.118	195.1	1,2,3,4,7
50	02:10	24.58	34.256	111	1,2,3,4,7
60	01:49	19.97	34.502	21.2	1,2,3,4,5,7
68	01:10	18.02	34.625	2.5	1,2,4,5,7
80	00:30	16.31	34.720		1,2,3,4,5,7
110 (DCM)	23:15	14.55	34.815		1,2,4,5,6,7
125	22:56	13.72	34.838		1,2
150	22:14	13.26	34.858		1,2
200	21:25	12.76	34.841		1,2
250	21:06	12.36	34.820		1,2
300	20:16	11.99	34.797		1,2
400	19:43	11.10	34.739		1,2

1.- Montserrat (NH4); 2.- Marks's group (Nutrients, DG); 3.- Marks's group 2 (oxygen); 4.- Bo's group (N cycling and CH4 rates); 5.- Frank's group (DNA, ARN); 6.- Emilio (experiment); 7.- Martin's group (DIC, pH, Alkalinity).

May 20. 06:20 hrs PPS/CTD deployment (output rate 4 scans/sec). **NH14_PPS_03.hex.**

Station 6T

Lat. 18° 54.209 N FINISH 18° 54.685 N

Long. 104° 54.134 W FINISH 104° 54.061 W

Time INI 13:20 UTC Time FINISH 19:15 UTC (12:15 LCL)

Winch speed 10 Hz downcast 20 Hz upcast

Downcast Time 01:43:33

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig group). Depth 400 m.

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	8:42				
200	9:15				
125	10:01				
85	10:43				Emilio DCM
50	11:23				

21:40 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_04.hex**

Station 7T

Lat. 18° 11.983 N FINISH 18° 13.977 N

Long. 104° 12.177 W FINISH 104° 12.603 W

Time. 04:40 UTC FINISH 14:55

Winch speed 10 Hz

Downcast Time 1:43:48

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig group). Depth 400 m.

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	00:02	10.26	34.693	1.46	
250	01:18	12:16	34.805	1.46	
175	01:54	12.84	34.843	1.50	
150	02:31	13.21	34.853	1.45	
140	03:05	13.40	34.855	1.48	
125	03:39	13.64	34.856	1.44	
100	04:15	14.30	34.833	1.45	
89	04:50	15.59	34.760	1.6	MA, Emilio
52	06:10	21.50	34.442	58.1	
37	06:44	26.80	34.241	194.3	
5	07:22	30.2	34.028	194.4	

MA: DNA, ARN, FCM, HPLC, CHLA, SCG, SEM. Experiment N° 4 of carbon fixation at DCM.

May 21. 20:00 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_05.hex**

Station 8T

Lat. 18° 11.935 N FINISH 18° 10.627 N

Long. 104° 53.965 W FINISH 104° 51.586 W

Time. 03:00 UTC FINISH 10:50 UTC 03:50 LCL

Winch speed 10 Hz

Downcast Time 1:45:00 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	22:34	9.92	34.676	1.56	O2
170	00:07	12.61	34.831	1.51	
155	00:42	12.78	34.839	1.54	
140	01:16	12.97	34.842	1.53	
125	01:50	13.55	34.849	1.48	
45	02:39	21.33	34.467	24.7	O2
5	03:19	30.17	34.090	190.4	O2

May 21. 04:00 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_06.hex**

Station 8T

Lat. 18° 10.231 N FINISH 18° 10.766N

Long. 104° 51.379 W FINISH 104° 52.152 W

Time. 11:08 UTC 04:08 LCL downcast FINISH

Winch speed 15 Hz (~3-4 m/min)

Downcast Time 00:24:30 150 m

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
90	05:20				Glucose intake
74	06:00				N2O production Exp.

2 Bottles were broken.

May 22. 23:29 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_07.hex**

Station 9T

Lat. 18° 12.013 N FINISH 18° 13.123 N

Long. 105° 11.977 W FINISH 105° 13.030 W

Time. 23:10 LCL 06:10 UTC FINISH 13:55 UTC 06:55 LCL

Downcast ini 23:29 hrs Upcast end 06:46

Winch speed 10 Hz

Downcast Time 1:43:43 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	01:12	9.78	34.656	1.61	NH_4^+
250	02:25	11.69	34.774	1.56	NH_4^+
150	03:16	12.93	34.843	1.50	NH_4^+
140	03:39	12.99	34.844	1.49	NH_4^+
125	04:03	13.32	34.862	1.51	NH_4^+ DCM EXP
90	04:33	14.49	34.798	1.58	NH_4^+
40	05:51	24.69	34.463	164	NH_4^+ SCM-CCS
10	06:27	30.23	34.111	191	NH_4^+

May 24. 01:10 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_08.hex**

Note. Cast delayed in 1 hour due CTD misconnection. Problem solved.

Station 10 T

Lat. 18° 12.316 N FINISH 18° 12.226 N

Long. 106° 17.897 W FINISH 106° 17.677 W

Time. 08:10 LCL 01:10 UTC FINISH UTC LCL

Downcast ini 01:31 hrs Upcast end

Winch speed 10 Hz

Downcast Time 1:43:39 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	03:14	9.26	34.613	1.7	NH_4^+
250	04:16	11.4	34.752	1.57	NH_4^+
150	05:01	12.65	34.802	1.51	NH_4^+

110	05:36	-	-	1.42	NH_4^+, EXP DCM
140	06:21	13.07	34.850	1.48	NH_4^+
90	06:58	15.79	34.697	1.6	NH_4^+
50	07:28	22.12	34.531		NH_4^+
10	07:58	28.39	34.620		NH_4^+

08:32 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_09.hex**

Lat. 18° 12.226 Long.106° 17.677.

May 25. 06:44 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_10.hex**

Station 11 T

Lat. 18° 12.015 N FINISH 18° -- N

Long. 107° 29.988 W FINISH 104° --W

Time. 06:44 LCL 13:44 UTC FINISH 20:04 UTC 13:04 LCL

Downcast ini 07:03 hrs Upcast end

Winch speed 10 Hz

Downcast Time 1:42:43 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	08:45	9.45	34.622	1.81	-
250	10:03	-	-	1.79	-
130	10:55	-	-	1.7	-
100	11:23	15.01	34.538	23.9	-
75	11:51	18.61	34.480	64.9	-
50	12:17	22.38	34.460	198.2	-
10	12:47	27.54	34.521		-

Note: No DCM developed

May 26. 08:00 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_11.hex**

Station 2 T

Lat. 18° 54.000 N FINISH 18° 53.066 N

Long. 108° 48.030 W FINISH 108° 48.978 W

Time. 08:00 LCL 15:00 UTC FINISH 21:00 UTC 14:00 LCL

Downcast ini 8:26 hrs Upcast end

Winch speed 10 Hz

Downcast Time 1:43:12 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	10:09	9.27	34.625	1.87	
150	11:46	-	-	1.7	
125	12:13	13.14	34.740	2.49	
100	12:43	13.98	34.660	15.2	O_2
50	13:15	17.81	34.434	110	O_2
10	13:45	26.6	34.889	200.6	O_2

Note: No DCM developed. Craig's system was not connected to the PPS flow in the way down.

May 27. 06:20 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_12.hex**

Station 3 T

Lat. 18° 54.079 N FINISH 18° N

Long. 107° 29.751 W FINISH 104° W

Time. xx:00 LCL 15:00 UTC FINISH UTC LCL

Downcast ini 06:42 hrs Upcast end 13:15 LCL

Winch speed 10 Hz

Downcast Time 1:46:16 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	08:26	8.98	34.590	1.67	
150	10:07	12.91	34.792	1.62	
112	10.37	13.89	34.766	1.65	O_2
100	11:20	14.35	34.742	2.38	O_2
50	12:05	23.10	34.504	215.3	O_2
10	12:45	28.01	34.677	194.8	O_2

Note: Small DCM.

May 28. 12:05 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_13.hex**

Station F 9

Lat. 20° 26.664 N FINISH 20° 28.796 N

Long. 107° 37.773 W FINISH 107° 40.656 W

Time. 19:05 UTC FINISH 02:10 UTC

Downcast ini 12:19 hrs Upcast end LCL 19:10

Winch speed 10 Hz

Downcast Time 1:44:36 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	14:03	9.61	34.648	1.67	
150	15:41	12.44	34.798	1.64	
130	16:06	13.02	34.820	1.69	
125	16:33	13.10	34.816	1.57	
120	16:48	13.18	34.803	1.60	
100	17:07	14.07	34.760	1.56	
82	17:40	15.45	34.723	1.49	
45	18:22	21.53	34.520	102	O_2
10	18:51	29.39	34.519	193	O_2

May 29. 10:10 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_14.hex**

Station F10

Lat. 20° 37.391 N FINISH 20° 37.935 N

Long. 107° 51.284 W FINISH 107° 52.260 W

Time. 17:10 UTC FINISH 20:20 UTC 13:20 LCL

Downcast ini 10:30 hrs Upcast end 13:16 LCL

Winch speed 10 Hz

Downcast Time 00:35:46 150 m

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
150	11:05	12.78	34.806	1.57	Bo
95	12:03	14.59	34.763	1.58	Frank
75	12:19	16.00	34.691	2.5	O_2
48	12:36	21.91	33.793	8.2	O_2
10	13:02	28.92	34.249	45	O_2

Bo: N_2O Production Experiment. Oxygen sensor report low concentration values. Probable clogging.

12:05 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_15.hex**

Station F10

Lat. 20° 37.936 N FINISH 20° 40.353 N

Long. 107° 52.277 W FINISH 107° 54.890 W

Time. 19:05 UTC FINISH 00:35 UTC 17:35 LCL

Downcast ini 13:30 hrs Upcast end 17:35 LCL 00:35 UTC

Winch speed 10 Hz upcast to 20 Hz

Downcast Time 1:44:30 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	15:14	-	-	85	
125	16:02	13.08	34.670	10	
50	16:42	20.33	33.868	11	Happy

Notes. SBE43 and Stox don't work

May 30. The wind and high waves make very hard to deploy the PPS. We work on processing data and filling out the sampling log sheet.

May 31. 10:10 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_16.hex**

Station F12

Lat. 20° 48.183 N FINISH 20° 48.944 N

Long. 107° 54.436 W FINISH 107° 55.044 W

Time. 17:10 UTC FINISH 13:15 LCL surface

Downcast ini 10:22 hrs

Winch speed 10 Hz

Downcast Time 00:38:30 160 m

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
160	11:00				Bo
85	11:25			1.40	DCM Exp
70	12:10			4.01	O_2
40	12:48			161	O_2

Note. SBE43 was maintained and works fine.

May 31. 13:26 hrs PPS/CTD deployment (output rate2 scans/sec). **NH14_PPS_17.hex**

Station F12

Lat. 20° 49.015 N FINISH 20° 48.944 N

Long. 107° 55.060 W FINISH 107° 55.044 W

Time. 20:26 UTC FINISH

Downcast ini 13:26 hrs

Winch speed 10 Hz

Downcast Time 01:44:00 400 m

Continuous Profile for Nitrite and dissolved gas (Mark's group), DIC (Martin's group) and Nitrate, oxygen (optode, SBE43), pCO2 (Craig's group).

Depth	Time (LCL)	Temperature	Salinity	Oxygen	Sampling
400	15:10			1.7	
350	15:48			1.71	

Note. BIG FAIL. Winch wire was stuck in the block and the wire was ripped. Pump also was damaged and need to be discarded. Way up to 35 HZ.