Cruise Report

California Current Ecosystem LTER Program

CCE-P1706 Cruise

R/V *Roger Revelle*, 1 June – 2 July 2017

Compiled and submitted by: Mark D. Ohman, Chief Scientist

Scripps Institution of Oceanography, University of California, San Diego

Cruise ID: CCE-P1706 (= RR1710)

Depart: 1 June 2017, 0800 (PDT), MARFAC

Return: 2 July 2017, 0800, MARFAC

Vessel: R/V *Roger Revelle*

Master: Captain David Murline

Chief Scientist: Mark D. Ohman

Science Technicians: Matt Durham, Steven Jalickee, Carl Mattson, Victor Adeyokunnu

Operator: Scripps Inst. Oceanography

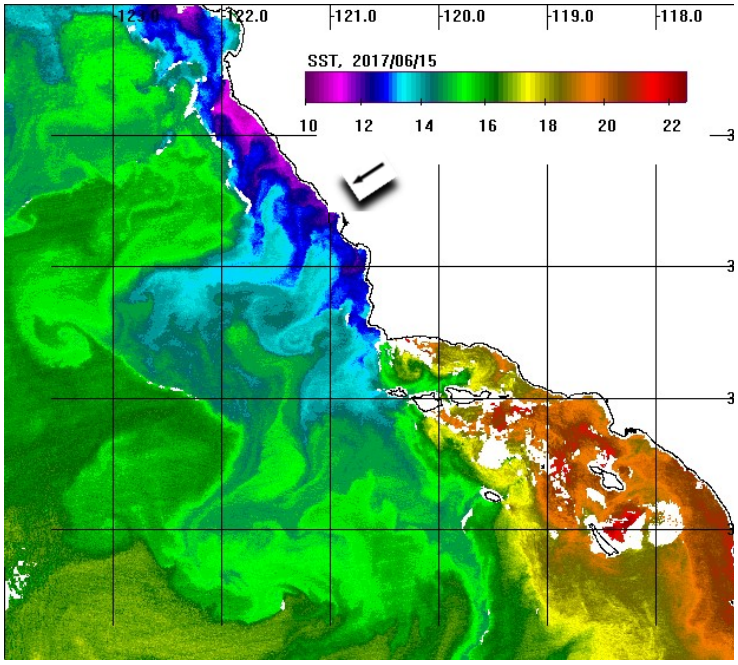

Fig. 1: Coastal filaments. Satellite image of sea surface temperature (SST, °C) on 15 June 2017, near the mid-point of cruise P1706. Note the blue-shaded cool water filaments. The central offshore-flowing filament (arrow) was the primary focus of detailed analysis during P1706. Image courtesy of M. Kahru, SIO.

Contents

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SCIENCE OBJECTIVES

This cruise, designated P1706 in CCE parlance (but RR1710 according to the ship's nomenclature), was the first process cruise in Phase III of the *California Current Ecosystem* Long Term Ecological Research (CCE-LTER) program. This cruise focused on cross-shore fluxes and export of nutrients, organisms, nitrogen, and carbon associated with coastal upwelling filaments. P1706 employed a suite of integrated approaches: Lagrangian design experimental studies and in situ measurements, deployments of multiple autonomous instruments (*Spray* glider, in situ driftarrays, sediment traps, Carbon Flux Explorers), two Seasoar surveys, and remote sensing (including satellites and coastal high-frequency radar).

Our specific objectives were to ***understand and quantify key mechanisms that transport coastal production and populations offshore in the CCE region, including the magnitudes and length scales of transport and their climate sensitivities.*** The principal hypotheses we sought to test were:

H_1: Lateral transport dominated by the interaction of Ekman transport and westward propagating coastal filaments provides a significant flux of nutrients and organisms to offshore waters.

H_2: Carbon export associated with offshore transport is determined by in situ evolution of communities and nutrient regimes, and by subduction occurring largely at sharp frontal density gradients.

The processes measured on this cruise included primary and secondary production, net community production, grazing by microzooplankton and mesozooplankton, dissolved iron and ligand effects on phytoplankton growth, carbon and nitrogen cycling, and elemental export in both particulate and dissolved forms. The pelagic food web ranging from viruses, prokaryotic and eukaryotic microbes, micro- and meso-zooplankton, to nektonic organisms (the latter as acoustic backscatter) was characterized by state-of-the-art measurement methods. Most measurements were made in a Lagrangian reference frame while following discrete water parcels for 3-5 days at a time. These water parcels were selected to represent different stages in the temporal evolution of a coastal filament: i.e., nearshore near the upwelling source and presumed origin of the filament; somewhat further offshore, along the axis of the filament, as upwelled waters and entrained communities were advected offshore; and still further offshore, near the terminus of a filament, where export fluxes were expected to be elevated. We also conducted a Benthic Boundary Layer (BBL) study to understand the relationship between coastal iron supply in nearshore sediments and the flux of iron into the coastal ocean via coastal filaments.

Our Broader Impacts activities included providing seagoing research opportunities and training for 11 graduate students, 8 undergraduate students and other volunteers, as well as communication with the general public via an online blog created by graduate student Laura Lilly (http://cce.lternet.edu/blogs/201706/).

OVERVIEW OF THE SCIENCE PLAN

Preparations for this cruise began with deployment of a *Spray* ocean glider on 18 May 2017 (Dan Rudnick and IDG, SIO), in order to characterize cross-shore fluxes on a line extending from Pt. Conception to Pt. Piños at the southern end of Monterey Bay. The glider profiled from 500-0 m. Concurrently with this deployment, and prior to departure of the R/V *Roger Revelle* from MARFAC on 1 June 2017, satellite and high frequency coastal radar (CODAR) images were generated daily to identify regions of filament formation. The remotely sensed variables analyzed included Chl-*a* and SST (Mati Kahru, SIO); Sea Surface Height and derived properties (Finite Size Lyapunov Exponents, Okubo-Weiss parameter, Alain de Verneil at MIO, Marseille, France); and near-surface circulation inferred from CODAR (Ralf Goericke, SIO). Glider and remote sensing data were also examined daily at sea to guide site selection for experimental Lagrangian Cycles.

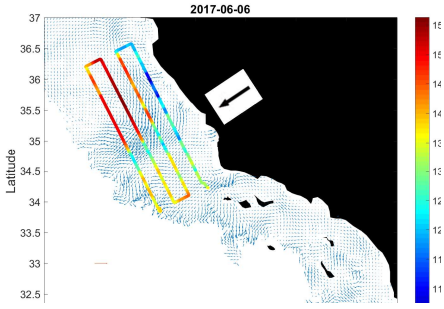

Fig 2: Seasoar Survey #1. Near-surface SST (° C, colored track), superimposed on CODAR surface currents (blue vectors). Arrow indicates location of cool water, cross-shore filament. (Fig. by Ralf Goericke)

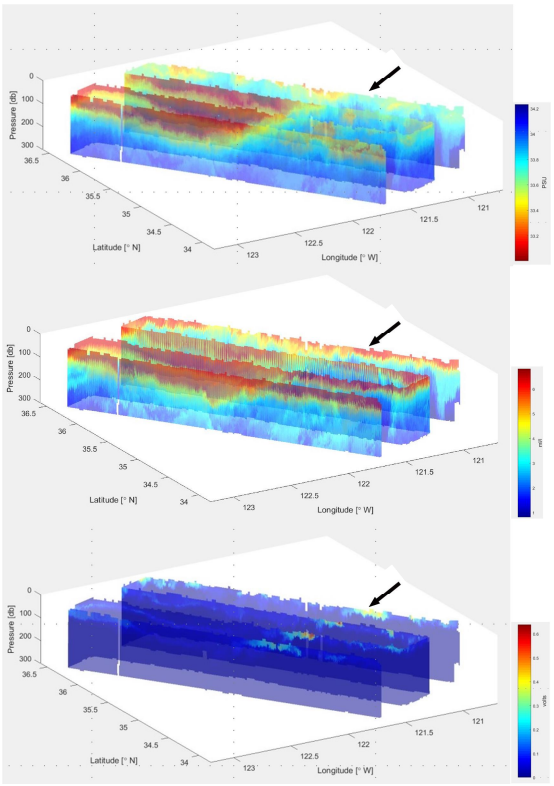

Fig 3: Seasoar Survey #1. Coastal filament characterized by salty (upper panel), somewhat lower subsurface dO_2 (middle panel), and high Chl-*a* (lower panel) water. Arrow indicates location of cross-shore filament. (Figs. by Ben Whitmore & Mark Ohman)

After departure from Scripps' MARFAC on 1 June and completion of instrument test stations, including profiles at the Santa Barbara Basin (34° 16.5'N, 120° 1.5' W), our initial shipboard activity was a Seasoar survey (combined with ADCP profiling) conducted along 4 south-north lines extending from Pt. Conception to Pt. Piños, at successively greater distances from shore (Figs. 2,3). Seasoar profiled from ~260-8 m, in order to provide measurements needed to calculate cross-shore fluxes of mass, nitrate, and carbon, between each pair of Seasoar lines. From this Seasoar survey a major offshore-trending cool-water filament was located whose origins appeared to be near Morro Bay, CA (see arrows in Figs. 2,3). This filament, provisionally named the Morro Bay filament, was the primary focus of the remainder of the P1706 cruise. During Seasoar surveys, continuous underway measurements were made of Net

Community Production (O_2/Ar), pCO_2/pH, phytoplankton pigments and variable fluorescence (by ALF), and discrete samples were taken from the continuous underway seawater system for ^{234}Th, particulate and dissolved C and N, and other variables.

We then conducted a series of rate process measurements on four Lagrangian experimental "Cycles" in water parcels selected to represent four states in the development of the Morro Bay coastal filament (Figs. 4,5 below). Site selection for each Cycle entailed examining *Spray* glider and remote sensing data, followed by localization of each water parcel of interest by a preliminary site survey using a Moving Vessel Profiler (MVP) profiling to a depth of 200 m (Fig. 30, below). MVP surveys permitted regions of strong frontal gradients to be localized and avoided prior to deployment of drifting instruments. Following this approach, **Cycle 1** was located in freshly upwelled waters; **Cycle 2** was in waters located ~77 km to the southwest of the start point of Cycle 1, in partially aged upwelled waters; **Cycle 3** was in waters ~140 km southwest of the start part of Cycle 3, in post-bloom waters; **Cycle 4** was begun ~26 km northeast of the start point of Cycle 3, in waters from Cycle 2 to which we returned after having deployeda sediment trap to continue drifting with the waters at the end of Cycle 2 (see Figs. 4,5). Either before or after each of Cycles 1-3, a cross-filament transect was conducted, whereby waters across the core of the filament were sampled using a rapid CTD-rosette profile, vertical bongo net, and trace metal sampling (at some transect stations). Each cross-filament transect was conducted as rapidly as feasible, attempting to sample (to the extent possible) in nighttime hours in order to minimize diel variations attributable to phytoplankton photophysiology and zooplankton diel vertical migration.

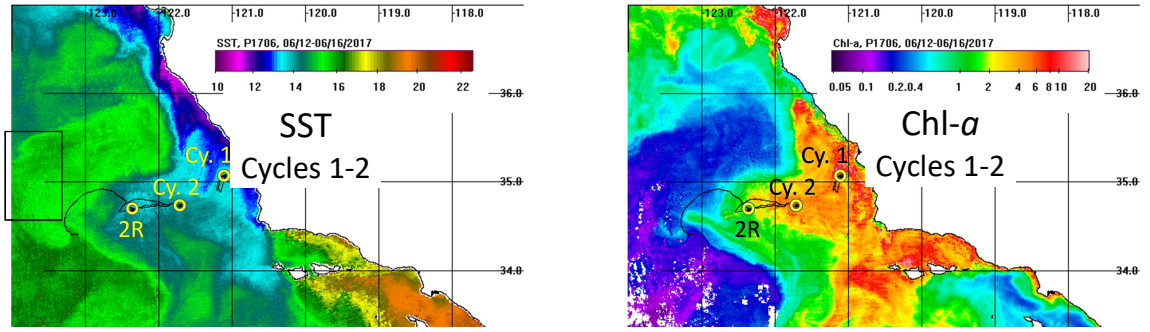

Fig. 4: Cycles 1 and 2 (and the redeployed sediment trap [2R] following Cycle 2) and associated tracks of driftarray and sediment trap (black lines). Satellite SST (left) and Chl-*a* (right) images centered on 14 June 2017.

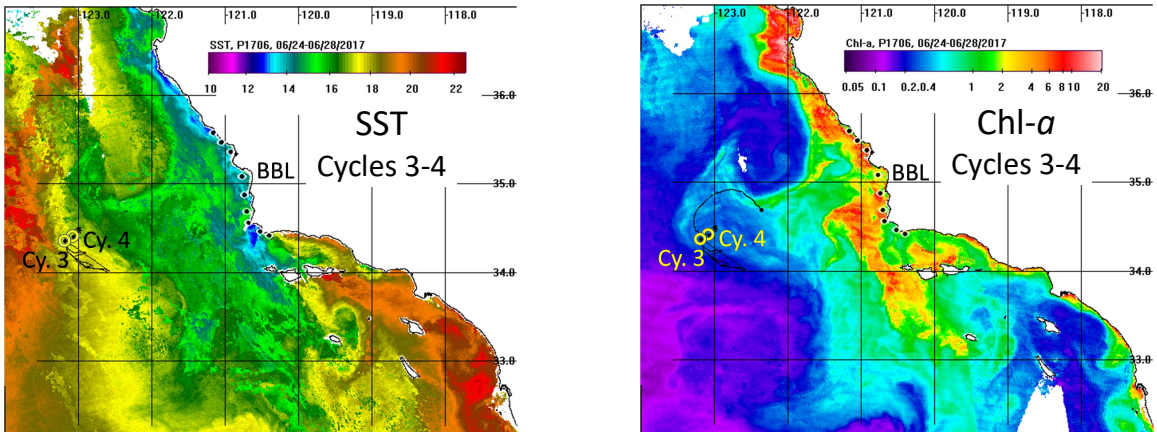

Fig. 5: Cycles 3 and 4, and tracks of driftarray and sediment trap (black lines), as well as Benthic Boundary Layer (BBL) stations. Satellite SST (left) and Chl-*a* (right) images centered on 26 June 2017. Images courtesy of Mati Kahru.

For each Cycle, satellite-tracked sediment traps and in situ incubation driftarrays were used to follow water parcels over repeated day/night measurements in order to quantify the temporal evolution of rate processes and plankton community composition. Both sediment traps and driftarrays employed a holey sock drogue centered at 15 m depth. All other measurements were made in these same water parcels in close proximity to the driftarray, or centered on the driftarray (in the case of towed nets like the bongo and MOCNESS). Incubation bottles were suspended from the driftarray at six light depths spanning the euphotic zone in order to determine specific growth rates of phytoplankton and specific grazing rates of microzooplankton (seawater dilution experiments), virus-induced mortality of phytoplankton, in situ rates of ^{14}C-based primary production, and in situ New Production from $^{15}NO_3$ uptake. Additional measurements/samples at the drifter locations included Fe limitation and ligand production incubations; vertical profiles of trace metals sampled with a Trace Metal clean rosette; carbon species taken up to supply C-fixation; analysis of stable isotopes of N, C, and O; reactivity of DOC and DON; ^{234}Th:^{238}U disequilibrium; microbial diversity assessed by 16S and 18S ribosomal subunit genes; bacterial production by ^{3}H-leucine incorporation; phytoplankton pigments by HPLC; size-fractionated Chl-*a*; POC and PON; picoplankton samples for flow cytometry; microplankton samples for epifluorescence microscopy; mesozooplankton biomass and grazing (via gut fluorescence) in five size fractions; copepod egg production rates for the dominant species of calanoid copepod; mesozooplankton vertical distributions via vertically stratified MOCNESS samples; and vertical profiles of macronutrients and standard hydrographic variables. Carbon Flux Explorers (CFE), including calibration CFEs that obtained pumped water samples, were deployed at each Cycle (Jim Bishop lab). In addition, continuous underway measurements were made on the ship's uncontaminated seawater system, including phytoplankton pigments, variable fluorescence (F_v/F_m), and CDOM, all using an Advanced Laser Fluorometer (ALF; Chekalyuk and Hafez. 2008. LOM: 6:591); O_2:Ar ratios as a measure of net community production (Sven Kranz); continuous pCO_2 and pH (Taylor Wirth, T. Martz lab); standard ship-provided measurements of ocean surface properties and meteorological variables; ADCP-derived currents at 75 and 150 kHz; and EK60 acoustic backscatter at four frequencies (38, 70, 120, 200 kHz). In situ plankton images were acquired on all CTD-rosette casts using a high definition Underwater Vision Profiler (UVP5-HD). Measurements are described in greater detail below.

In addition to our core measurements at the four Lagrangian Cycles, we conducted a Benthic Boundary Layer (BBL) survey at 9 stations on the continental shelf north of near Pt. Conception (Fig. 5). This study tested the hypothesis that dissolved iron is elevated in the benthic boundary layer (BBL) above continental shelf sediments (Katherine Barbeau lab), a likely source of dissolved iron in coastal filaments.

This cruise was extremely successful, thanks largely to the professionalism and assistance of the Captain, crew, resident marine technicians, and electronic technician. Some of the challenges experienced en route included the need to inform multiple entities (submarine fleet control, U.S. Navy, and Vandenberg Missile test range) of our operations areas, which could not be predicted long in advance because of the Lagrangian design of the cruise. At times our operating plans had to be modified as many as four times in a single day because of changing (and partially conflicting) information from these sources, although in the end all our science objectives were fully met. We originally intended to make dissolved nitrate measurements from the *Spray* glider deployed in support of this cruise, but the onboard uv radiometer

proved intermittent and was deactivated, nevertheless permitting us to make all other glider-based measurements. Finally, one Carbon Flux Explorer was floating at the sea surface and about to be recovered when it was attacked and destroyed by a shark (apparently a shortfin Mako).

Brief chronology of cruise P1706

(see Event Log for details)

1 June 2017 (0800)	Depart MarFac; steam to test station location
1 June (1300-2000)	Test stations
2 June (0900)	Santa Barbara Basin casts; then transit to SeaSoar #1
2 June (2000)–6 June (1400)	Seasoar #1
7 June (0600)	Personnel transfer, Santa Barbara harbor; then transit to Transect 1
7 June (2000)–8 June (0900)	CTD-Bongo-TM Transect #1 (across filament)
8 June (1200-1600)	MVP Transect #1
8 June (1800-2300)	MVP Transect #2
9 June (0100)	Deploy sediment trap, begin CYCLE 1
12 June (0630)	Recover sediment trap, end CYCLE 1
12 June (1800)	MVP Transect #3
13 June (0200)	CTD, begin CYCLE 2
16 June (1500)	Deep CTD #1 (3500 m)
17 June (0900)	Recover sediment trap, end CYCLE 2
17 June (1400)	MVP Transect #4
17 June (1930)-18 June (1330)	CTD-Bongo-TM Transect #2 (across filament)
18 June (1630)	MVP Transect #5
19 June (0100)	Deploy sediment trap, begin CYCLE 3
22 June (0500)	Recover sediment trap, end CYCLE 3
22 June (0830)	MVP Bow Tie Survey #1
22 June (1300)	Deep CTD #2 (3500 m)
22 June (1800)–23 June (0800)	CTD-Bongo-TM Transect #3 (across filament)
23 June (1100)	MVP
23 June (2300)	Deploy sediment trap, begin CYCLE 4 (aka, Cycle 2 revisited)
26 June (0500)	Recover sediment trap, end CYCLE 4
26 June (1300)-29 June (2230)	Seasoar #2
28 June (1900)	Onboard science tour; all invited
30 June (0200-1800)	BBL stations 1-9
1 July (0630-1800)	MVP vs. UVP comparison, Santa Cruz Basin
2 July (0800)	Arrive MARFAC

GROUP REPORTS

SeaSoar - (Operations directed by Carl Mattson; many others participated)

Two SeaSoar surveys were conducted. The first consisted of four south-north legs running from Point Conception, CA to just west of Monterey Bay, CA (Fig. 2). The SeaSoar was equipped with a Rinko 3 dissolved oxygen sensor, fluorometer, beam transmissometer, dual temperature and conductivity probes, and a pressure sensor. This survey was used to identify the location, vertical structure, and offshore extent of the target filament within the California Current Ecosystem. SeaSoar data were used in combination with satellite imagery, Moving Vessel Profiler Transects, and glider profiles to identify the starting locations of each Cycle. After completion of the four Lagrangian Cycles, a second SeaSoar survey of somewhat more limited latitudinal extent was conducted to resolve the subsurface structure of the coastal filament. After the cruise, the two SeaSoar transects will be used to calculate cross-shore fluxes and to help parameterize physical models of the California Current Ecosystem.

Hydrography, Primary Production – Goericke Group (Ralf Goericke, Megan Roadman, and volunteers Hailey Rosenthal and Shailja Gangrade)

Hydrography: CTD casts were carried out every 8 to 12 hours while the drifting sediment trap was in the water. The package (SBE 9Plus) had instruments for temperature (SBE 3), conductivity (SBE 4), oxygen (SBE43), chlorophyll-*a* fluorescence (Seapoint), light attenuation (Wetlabs C-Star), and photosynthetically active radiation (Licor PAR sensor). Samples were collected from the CTD at about 8 depths per cast for concentrations of plant nutrients (nitrate, nitrite, silicic acid, phosphate, and ammonium), salinity, concentrations of Chl-*a* (determined fluorometrically aboard ship), concentrations of particulate organic carbon and nitrogen, and concentrations of taxon-specific pigments. Results from these observations are summarized in Table 1 as averages for the surface layer of individual experimental cycles.

Table 1: Cycle averages of surface layer hydrographic properties: temperature (° C), salinity (PSU), oxygen (µmol/kg), nitrate as estimated using the ISUS sensor (µM), Chl-*a* fluorescence (Volt), and beam transmission (% light transmission).

Cruise	Cycle	Date	Depth	Temp	Sal	Oxygen	ISUS_NO3	FluorVolt	TransPer
			(m)	(° C)	(PSU)	(µM)	(µM)	(V)	(%)
CCE-P1706	Cycle1	10-Jun	11	12.8	33.7	220.7	14.4	2.3	80.0
CCE-P1706	Cycle2	14-Jun	11	12.9	33.6	201.5	15.3	1.6	85.6
CCE-P1706	Cycle3	20-Jun	11	14.8	33.2	193.9	6.6	0.4	96.1
CCE-P1706	Cycle4	24-Jun	12	14.5	33.6	198.7	7.7	0.1	97.8

Temperature-salinity diagrams allow the identification of water masses and tracking of changes of water masses between stations. The TS diagrams for all P1706 Cycles are shown in Fig. 6. In terms of hydrography Cycles 1 and 2 were very similar, sampling waters with cold and saline surface waters, likely derived from upwelling. During Cycle 1 diurnal warming of the surface layer occurred. Cycle 3 sampled waters affected by low-salinity waters of the California Current. The TS diagram suggests that rather than tracking surface waters, we tracked water of 8 to 9 deg. C. Cycle 4 was located in warm and saline surface waters; possibly upwelling derived waters that had warmed.

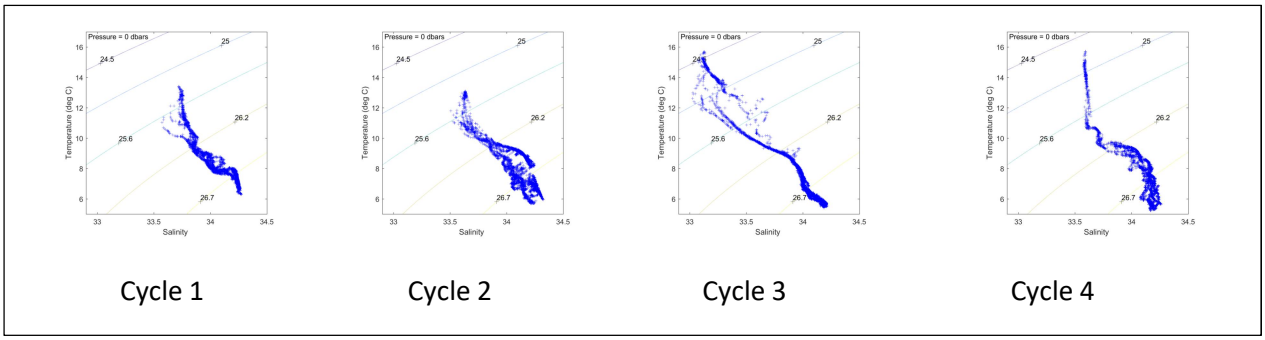

Fig. 6: TS diagrams for Cycles 1 - 4, illustrating the water mass variability, or the absence thereof, during the cycles.

***Phytoplankton Biomass*:** Chl-*a* is often used as a proxy for phytoplankton biomass. It is determined by measuring the fluorescence of acetone extracts. The depth distribution of Chl-*a* for the four cycles is shown in Fig. 7. The patterns shown in Cycles 1 and 2 are typical for phytoplankton blooms, i.e. large maxima of Chl-*a* in the surface layer. Patterns for Cycles 3 and 4 suggest declining phytoplankton blooms or, Cycle 4, patterns often associated with the California Current waters.

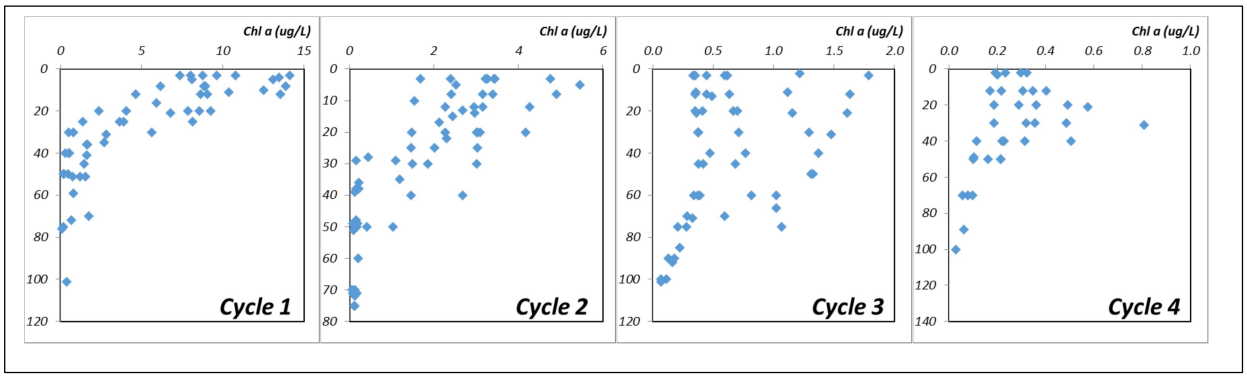

Fig. 7: Vertical profiles of Chl-*a* at Cycles 1-4. Note the changes in x- and z-axis scales.

Phytoplankton Community Structure: The pigments of microalgae are often characteristic of their taxonomic affiliation. Concentrations of taxon-specific pigments, e.g. chlorophylls and carotenoids, can be used to determine relative contributions of different taxonomic groups to total phytoplankton pigment biomass. We collected samples for the analysis of phytoplankton pigments by High Performance Liquid Chromatography from most casts. These samples will be analyzed ashore for concentrations of pigments; phytoplankton community structure will be determined from these data.

Phytoplankton size is another dimension of community structure. To assess size structure, Chl-*a* size fractionation experiments were carried out on samples from the mixed layer or the deep chlorophyll maximum (DCM). Results from these experiments are shown in Table 2. The size distribution for the surface layer is shown in Fig. 8 for all 4 Cycles. The patterns observed during Cycles 1-3 are consistent with the total phytoplankton biomass present, based on past observations. The pattern observed during Cycle 4 is unusual; the size spectrum is dominated by cells in the 3 to 20 µm size range, rather than by cells > 20 µm. This may either reflect an unusual oceanographic condition or the decline of the phytoplankton bloom.

Table 2: Chlorophyll size fractionation experiments: Experiments were done with water from the 0200 casts from the mixed layer (ML) and the noon CTD with water from the Deep Chl Maximum (DCM; if present). Shown are the number of experiments (N), Chl-*a* concentration for the sample (TChl-*a*) and the % of TChl in the < 1 µm, 1-3 µm, 3-8 µm, 8 -20 µm and > 20 µm size fractions.

Cruise	Cycle	Location	Depth	N	TChl-*a*	< 1µm	1-3µm	3-8µm	8-20µm	> 20µm
-	-	-	(m)	-	(µg-Chl/L)	(% TChl *a*)	(% TChl *a*)	(% TChl *a*)	(% TChl *a*)	(% TChl *a*)
P1706	1	ML	8	7	10.9 ± 3.08	15 ± 4	2 ± 3	6 ± 2	2 ± 4	75 ± 4
P1706	1	DCM			-	-	-	-	-	-
P1706	2	ML	10	8	3.0 ± 1.06	14 ± 6	3 ± 7	12 ± 11	n.d.	71 ± 12
P1706	2	DCM			-	-	-	-	-	-
P1706	3	ML	6	5	0.74 ± 0.52	41 ± 18	17 ± 8	9 ± 5	3 ± 2	30 ± 27
P1706	3	DCM	45	2	0.54 ± 0.20	45 ± 10	12 ± 8	11 ± 2	0 ± 5	32 ± 22
P1706	4	ML	2	2	0.23 ± 0.02	50 ± 2	11 ± 4	11 ± 2	0 ± 1	28 ± 2.7
P1706	4	DCM	20	2	0.36 ± 0.27	47 ± 11	14 ± 0	10 ± 3	6 ± 3	23 ± 11

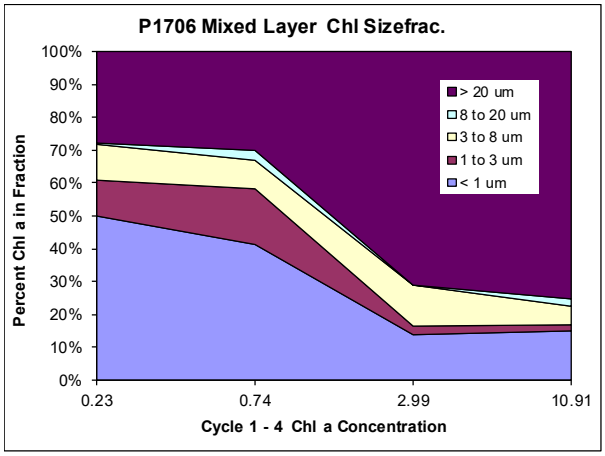

Fig. 8: Average Chl-*a* size distributions for the 4 Cycles. Chl-*a* concentrations in the mixed layer increased with Cycle number (Cycle 1-4: 0.23, 0.74, 3.0 and 11 µg-Chl-*a*/L respectively).

Primary Production: Rates of primary production were determined from the incorporation of ^{14}C into particulate carbon and dissolved organic carbon. Such rates constrain how much carbon is available for higher trophic levels. Samples will be analyzed ashore.

Phytoplankton community structure and physiology were also studied using the Advanced Laser Fluorescence (ALF) system, designed by Alexander Chekalyuk. The system was used to make continuous measurements on water from the ship's clean seawater system and from water collected at different depths using the CTD rosette. Data collected using the system during SeaSoar survey 1 are shown in Fig. 9.

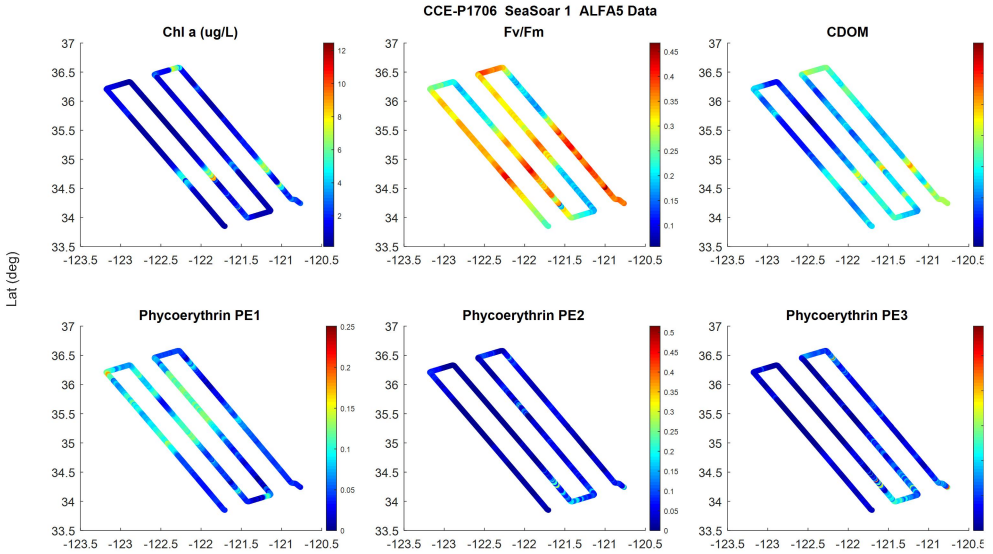

Fig. 9: Spatial patterns of phytoplankton biomass (Chl-*a*), photosynthetic capacity (Fv/Fm), colored dissolved organic matter (CDOM) and distributions of phycoerythrins characteristic of oceanic (PE1) and coastal (PE2) cyanobacteria and cryptophytes (PE3) observed during SeaSoar survey 1. All units are relative.

pCO_2 and pH – **Martz lab** (Taylor Wirth)

Continuous underway measurements were made with a modified underway pCO_2, pH, temperature, conductivity sensor system developed for the CCE-LTER and CalCOFI programs. Underway measurements permit greater spatial and temporal coverage of the study sites compared to discrete sampling. Running continuously, this system can provide a larger scale description while also showing smaller scale features that would not be resolved by CTD casts. Including pH measurements yields two of the four carbonate system parameters that can be used to calculate Total Alkalinity and Total inorganic CO_2 (with input temperature, salinity and pressure). The use of precise carbonate measurements is vital in order to understand long term atmospheric and oceanic changes.

This underway system is a modified SuperCO_2 System developed by Sunburst Sensors. We modified the system by adding a separate Seabird TSG (SBE 45) external flow cell containing a Honeywell Durafet III pH Electrode and Conductivity Probe, GPS puck, and external computer to compile all data simultaneously. The Labview program on the external laptop reads the Honeywell Probes via a

Honeywell UDA2182 Analyzer. Three standard gases are measured every 4 hours for pCO_2 calibration along with atmospheric pCO_2 for 4 minutes each. Underway measurements were recorded every 4 seconds. Discrete samples were taken daily from the continuous underway seawater system, to be later analyzed via benchtop DIC, pH and Alkalinity systems (Martz Lab). Bottles were prepared and provided by Andrew Dickson's Lab.

Preliminary results (Fig. 10) show that this system was able to capture nearshore variability along with offshore filament-related transport of colder, saltier, high pCO_2, low pH water. Verification/calibration with discrete samples will be used to confirm underway results.

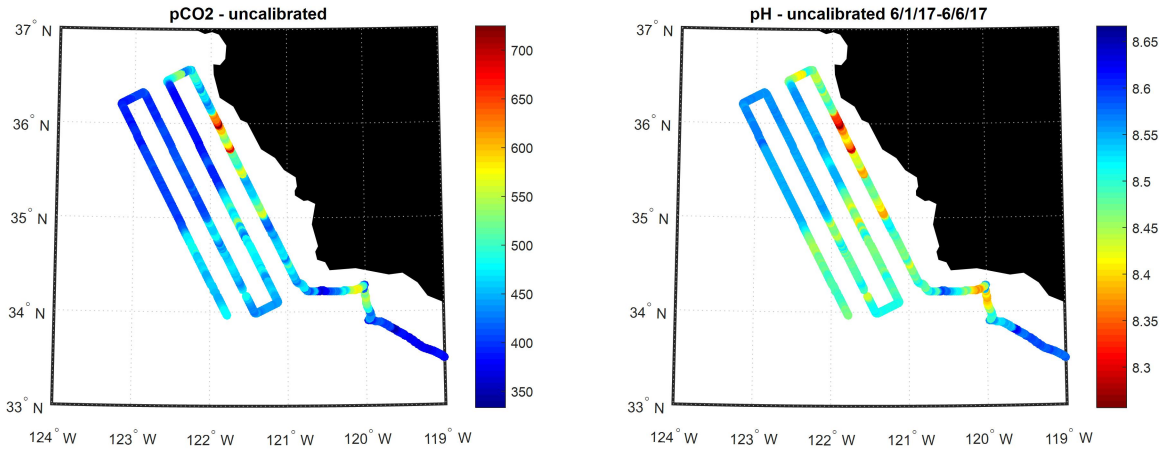

Fig. 10: Preliminary pCO2 and pH results from continuous underway sampling on Seasoar Transect 1.

Net Community Production, FRRF, and C Acquisition - (Sven Kranz)

O_2/Ar measurements – NCP: In the surface ocean, net community productivity (NCP) equals the rate of photosynthesis (phytoplankton) minus the rate of respiration (phytoplankton + all other organisms). In collaboration with Nicolas Cassar (Duke University), O_2/Ar measurements were conducted using mass spectrometers to estimate diel variations in NCP during Cycles 1-4 (e.g., Fig. 11) and to analyze the spatial NCP differences in the region during Seasoar transects. Two similar mass spectrometers were used to measure O_2/Ar ratios. Oxygen derived from biology ($[O_2]_b$) is equal to the total O_2 minus the oxygen derived from physical processes: $[O_2]_b = [O_2] - [O_2]_p \approx [O_2] - ([Ar]/[Ar]_{sat}) = ([Ar]/[Ar]_{sat})$ $[O_2]_{sat}\,\Delta(O_2/Ar)$ where $\Delta(O_2/Ar) = [(O_2/Ar)/(O_2/Ar)_{sat}\text{-}1]$ and is defined as the biological oxygen supersaturation. $[O_2]_b$ is a synthetic tracer of biological activity within the mixed-layer, and can be negative if the mixed-layer is net heterotrophic.

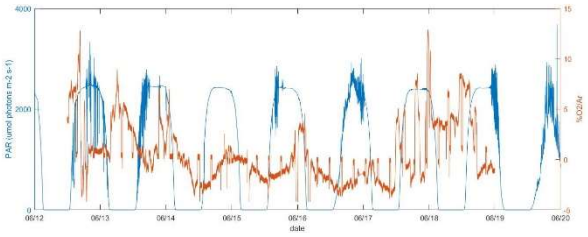

Fig. 11: dO_2/Ar (orange) and PAR intensity (blue). A clear diel cycle is present during Cycle 2 (shown here) with both net autotrophic phases and net heterotrophic phases (raw data).

NCP is subsequently derived from the oxygen concentration at saturation, the air-sea gas exchange coefficient, and biological oxygen supersaturation.

Fast Repetition Rate fluorometry - FRRF: FRRF is used to analyze the photosynthetic properties of phytoplankton cells. For each sample a photosynthesis vs. light curve (P vs. E) is measured. Data are analyzed for dark Fv/Fm (overall photo-physiological status of the cell), alpha (initial slope of the P vs. E kinetics, Ek (light saturation) and other photochemical parameters (Fig. 12). The instrument also approximates Chl-*a* concentration and gross photosynthesis (Oxborough et al 2012). We intend to calculate phytoplankton gross production and to gain a better understanding of processes of photosynthesis in the upper water column along and across the filament of interest.

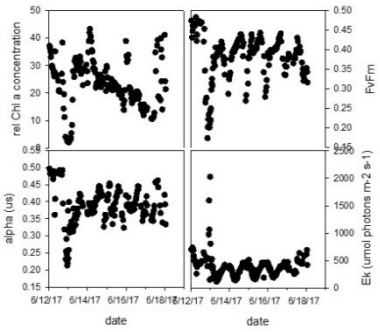

Fig. 12: Relative Chl concentration, dark Fv/Fm, alpha and Ek from phytoplankton during Cycle 2.

C-acquisition: To develop a process-based understanding of phytoplankton productivity along the filament, we measure the dependence of photosynthesis on inorganic carbon, as well as the carbon species taken up to supply C-fixation (Fig. 13). Using radiolabeled ^{14}C HCO_3^-, short term incubation experiments are performed. As photosynthesis is substrate-limited under lower DIC concentrations, C-fixation will increase with increasing substrate in a Michaelis-Menten type relation. Using a transient disequilibrium approach (Rost et al., 2007), the preferred carbon species taken up by the phytoplankton community is determined. The uptake of CO_2 or HCO_3^- determines the energetic demand for C-fixation and thus competitiveness and also affects the isotopic composition of the POC and DOC, since CO_2 is depleted in ^{13}C compared to HCO_3^-.

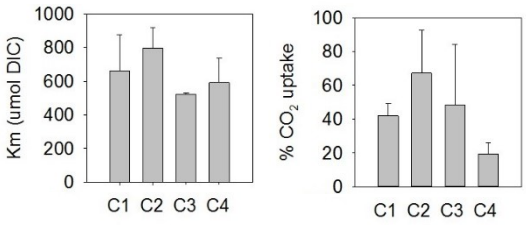

Fig. 13: Half saturation concentration and % CO_2 uptake of the phytoplankton in Cycles 1 to 4. Cells appeared not to regulate their C-acquisition affinities, yet a trend from CO_2 to HCO_3^- uptake was observed following the filament.

Trace Metal Studies – **Barbeau Group** (Kathy Barbeau, Lauren Manck, Kiefer Forsch, Kayleen Fulton. Sarah Schwenk also assisted with some deployments and array incubation studies)

We seek to understand the role of iron as a limiting or co-limiting micronutrient in shaping the composition of the phytoplankton community, and related impacts on biogeochemistry. We are measuring the distribution of iron, and conducting experiments to gauge the degree of iron limitation experienced by the phytoplankton community in different regimes. Iron sources in the benthic boundary layer of the filament source region and points south were characterized. Secondary goals were to conduct experiments to examine aspects of the biogeochemical cycling of iron, such as production of iron-binding ligands in sinking fecal pellets. Masters student Kayleen Fulton is taking samples for the determination of biogenic silica in the water column and in iron addition grow-out experiments, to examine linkages between silica cycling, biogenic silica ballasting, and phytoplankton iron limitation status.

Sample/measurement coverage: To date we have made 37 trace metal casts, including dissolved Fe profiles at all cycles (2 profiles each at Cycles 1, 2, and 3, and one at Cycle 4), multiple profiles during cross-filament Transects 1, 2, and 3, and several casts to obtain water for iron limitation and other incubation studies. 10 iron addition grow-out experiments were conducted at Cycles 1,2,3, and 4, both on-deck and on the in-situ array. 24-hour on-array iron stress gene studies were carried out in collaboration with Sarah Schwenk of the Allen lab. bSi sample profiles were taken daily at all cycles, at every other station on transects, and from iron addition incubation experiments. A 9-station benthic boundary layer along-shelf transect was conducted starting on 30 June.

Methods: Trace metal clean water column samples were collected using Teflon-coated 5-L Niskin-X bottles (Ocean Test Equipment) mounted on a powder-coated rosette, equipped with a CTD and auto-firemodule (Seabird Electronics), suspended from a coated metal cable (Space-Lay Wire Rope). Bottles were tripped at preprogrammed depths during the up-cast, while moving upward at minimum winch speed. Benthic boundary layer samples will be obtained via GO Flo casts with bottles mounted directly on the coated metal cable and tripped via Teflon messenger. Immediately following retrieval, Niskin-X and GO Flo bottles were transferred into a Class 100 trace metal clean van and filtered in-line using acid-washed Teflon tubing and an acid-washed Acropak-200 (0.2 µm) capsule filter pressurized by filtered air. Filtered samples for dissolved iron (dFe) analysis were placed in 250 mL of acid-cleaned low-density polyethylene bottles, acidified to pH 1.8 (Optima HCl), and stored until analysis in the laboratory.

Deckboard grow-out experiments were conducted to test for Fe limitation in 4-L acid-cleaned polycarbonate bottles. Three controls and three treatments with 5 nmol·L−1 dissolved Fe added were incubated for 3 d. Nutrient and chlorophyll samples were taken daily.

Preliminary results: Preliminary data from experiments completed on aboard ship relate to our iron addition grow-out experiments. Throughout Cycle 2 and for samples taken the first day of Cycle 3, we observed clear responses to iron addition in our incubation studies. In contrast, Cycle 1 incubations did not show pronounced responses to iron addition. We are analyzing incubations from Cycle 4. Fig. 14 is a photograph of control vs +Fe filters taken after just one day of incubation on deck with added iron from Cycle 2, Day 1 (sampled from 12 meters depth). Fig. 15 shows Chl-*a* responses from an iron addition grow-out carried out with water sampled from 15 meters depth at Cycle 2, Day 4, and incubated on-deck for three days. Many of our grow-out experiments that showed a response to iron exhibited a similar pattern in which the Chl response was pronounced and relatively fast, within 1-2 days, followed by a dropoff. We suspect this is due to accelerated nitrate utilization in the +Fe bottles but await the results of nutrient analyses. In addition to bulk Chl results, positive responses to iron addition were verified at Cycles 2 and 3 by active fluorescence measurements made in collaboration with Sven Kranz.

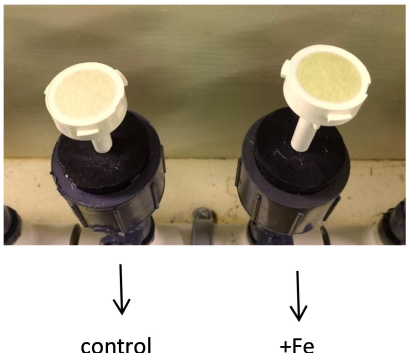

Fig. 14: Filters indicating the phytoplankton biomass response to added Fe. Cycle 2, day 1.

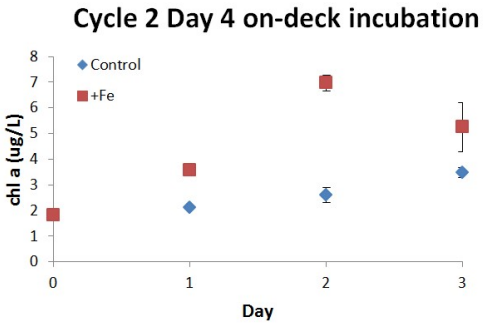

Fig. 15: Time course of Chl-*a* response to added Fe. Cycle 2, day 4.

N Cycling – (Brandon Stephens)

(1) Suspended Particulate Organic Matter (POM)

Samples were collected onto GF/F filters to measure particulate organic carbon (POC) and particulate organic nitrogen (PON) concentrations as well as to determine the ^{15}N and ^{13}C content of suspended POM, as measured by isotope ratio mass spectrometry coupled to a CHN analyzer. The primary intent from the isotope data is to provide a ^{15}N estimate of the instantaneous product of nutrient uptake, where the expectation is that Rayleigh-type isotopic fractionation will identify regions of nutrient limitation. POM concentrations will be valuable for the biogenic silica measurements made by the Barbeau lab. Samples were collected from noon time CTD casts for Cycles 1 - 4 and every other station during transects. 4L volumes were drawn from the CTD Niskin bottles using Masterflex tubing into carboys (rinsed 3x) covered with black plastic bags to prevent influences due to light. Samples were pulled by vacuum pump at a high rate to reduce time that the samples sat at room temperature (isolated within 1.5 hours of collection), and the filters finally stored at -80° C.

(2) $\delta^{15}NO3$

Samples were collected into 60ml HDPE bottles to later measure the ^{15}N and ^{18}O composition of nitrate in the seawater. The primary intent is to provide a direct isotopic source to the hypothesized primary limiting source nutrient to the California Current Ecosystem (NO_3), given that as the nitrate becomes isotopically enriched in ^{15}N (due to limited supply) we might expect the base of the food web in turn to become enriched. Samples were collected from noon CTD casts for Cycles 1 - 4 and every other station during transects. 60mL volumes were collected from a 47mm GF/F filter holder attached directly to the Niskin bottle's nozzle. Samples were immediately frozen at -80° C (within 30min of collection).

(3) TOC/DOC

Samples were collected into 40mL pre-combusted clear borosilicate vials to later measure either the total or dissolved organic carbon concentrations. The primary intent from the TOC/DOC measure is to quantify one of the largest reactive organic reservoirs in the ocean. Based on data from prior CCE and CalCOFI cruises we find this reservoir to adequately track the processes of physical mixing (or stratification) and primary productivity (or post-production accumulation). Samples for DOC were collected from noon time CTD casts for Cycles 1 - 4 and every other station during transects. 40mL volumes were collected from a 47mm GF/F filter holder attached directly to the Niskin bottle's nozzle. Samples for TOC were collected from the flow through during SeaSoar 1 and 2. Samples were immediately acidified to a pH of 2 using trace metal grade acid upon collection (within 30min).

(4) FDOM

Samples were collected into 40mL pre-combusted amber borosilicate vials to later measure the fluorescent properties of DOM. The primary intent from the FDOM measure is to identify properties more strongly influencing both the production of recent dissolved organics (typically termed protein-like) and distribution of refractory organics (typically termed humic-like). Samples for FDOM were collected from noon time CTD casts for Cycles 1 - 4 and every other station during transects. 40mL volumes were collected from a 47mm GF/F filter holder attached directly to the Niskin bottle's nozzle. Samples were immediately placed in the refrigerator upon collection (within 30min).

(5) Nitrification Rates and Ammonium Concentrations

Samples were incubated on the in situ driftarray to estimate rates of ammonium oxidation + nitrite reduction (i.e., nitrification). The primary intent from this experiment is to estimate the relative contribution of recycling back to nitrate, and in particular to estimate whether this is occurring within the euphotic zone, thereby contributing a recycled nutrient to a supposed 'new' nutrient (see schematic in figure below). It has been previously demonstrated for the California Current region that nitrification occurs near the 1% light level, and the stable isotopes of nitrate had been used to predict that up to 30% of nitrate uptake by phytoplankton is sourced from this nitrification pathway. Samples from 5-8 depths were collected during the 0200 cast and placed on the array for 24 hours. This measure necessitated knowing ammonium concentrations in order to add ^{15}N-labeled $NH_4(SO_4)_2$ at ~20% of ambient [NH_4^+] (see figures below).

(6) Fecal Pellet Collection

Samples containing mostly fecal pellets were collected to estimate the ^{15}N and ^{13}C composition of fecal pellets, which will be compared with the isotopic composition of sediment trap material. The primary intent of these analyses is to assess whether the stable isotope composition of sediment trap material (shared by the Stukel lab) reflects that of the fecal material (which is often assumed). Samples for these experiments were provided by the Ohman lab from 0830 oblique bongo net tows (202 μm mesh). After collection, samples were brought into a cold room and placed in a 1 gallon bucket, containing a 100μm mesh at the base. After 5-7 hours the experiment was terminated and the mixed assemblage preserved with Formalin (and a portion frozen). The remaining water was then siphoned down, the fecal material drawn up by fine-tip pipette and the pellets inspected under the microscope before isolating onto a pre-combusted GF/F filter. Most frequently the total material examined was >90% fecal pellets.

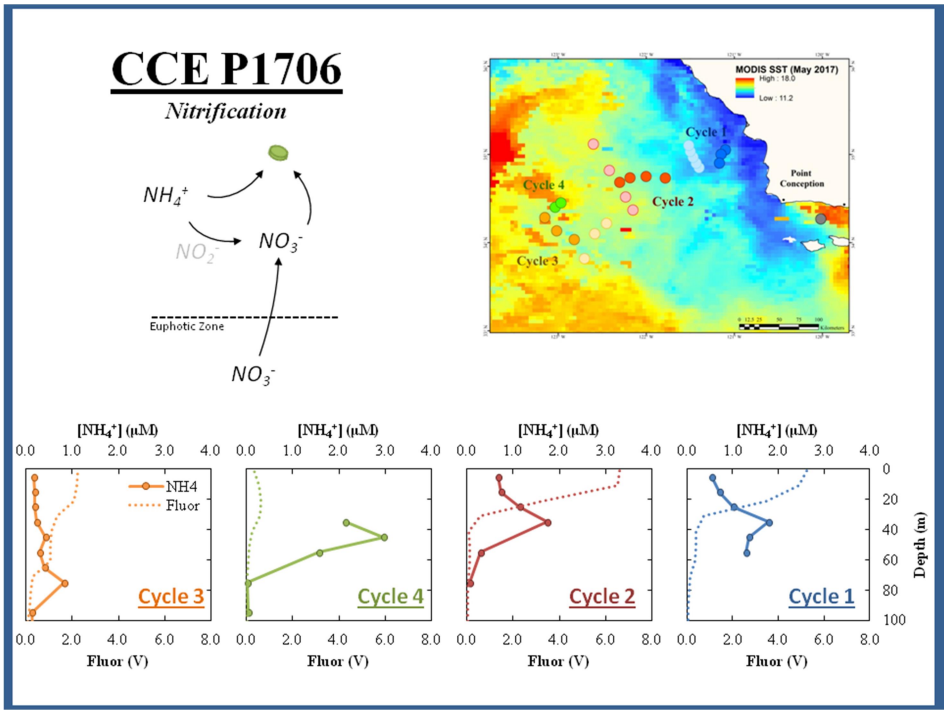

Fig. 16: Schematic of N sources; sampling locations; and vertical profiles of NH_4, and fluorescence.

(7) Locations of Opportunity

a. Santa Barbara Basin

Upon observing the decrease in oxygen at ~800m, we collected deep water spanning the oxygen minimum zone within the Santa Barbara Basin. In this location we collected samples for nutrients, $^{15}NO_3$, POM, community composition by 16s/18s, and DOM composition. The intent is to evaluate potential nutrient and community composition coupling across an oxygen gradient.

b. Deep Casts

We collected 20L from 3500m for each deep sea cast (2x). The water will be used as a reference standard during TOC analysis. We collected this volume twice in case there was contamination, either from the reservoir itself or during acid addition. In order to detect contamination three vials were taken directly from the Niskin bottle for each cast. Two samples were taken from one of these deep casts in order to potentially identify deep organic components by LC-MS and GCxGC MS. One gram PPL cartridges were used on 5L volumes.

c. BBL

We collected TOC and POM from 3 depths across 9 stations in order to address questions related to community composition and iron availability, where particle dynamics are of interest.

Spatial mapping of microbial metabolites in the California Current Ecosystem -

(Daniel Petras, Brandon Stephens , Pieter Dorrestein, and Lihini Aluwihare)

Phytoplankton communities play a crucial role in biogeochemical processes in the ocean and represent extensive taxonomic and genomic diversity. The investigation of these communities is of great importance to understand their role in planetary processes such as carbon fixation and their role in climate change. With next generation sequencing we are able to obtain highly resolved microbial inventories of microbial communities. However, to better understand the complex interactions within these microbial ecosystems, the integration of metabolic information is essential. In order to analyze marine community metabolomes in the California Current Ecosystem we took seawater samples at several depths at 26 stations during 4 cycles and 3 transects of the CCE-LTER cruise 2017. To enrich the metabolites and to separate them from salts, we extracted the samples via solid phase extraction and stored the cartridges at -80°C until further processing ashore. Ashore we will elute metabolites with methanol from the cartridges and analyze them via Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS). Mass spectra will be annotated through spectrum library comparison and molecular networking and quantified through peak integration. This annotation results in a molecular inventory of metabolites. Together with other metadata collected during the cruise, such as metagenomic community composition and high resolution chlorophyll concentrations, we will perform multivariable statistical analysis in order elucidate metabolites that correlate with community changes. This will be performed both time- and spatially resolved. Fig. 17 provides an overview of this work flow.

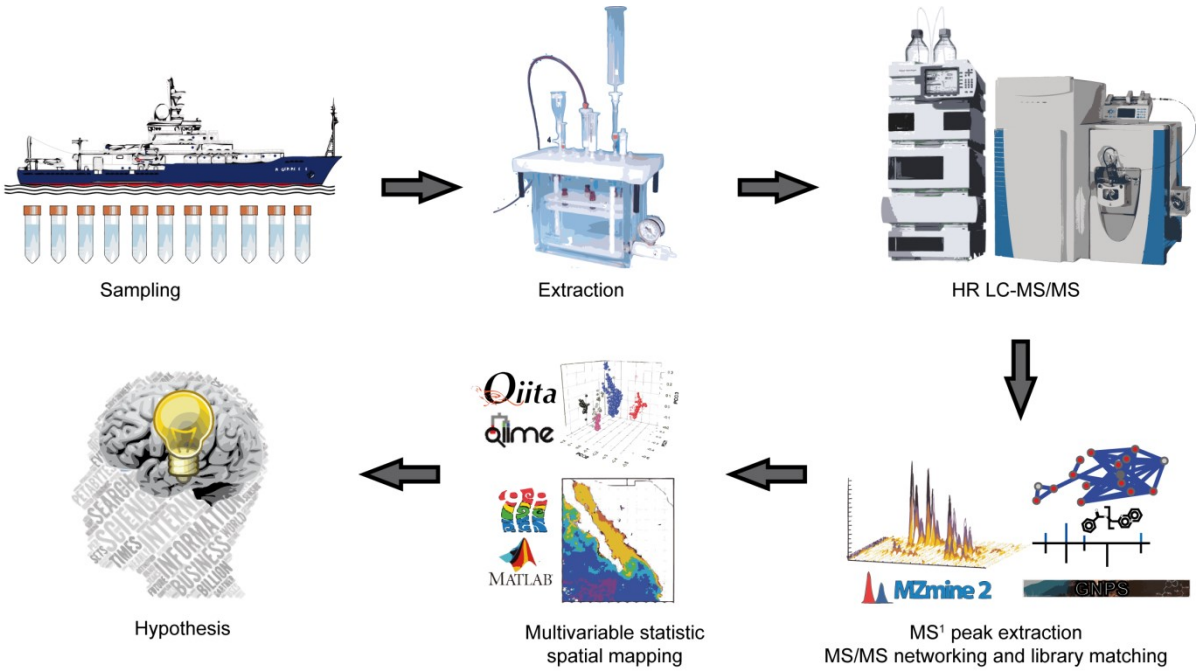

Figure 17: Overview of sampling, data acquisition and data analysis workflow

Bacterial Biomass and Production - Aluwihare and Azam Group (Sara Rivera)

Cycles 1,2,3,4; Transects 1,2,3; BBL
Seawater samples were taken from 6 depths from each mid-day CTD cast, typically at 1100, from strategic stations during each transect, and for 3 depths at all BBL stations to measure bacterial cell abundance and size. At each depth, in triplicate, cryovials were filled with 3 mL seawater, fixed with 120 µL of 25% glutaraldehyde, flash frozen in liquid nitrogen, and stored at -80°C. On shore, the cryovials will be thawed, filtered onto 0.2-µm pore polycarbonate filters, stained with DAPI, and examined microscopically. Bacterial cell abundance and size will be measured.

Seawater samples were also taken from 6 depths from each mid-day CTD cast, typically at 1100, from strategic stations during each transect, and for 3 depths at all BBL stations to estimate rates of bacterial protein synthesis. For each sample, 1.7 mL seawater were incubated with approximately 20 nM ^{3}H-leucine for one hour at 9°C in triplicate with one control killed with final concentration 5% TCA. After the incubation was complete, all samples were killed with an addition of 100% TCA for a final concentration of 5% TCA. The Cycle samples were then pre-processed by the centrifugation method. The dried pellets after the 80% EtOH wash were frozen and stored at -20°C. The transect samples were initially frozen and stored at -20°C until the last week of the cruise. These samples were then pre-processed by the centrifugation method. Again, the dried pellets after the 80% EtOH wash were frozen and stored at -20°C. On shore, the pellets will be defrosted, scintillation cocktail added, and the tube assayed in the liquid scintillation counter. The BBL samples were frozen and stored at -20°C; they will be fully processed using the centrifugation method on shore. Disintegrations per minute are converted to protein synthesis rates. This calculation is normalized by the corresponding cell abundances.

Microbial Community Composition - Allen and Aluwihare Group (Sara Rivera and Sarah Schwenck)

Cycles 1,2,3,4; Transects 1,2,3; BBL
Seawater samples were taken from 6 depths from each mid-day CTD cast, typically at 1100, from strategic stations during each transect, and for 3 depths at all BBL stations to determine the microbial community composition. For each sample, 2 L of seawater were filtered through a 0.22 μm Sterivex filter using a peristaltic pump. Excess water from the Sterivex filters was removed using a syringe; the filters were then sealed with putty, flash frozen with liquid nitrogen, and stored at -80°C. Either replicate or triplicate samples were taken at each Cycle, each day. For Transects, single samples were taken for strategic stations. BBL stations will have triplicates. On shore, the DNA from the filters will be extracted and sequenced. The sequence data will be analyzed to determine the microbial community composition.

Microbial responses to Fe addition; Viral dilution experiments – (Sarah Schwenck)

1. Iron Incubation Experiments

Iron incubation experiments were set up on Day 1 of each of the four Cycles using water from the 0300 Trace Metal cast. Incubations were done in 1L polycarbonate bottles with three treatments: 1) control, 2) +100μmol $FeCl_3$, and 3) + 100μmol DFO. Bottles were first rinsed three times with seawater in the trace metal clean van before being filled to the top. They were then spiked with the appropriate treatment, sealed with electrical tape, and placed onto the driftarray. An additional incubation was set up on Day 1 of Cycle 1 in the Barbeau on-deck incubators as a comparison between on-deck and on-array as well as a more direct comparison to the Barbeau group's on-deck incubations. After 24 hours, bottles were removed and filtered onto 0.22μm Sterivex filters, covered by black bags during filtration to prevent any light influences. Excess water was removed from the Sterivex filters, which were then sealed using cha-seal, flash frozen in liquid nitrogen, and stored at -80° C. On land, these filters will be processed using metagenomics and transcriptomics to determine the response of these communities to iron addition. These experiments will be interesting to compare across Cycles as iron limitation was observed in some and not others.

2. Viral Dilution Experiments

Viral dilution experiments were set up in conjunction with the Landry grazing dilution experiments to investigate the influences of viral infections versus grazing through an upwelling filament. Four treatments (20, 40, 70, and 100% whole sea water) were set-up in triplicate on the first day of each of the four cycles. Water was first collected on the evening thorium cast to begin the 0.1μm filtration followed by TFF filtration to get virus-free water, which was obtained through serial filtration (see Fig. 18). The water for the concomitant Landry grazing dilution was collected on the following full dilution cast so that the virus free water and 0.1μm water for both sets of experiments was ready at approximately the same time. Virus-free water was measured out to pre-marked lines on the dilution bottles and then brought back out to the CTD where first nitrate and phosphate were added and then

the bottles were gently filled to the top with whole sea water using a continually mixing carboy filled from the CTD. The bottles were sampled for FCM and then incubated in the Landry incubators for 24 hours. Following incubation, the bottles were sampled first for FCM and chlorophyll, and then for TEM and viral counts. The remaining water was filtered onto 0.22μm Sterivex filters, which were then sealed, flash frozen, and stored at -80° C. The filtrate was then concentrated using TFF down to <100mL, which was then stored in 10% glycerol at -20°C. These viral concentrates will be used to create viral libraries back on land and will give insight into how the viral community was changing with the microbial community (composition from the Sterivex filters) during each incubation.

Fig. 18: Serial filtration system used to obtain virus-free seawater.

Microbial Community Biomass, Growth and Grazing – Landry Group (Mike Landry, Shona Dovel, Cameron Quackenbush, with abundant help from Mike Stukel, Tom Kelly, Megan Roadman and others)

Twelve drift array experiments were conducted to follow parcels of advected filament water from inshore to offshore and to estimate rates of phytoplankton growth and microzooplankton grazing rates by the dilution method. For each of 6 depths per array (Cycles 1-4), seawater was collected from the early morning (0200 local) CTD cast. The incubations were done in mesh bags at the depth of sample collection below the drifter float for 24 h. Initial and final samples were taken for abundances and biomass of bacteria and picophytoplankton by flow cytometry (FCM), for total Chl-*a* by fluorometry, and for class-specific phytoplankton pigments by high-performance liquid chromatography (HPLC, Goericke group). Initial samples only were also taken for composition, biomass and size structure of auto- and heterotrophic protists by epifluorescence (EPI) and inverted microscopy. Samples from additional 6-depth profiles were taken for FCM, EPI, inverted microscopy and pigments (Goericke) at the end of each cycle to assess net changes of the ambient community over the 2-4 days of each cycle. Lastly, during

transect sampling, FCM samples were taken at 8 depths per station (Transects 1-3; 33 stations total) and microscopy samples were taken from stations from the mid-filament and from adjacent (non-filament) water on each side of the filament.

***Community composition and biomass*:** Samples (2 mL) for FCM analysis of phototrophic bacteria (*Prochlorococcus* and *Synechococcus*) and heterotrophic bacteria were preserved with 0.5% paraformaldehyde (final concentration) and flash frozen in liquid nitrogen. On shore, the samples will be stained with Hoechst 34442 prior to analysis. For epifluorescence microscopy (EPI), seawater samples (500 mL) were preserved and cleared with sequential additions of 260 µL of alkaline Lugols solution, 10 mL of buffered Formalin and 500 µL of sodium thiosulfate, followed by staining with 1 mL of proflavin (0.33% w/v) and 1 mL of DAPI (0.01 mg mL^{-1}). Aliquots of 20-50 mL were filtered onto 25-mm, 0.8-µm pore black polycarbonate filters to determine concentrations of nanoplankton, and 100-450-mL of the remaining samples were filtered onto black 8.0-µm polycarbonate filters to determine concentrations of larger cells (microplankton). Filters were mounted onto glass slides and frozen at -85°C for later digital imaging in Z-stack mode at 630X (nanoplankton) and 200X (microplankton) using an automated Zeiss Axiovert 200M inverted compound microscope. Samples for analyses of delicate heterotrophic protists, notably ciliates, were collected in 125-mL volumes, preserved with 5% acid Lugols fixative. In the laboratory, these samples will be further fixed with formaldehyde, filtered onto 8-µm pore polycarbonate filters, mounted on slides with Cargille Series A immersion oil, and imaged at 200X by light microscopy on a Zeiss Axiovert 200 M inverted compound microscope with a Zeiss AxioCam MRc black and white 8-bit CCD camera.

***Growth and grazing rates*:** We used 2- and 3-treatment dilution experiments incubated at each depth on the drift array and one full dilution experiment per cycle (12-bottle experiments, 5 m water, incubated on deck at 30% incident radiation) to determine rates of growth and protozoan grazing for the total phytoplankton community (Chl-*a*) and for specific FCM and pigment populations. For the drift array, we generally prepared one diluted treatment and one control bottle (2.7-L polycarbonate) per depth, respectively, with 33% whole seawater (diluted with 0.1-µm Suporcap filtered seawater) and 100% seawater collected from Niskin bottles from the CTD-rosette. For the upper 4 depths at stations where Chl-*a* concentrations were unusually high (most of Cycles 1 and 2), we prepared an additional treatment bottle with more highly diluted water (7-8% whole seawater) to evaluate nonlinear effects. Initial FCM samples were taken from each bottle prior to deployment, and initial samples for pigments and microscopy were taken from the same mixing carboy as the incubation water. After incubation for 24 hours (deployment/recovery ~0430 local time) on the drift array, the incubation bottles were subsampled for FCM and pigments.

Preliminary data based on fluorometric chlorophyll *a* indicate relatively high rates of phytoplankton growth in near-surface waters, exceeding one cell doubling day^{-1} (> 0.7 d^{-1}) on all cycles (Fig. 19). Estimates of the percentage of phytoplankton production consumed by microzooplankton generally vary between 30 and 80%, with no evidence of a systematic decline in higher Chl-*a* waters presumably dominated by larger phytoplankton (Fig. 19b). The resulting net growth rates of phytoplankton after microzooplankton grazing vary from 0 to 0.8 d^{-1} in individual bottle results, and from 0.2 to 0.5 d^{-1} in cycle averages (Fig. 19c).

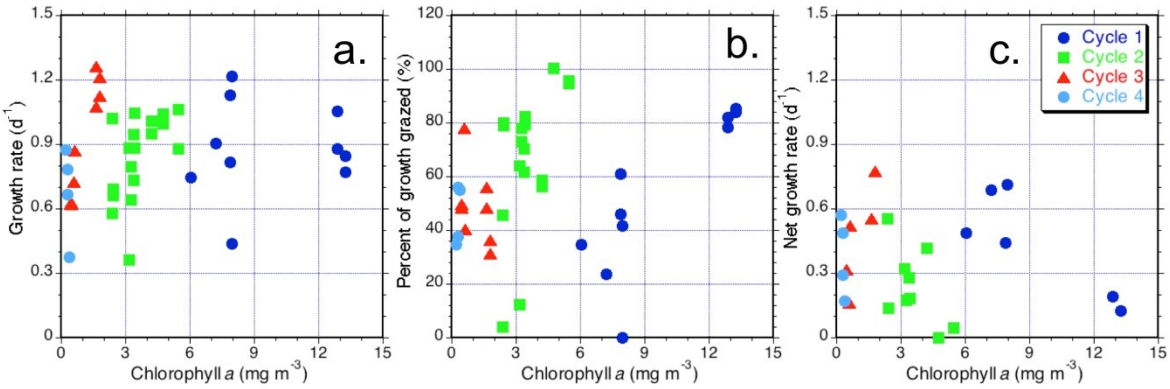

Fig. 19: Intrinsic growth rate, percentage consumption by microzooplankton and realized net growth rate of phytoplankton plotted against initial Chl*a* for all near-surface samples incubated on the drift array during Cycles 1-4. Data are from incubations at the upper two depths on each deployment (all upper 5 to12m), representing light-sufficient conditions.

More detailed, but still preliminary, results from individual cycle experiments suggest potentially interesting patterns of temporal and depth variability. In Cycle 2, for example, where the data are richest, the Chl-*a* profile deepens between Days 1 and 2 and total concentration declines from Days 3 to 5 (Fig. 20). Phytoplankton intrinsic growth rate is highest in the upper 12 m on all days of Cycle 2, but declines in shallower depths between Days 1-2 and Days 3-4. Net growth rates further suggest a subsurface maximum (0.4-0.5 d^{-1}) throughout the 4-day experiment, with a sharp drop off to negligible or negative net rates below 25 m. Taken together, these data suggest that *in situ* growth is insufficient to account for the significant Chl-*a* below 25 m, which must arrive there, where it is ultimately consumed, mainly as a consequence of mixing or slow sinking.

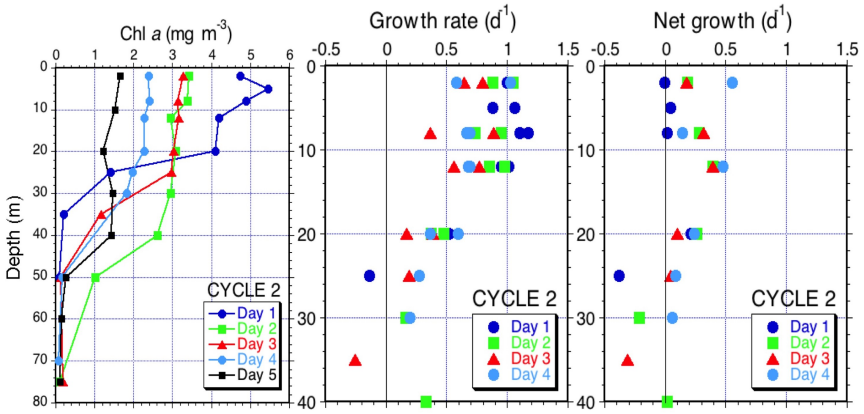

Fig. 20: Depth distributions of phytoplankton biomass, intrinsic growth rate and net growth rate for Cycle 2 based on shipboard Chl*a*.

Mesozooplankton – Ohman Group (Mark Ohman, Laura Lilly, Ben Whitmore, Stephanie Matthews, Valerie Bednarski, Cynthia Martinson, Joseph Gish, Katalina Kimball, and Paul Lerner)

***Moving Vessel Profiler (MVP)*:** A free-fall Moving Vessel Profiler (MVP) was deployed to characterize horizontal gradients in hydrographic and plankton properties and guide site selection for experimental Cycles (Fig. 30). The MVP sensors included a Laser Optical Particle Counter (LOPC, SN 11432), Wetlabs FLRT Chl-*a* fluorometer (SN 247), and AML Micro fast response CTD (SN 7209). A total of 281 MVP casts was completed. The MVP tow cable was replaced at sea on 10 June following extensive abrasion of the outer cable sheath, apparently caused by an irregular, bumpy, oxidized aluminum surface on the MVP winch drum. Six MVP transects and 2 bowtie surveys were completed, sampling either just before or after each Cycle and before or after CTD-Bongo-TM Transects 1 and 2. In addition, near the end of the cruise on 1 July, a comparison of LOPC/MVP particle distributions with UVP5 particle distributions was carried out over Santa Cruz Basin. First, 12 automated MVP casts to 250 m were made while the ship steamed from W->E at ~ 10 kts; then 6 manual stationary MVP casts to 200 m were completed immediately following each of the 6 CTD-UVP5 stations returning E->W on the same sampling line; and finally an additional 12 automated MVP casts to 250 m were completed while repeating the track from W->E at the same speed as before.

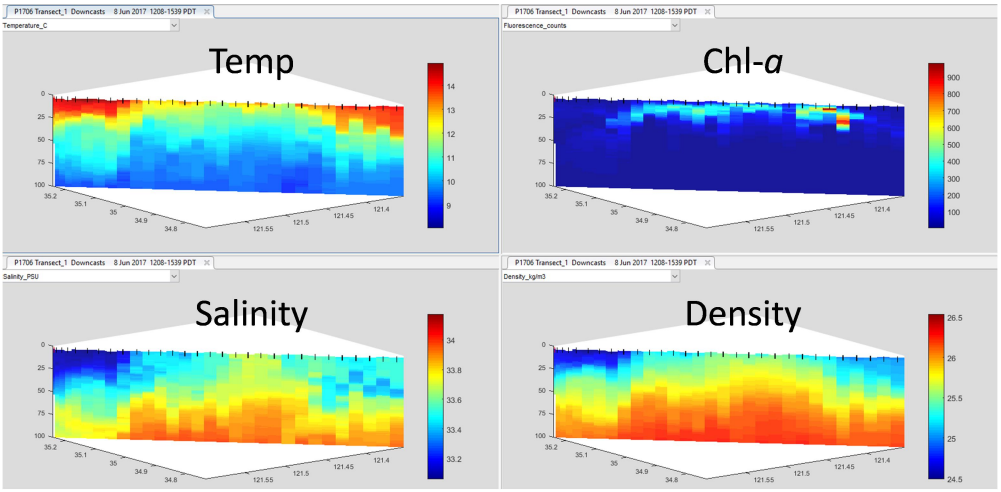

Fig. 30: MVP transect 1, illustrating the central filament that is characterized by cool, salty, denser, Chl-*a* enriched waters near the sea surface.

***Vertically stratified MOCNESS sampling*:** Vertically stratified plankton sampling was carried out with a 1 m^2 MOCNESS with 202-µm mesh nets. A total of 16 MOCNESS tows was completed, including duplicate day and night tows at each of Cycles 1-4. The SIO MOCNESS frame accommodated 10 nets. The MOCNESS control software was the Labview interface designed by Carl Mattson. The MOCNESS was equipped with sensors for temperature, salinity, O_2, beam transmission, Chl-*a* fluorescence, and dissolved oxygen. Zooplankton were sampled from 400 m to the surface, in 50 m intervals between 400 and 50 m, then 25 m intervals from 50-0 m. Each sample from the first day and first night MOCNESS tows of each Cycle was split into two 50% aliquots with a Folsom splitter. One aliquot was preserved in 95% non-denatured ethanol to which 5 mM NH_4OH had been added to stabilize pH. The other aliquot

was preserved in 5% Formalin. For the remaining two tows of each Cycle, 100% of all samples was preserved in 5% Formalin. For all samples preserved in ethanol, the ethanol solution was drained off within 24 hours and replaced with a fresh solution also containing 5 mM NH_4OH.

***Mesozooplankton biomass and grazing rates*:** (Laura Lilly, Ben Whitmore, Stephanie Matthews, Cynthia Martinson, Valerie Bednarski, Kat Kimball, Paul Lehrer, Joseph Gish)

- *Oblique Bongos:* Cycle 1 (N=6 tows), Cycle 2 (N=8), Cycle 3 (N=6) , Cycle 4 (N=4) – Tows at 0930 and 2130 every day of each cycle.
- *Vertical Bongos:* Transects 1,2,3 (N=11 tows along each transect)

Zooplankton samples were collected using a CalCOFI bongo frame with 71-cm diameter openings, equipped with 202 µm mesh dark-dyed nets. For oblique Bongos (conducted during Cycles), nets were deployed from the surface to 300 m wire out (mwo) at a 45° wire angle at 50 m min^{-1} wire speed, with the ship travelling at ~1.5 kts. Nets were towed with 300 mwo for 30 seconds, then hauled back to the surface at a 45° wire angle and 20 m min^{-1} wire speed. The port side net sample (with General Oceanics flowmeter across the net mouth) was immediately placed in a bucket and anesthetized with carbonated water. The net was rinsed fully, and the remaining rinsed sample also placed in the bucket. That bucket was immediately taken to the lab and split into three parts using a plankton splitter:

- Molecular probes – 1/4 was filtered into a plastic cup with 202 µm mesh bottom and immediately frozen in liquid nitrogen for future probes.
- Gut fluorescence – 3/8 was size-fractionated through a five-filter sieve (5 mm, 2 mm, 1 mm, 0.5 mm, and 0.2 mm), and each size-fraction was transferred to a 202 µm filter, placed in a petri dish, and frozen in liquid nitrogen for analysis ashore.
- Biomass – 3/8 was size-fractionated through the same five-filter sieve and each size-fraction transferred to a pre-weighed 202 µm Nitex filter, placed in a petri dish, and frozen in liquid nitrogen. Filters will be weighed on land.

The starboard side sample was rinsed into a bucket (but not anesthetized) and preserved in a pint or quart jar with 5% Formalin buffered with sodium borate, for analysis by Zooscan and microscopy.

For sampling across the filament on each of the three cross-filament Transects, the bongo frame was configured for vertical bongos by securing the central pivot with bolts and affixing a vertical cable pigtail and horizontal spreader bar. For vertical bongo deployments, nets were deployed from the surface to 100 mwo at a desired 0° wire angle and 30 m min^{-1} wire speed. Nets were held at 100 mwo for 20 seconds, then hauled back to the surface at 0° wire angle and m min^{-1} wire speed. Samples were processed as for oblique bongo except that gut fluorescence and biomass samples were preserved whole (i.e., without size-fractionation).

Fig. 31: Plankton samples – Transect 1. Jars are arranged from Station 1 (south, right) to Station 11 (north, left). Station 5 (quart jars, middle) occupied three sample jars. The dark, dense samples in Jars 7-10 indicate the core of the filament.

Copepod egg production experiments **-** (Laura Lilly, with sorting assistance from Stephanie Matthews and Mark Ohman)

This study quantified egg production rates (EPR) and egg hatching success of the copepod *Calanus pacificus* at each of the 4 Cycles, reflecting different temporal stages of development of a newly-upwelled filament off Morro Bay, CA as it moved offshore and evolved over time (Fig 32). Egg-laying rate and hatching success are metrics of reproductive capacity, and are useful both alone and as a surrogate measure of copepod secondary production. Tows occurred at 0830 each morning.

Methods: Live copepods were collected using a Bongo net with two 333 µm mesh nets and sealed cod end jars (to protect animals from water flow damage) taken at 0830 each morning. Nets were deployed from the surface to 300 m wire out (mwo) at a 45° wire angle and 50 meters/min wire speed. Nets were towed at 300 mwo for 3 minutes, then hauled back to the surface at a 45° wire angle and 20 m/min wire speed. Animals were placed in 1-gallon jars of 13.5°C seawater collected at >200 m depth. Samples were immediately sorted and adult female *Calanus pacificus* removed and placed in individual 20 mL petri dishes filled with high-chlorophyll seawater (collected from the chlorophyll maximum layer, which ranged from 0-30 m depth). Copepods were incubated in darkness at 13.5°C for 24 hours to simulate in situ temperatures, and were checked twice (at 12 and 24 hour) for egg production. If females produced eggs, they were removed and placed in fresh high-chlorophyll seawater; eggs were counted and placed in the incubator for an additional 36 hours to assess hatching success. After the 24 hour incubation, females were preserved in seawater with 5% Formalin for prosome length measurements on land.

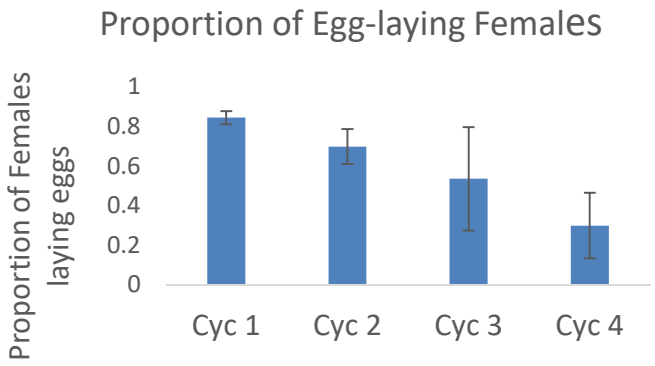

Fig. 32: Proportion of adult female *C. pacificus* that laid eggs at each Cycle within 24 h, averaged across all tows within a Cycle. Error bars indicate standard error. (Preliminary data.)

EK60 multi-frequency sonar: The EK60 was operated at four different frequencies (38, 70, 120, and 200 kHz) to resolve different-sized zooplankton and mesopelagic fishes in the water column. This sonar was mounted in the acoustic well of the R/V *Roger Revelle* at MARFAC by professional divers and removed following the cruise. Three of the transceivers used (38, 70, and 120 kHz) were EK60 transceivers; the fourth (200 kHz) was an EK80 transceiver loaned by Kongsberg to replace an EK60 transceiver damaged in shipping. Dual shipboard ADCPs (75 and 150 kHz) were triggered by the EK60. The TrigOut signals from the EK60 (via DB25 auxiliary port connector) was used for this synchronization, with the EK60 set as master in Ping Control. Prior to P1706, the EK60 was calibrated in the Southwest Fisheries Science Center pool by Ben Whitmore and Eadoh Reshef, under the guidance of David Demer. The EK60 was operated for the duration of P1706.

Underwater Vision Profiler (UVP5) – (Tristan Biard, Laura Lilly, Taylor Wirth)

The Underwater Vision Profiler 5 HD (UVP5-HD, serial number sn201), an *in situ* imaging system borrowed from Emmanuel Boss and Lee Karp-Boss at the University of Maine, was used for each CTD cast. Prior to the cruise, the UVP was mounted inside the lower part of the CTD rosette frame (to minimize disturbance to the flow prior to imaging). The UVP was operated onboard by Laura Lilly and Taylor Wirth. All casts were performed using the "mixtfd" settings in order to achieve the highest acquisition rate. Image volume is 1.14 L. Pixel size is 88 x 88 µm. Vignette processing uses: Gamma = 1 and Scale = 2. Imaging frequency ranged between 20-25 Hz.

A total of 90 casts was performed to a maximum depth of 3,500 m. These included casts at Cycles, Transects, the Santa Barbara Basin, two casts to 3,500 m depth, and a final UVP5 vs. LOPC/MVP comparison over the Santa Cruz Basin. For each cast, abundance of particles was displayed and recorded in the Seasave application. A typical cast started with the deployment of the CTD down to 25 m, then a wait at depth for 1-2 minutes until the UVP booted and registered a particle signal, then the CTD was brought back to the surface and deployed for its cast, generally to 100, 300, or 500 m. All casts were processed on board ship using ZooProcess software.

The Ocean Data View "baseuvp5_sn201hd_ccelter_2017_cal_lpm_odv.txt" compatible files include LPM (Large Particulate Matter) abundances and biovolume spectra binned in 5 m intervals. Fig 28 highlights some of the typical LPM abundance vertical profiles within the four different cycles.

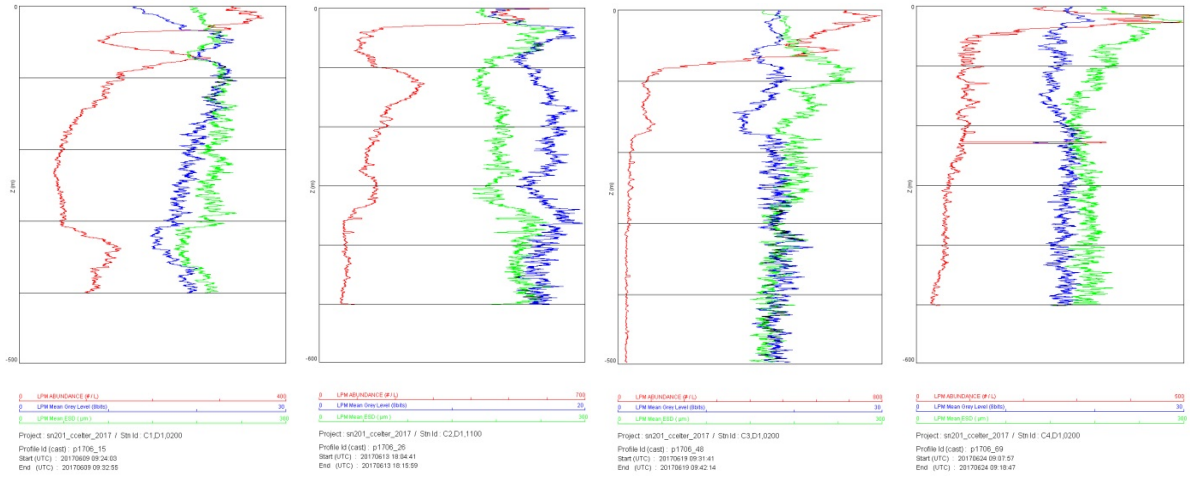

Fig. 28: Vertical profiles of Large Particulate Matter (red line, No. L^{-1}), mean grey level (blue), and mean ESD (µm), from LOPC profiles at Cycles 1-4 (from left to right). Depth scale is from 0-500 m; x-axis scales vary.

A total of 2,020,582 vignettes was recorded during the cruise. A subset of 11 casts accounting for 74,309 vignettes were sorted using the EcoTaxa* online application and further classified into 41 categories corresponding to both morphological and taxonomical categories such as copepods, different groups of radiolarians or gelatinous zooplankton. Example of the images in selected categories are shown in Fig 29. This initial pre-sorting permitted the creation of a Learning Set that will be used to sort the

remaining vignettes. Additional sorting, including processing the remaining casts, will allow more precise discrimination of organisms and their depth distribution in the CCE.

While the standard version of the UVP5 has been used in the past process cruises, this is the first time that an HD version of the UVP5 was deployed in CCE-LTER. With its resolution increase from 147 µm/pixel to 88 µm/pixel, the HD version will allow detection of smaller particles, thus expanding the size spectra of *in situ* plankton. This instrument also provides more detailed vignettes for improved taxonomic identification of specimens.

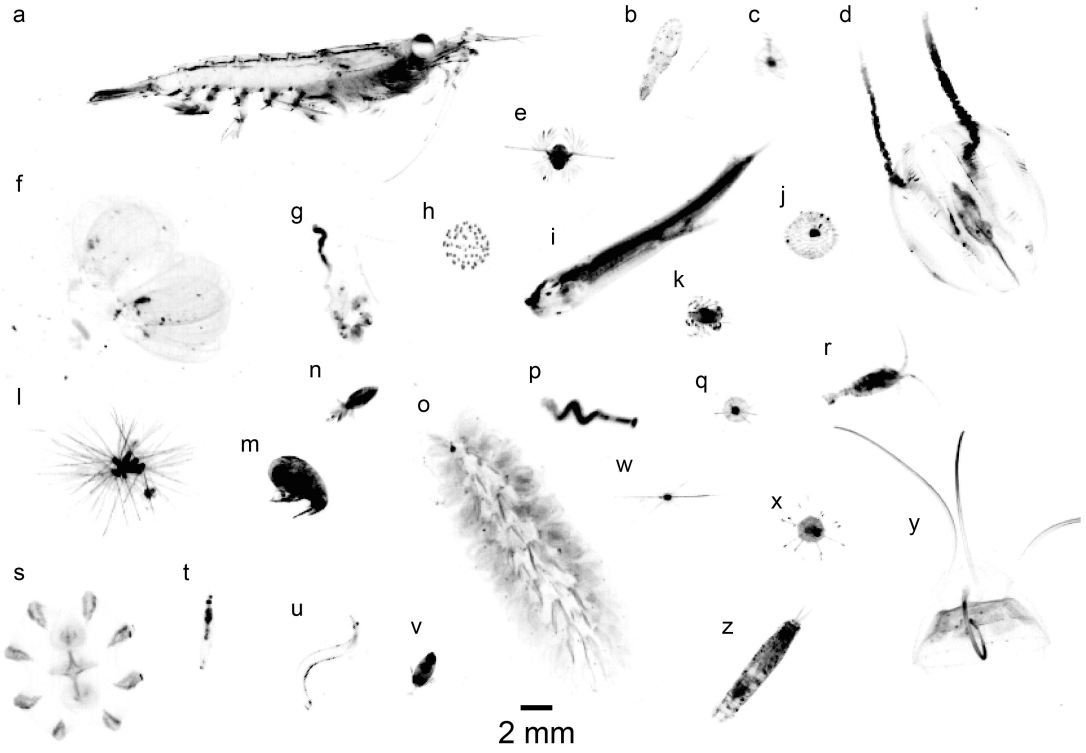

Fig. 29: Diversity of zooplankton recorded in situ by the UVP5-HD on P1706. (a) Euphausiid – (b) Cephalopod – (c) *Coelographis* - (d) Ctenophore - (e) Copepoda Calanoida - (f) Appendicularian_house - (g) Doliolid - (h) colonial Collodarian - (i) Gnathostomatid - (j) Aulosphaeridae - (k) Crustacea - (l) Foraminiferan - (m) Hyperiid amphipod - (n) Copepoda Poecilostomatoida - (o) Pyrosome - (p) Annelid - (q) Phaeodarian - (r) Copepoda Calanoida - (s) Ctenophora - (t) *Poeobius* - (u) Chaetognath - (v) Ostracod - (w) Acantharian - (x) Phaeodarian_like - (y) Narcomedusa - (z) Amphipod

Export and New Production - Stukel group (Mike Stukel, Tom Kelly)

We had two goals for this cruise: 1) to quantify the balance between new and export production along and across the filament as water was advected offshore and 2) to determine the composition of sinking material and the processes driving the biological pump.

To achieve our first objective, we measured $^{15}NO_3^-$ uptake, sediment trap C and N flux, and ^{238}U-^{234}Th deficiency. $^{15}NO_3^-$ uptake was measured during 24-hour *in situ* incubations conducted on our experimental array at 6 depths on each day of our Lagrangian cycles. This yielded a total of 78 samples that will be analyzed on land. We simultaneously deployed sediment traps during each Lagrangian cycle (with an additional sediment trap deployed in the filament between Cycles 2 and 4). Vertex-style sediment trap cross-pieces (8:1 aspect ratio, with a baffle on top of similar 8:1 aspect ratio) were typically deployed at the base of the euphotic zone (ranging from 40 – 60 m) and at depths of 100 and 150 m. To quantify the spatial variability and extent of carbon flux, we used ^{238}U-^{234}Th deficiency measurements. ^{238}U-^{234}Th deficiency was measured at 12 depths on two profiles during each of our Lagrangian cycles for comparison to the sediment trap results (96 samples). It was also measured at 7 depths at each station during transects across the filament region (231 samples). Preliminary results suggest that export was elevated throughout the study region and show a possibly increased deficiency in cold, salty waters of coastal origin (see Fig. 21). We also measured surface ^{238}U-^{234}Th deficiency in samples taken during SeaSoar spatial surveys through the study region at the beginning and end of the cruise (127 samples).

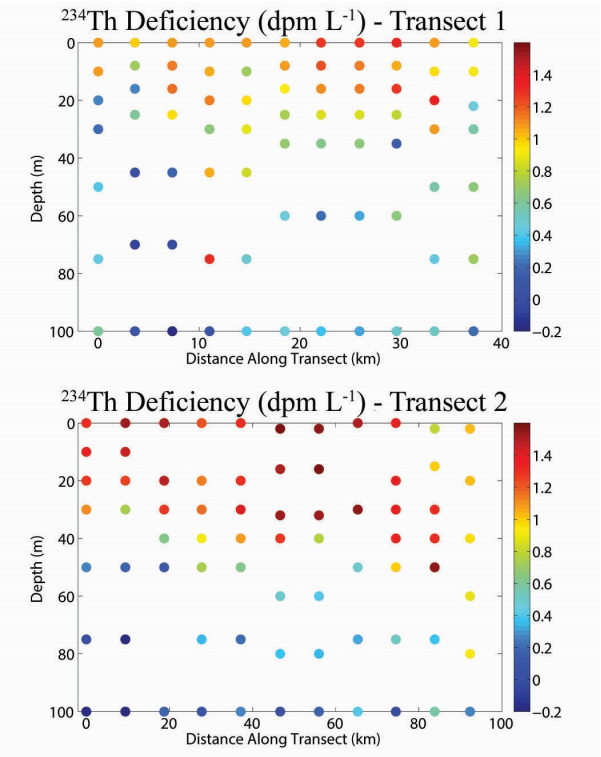

Fig. 21: Vertical profiles of ^{234}Th deficiency, across Transects 1 and 2.

To achieve our second objective, we subsampled the sediment trap samples for a multitude of measurements including: C and N, particulate Si, $\delta^{13}C$ and $\delta^{15}N$, C:^{234}Th ratios, Chl *a* and phaeopigments, trace metals, organic matter molecules, microscopy, genomics, and transcriptomics (transcriptomics sediment trap tubes deployed with RNA Later in tubes to preserve RNA contained in organisms on sinking particles). We also deployed tubes containing acrylamide gel at the shallowest and deepest depths

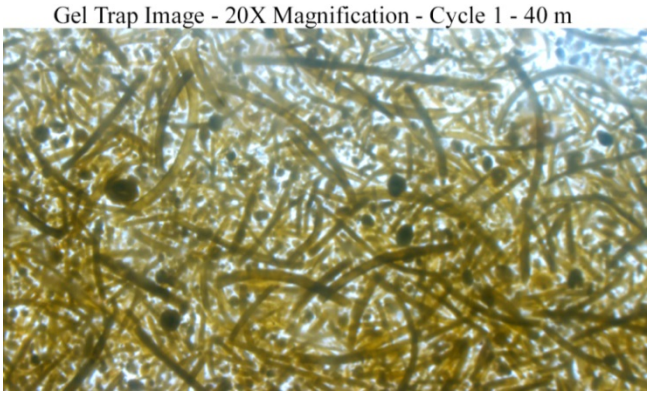

Fig. 22: Image of acrylamide gel trap contents dominated by fecal pellets (Cycle 1, 40 m).

to preserve aggregates and other sinking particles in their in situ shapes for microscopic analysis). Initial results (based on pigments and preliminary microscopic analyses) suggest that fecal pellets (produced primarily by euphausiids and/or copepods) were the primary source of sinking particles in the filament (see Fig. 22. Total pigment flux (and hence likely also carbon and nitrogen flux) were elevated in the filament relative to previous cruises (see Fig. 23).

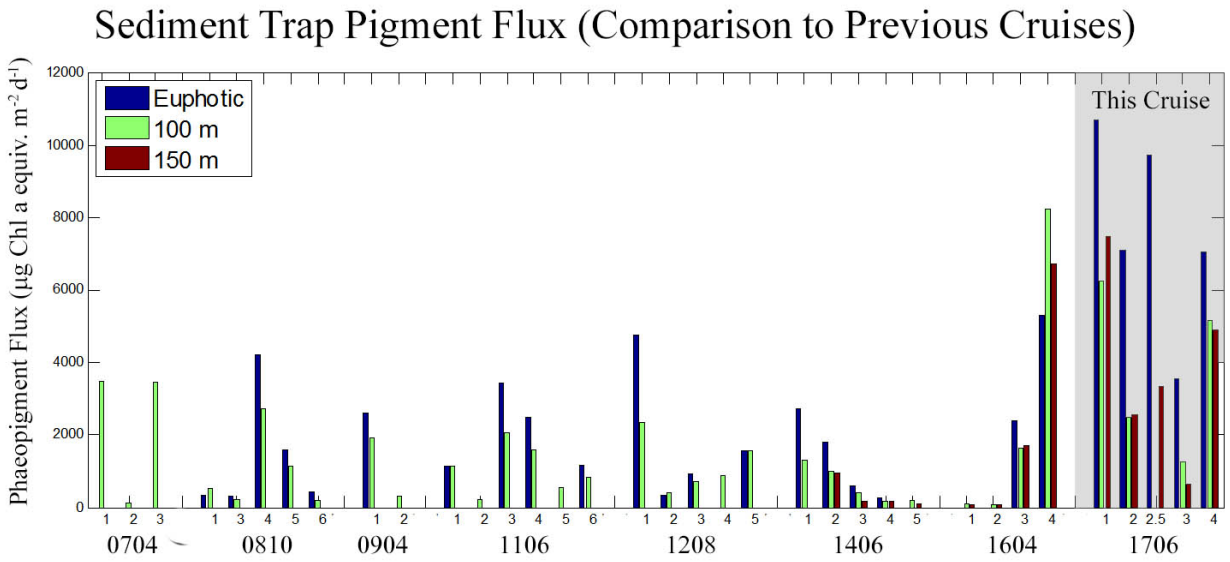

Fig. 23: Pigment flux from P1706 in comparison with measurements from previous CCE-LTER cruises in this region.

Carbon Flux Explorers (CFE) and Bio-optical measurements – **Bishop group** (Jim Bishop, Todd Wood, Hannah Bourne, and Sylvia Targ)

CFEs are Lagrangian instruments designed to measure the flux of settling particulate organic and inorganic carbon using an optical sedimentation recorder (OSR). They extend ship observations in time and space. Their purpose is to measure high frequency variability of carbon flux within the twilight zone (100-1000 m). An added goal for this cruise was to collect samples for calibration of the optical metrics of particle load achieved by the CFE. Support: NSF OCE- 1538686

***Sample/measurement coverage*:** Four CFEs (CFE001, CFE002-CAL, CFE003, and CFE004-CAL) were deployed during Cycles 1, 2, 3 and 4. CFE001 and CFE003 observed particle flux at depths of 150, 250 and 500 m over multiple days. The CFE-CALs, outfitted to collect four samples per 24 hour deployment, monitored particle flux at depths of 100 and 150 m and were deployed twice per cycle. Approximately 60 calibration samples were collected. Most deployments were made within 500 m of the surface tethered sediment traps. There were 24 deployments in total with one less recovery. CFE (CFE003) was destroyed, and sunk by a short fin Mako shark just prior to recovery on 20 June.

***Methods*:** Particles settle into the funnel on the top of the instrument and then land on a glass stage where the particles are imaged in three different lighting modes: transmitted, side-illuminated, and cross-polarized (Figs. 24-26). For the CFE-CALs, these particles are then directed into sampling bottles; for the CFEs, they are just flushed out. The images are then analyzed for light attenuation by particles. We also analyze the number and size distribution of particles. Using the CFE-CAL samples, we aim to calibrate the optical metrics of particle loading against particulate organic and inorganic carbon amounts sampled. Bishop et al. (2016; Robotic observations of high wintertime carbon export in California coastal waters, Biogeosciences,13, 3109-3129) describe the CFE methodology in detail.

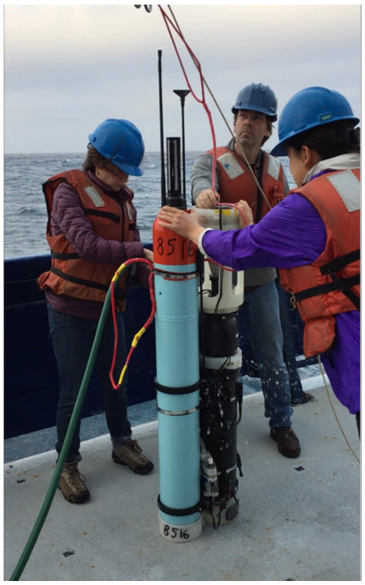

Fig. 24: CFE002-CAL after recovery

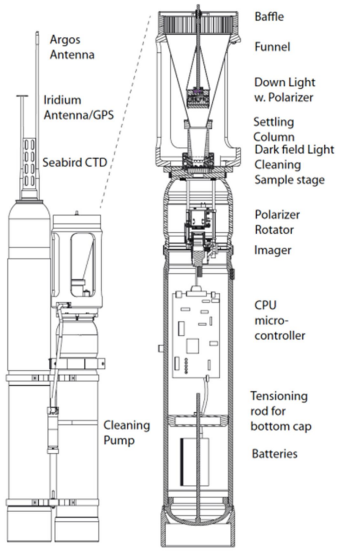

Fig. 25: Float and OSR setup for CFE001.

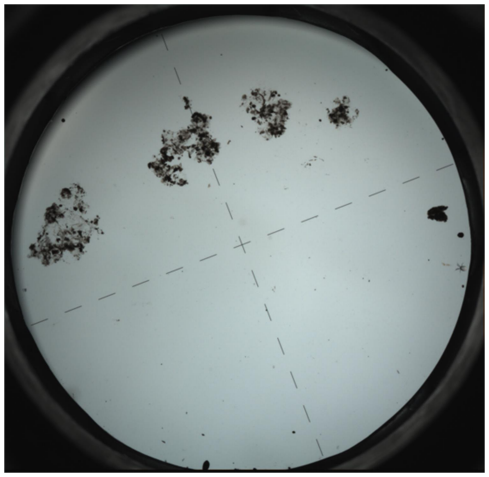

Fig. 26: Representative image of aggregates from 250 m. Dash scale is 1 mm. Image resolution is 13 µm.

***Berkeley CTD Optics*:** Transmissometer, birefringence, and scattering sensors on the CTD/Rosette system were used to characterize the concentration dynamics of particles in the water column, particularly particulate organic and inorganic carbon (POC and PIC). The transmissometer provides particle beam attenuation coefficient (c_p) data accurate to better than 0.003 m^{-1} and precise to better than 0.001 m^{-1}. In open ocean deployments, c_p is highly correlated with POC concentration in the water column. The birefringence sensor uses transmitted cross-polarized light to quantify birefringent particles in the water column. This instrument is believed to quantify the concentrations PIC. Support: NSF OCE-0964888, OCE-1355966, OCE-1460324.

Sample/measurement coverage: Data were acquired during 75 CTD rosette casts in Cycles 1 through 4 and Transects 1 through 3. Most casts were to either 500 or 800 m. Two profiles were made to 3500m. A further 9 CTD/Rosette casts were taken in 50-70 m deep waters as part of a benthic boundary layer study. 5-6 additional CTD casts were taken in the Santa Cruz Basin to intercompare 4 transmissometers that have been used during the CCE-LTER expeditions with our instruments. 200 1L samples were filtered for PIC sensor calibration.

Biooptical Methods: Bishop and Wood, 2008 and Boss et al., 2015 provide methodological detail. Transmissiometer CST1450, birefringence sensor PIC011, and Seapoint turbidity sensor (100x gain; SN 10595) were used. Transmissometer optics were capped (125 mL poly bottle tops while the CTD was on deck. Prior to deployment, transmissometer optics were cleaned using Kimwipes soaked in a dilute solution of dawn dishwashing liquid (1 drop to 50 mL of deionized water) then flushed with MilliQ DI water. The PIC sensor window housings were flushed with DI water. The scattering sensor was cleaned with the soap solution. At the end of the cast, DI water was used to flush the sensors and caps replaced on the Transmissometer. The 24 Hz sensor data were processed offline following Bishop and Wood (2008). Representative data from Transect 2 are shown in Fig. 27.

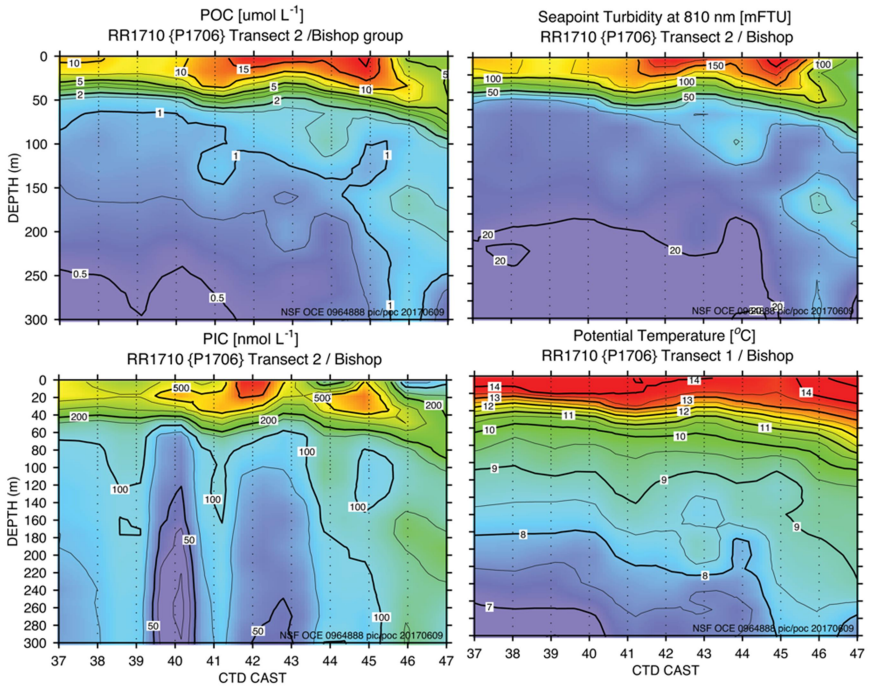

Fig. 27: Optical data from Transect 2. Top Left: POC, calculated as c_p*27 (Bishop and Wood, 2008), from transmissometer data. Top Right: Turbidity (mFTU) from Seapoint scattering sensor. Bottom Left: Preliminary data from PIC sensor calculated using a scaling factor of 10 nm/mV. Bottom Right: Temperature.

INFORMATION MANAGEMENT (James Conners)

CCE IM set up an event logger to provide an authoritative listing of each research activity, with assigned event numbers, date, time, and latitude/longitude. Pre-cruise preparations included setting up event logger laptop stations on the bridge and in the lab, coordination of program decoding with the ship's GPS string, and logger training. A glossary of activity names incorporated as a configuration file serves as a controlled vocabulary list. Event log cleaning will be done post-cruise, including checking for consistency and missing events, in order to facilitate post-cruise coordination of datasets. Cruise data will be served on CCE's DataZoo.

EDUCATION, OUTREACH, AND CAPACITY BUILDING (Laura Lilly at sea)

Our Education, Outreach, and Capacity Building included providing seagoing research opportunities and training for 11 graduate students, 8 undergraduate students, and other volunteers. Engagement with the general public was accomplished via an online blog created by CCE graduate student Laura Lilly, to which other CCE grad students also contributed (http://cce.lternet.edu/blogs/201706/). The blog presents, in accessible language, accounts of our science and life at sea. Also, as on previous cruises, the CCE group conducted at-sea science tours of our research activities, intended for two audiences. One is the science party itself, so that graduate students, volunteers, and others working intensively on one particular project at sea become better acquainted with other groups' science at sea and with the overall cruise objectives. The other audience is the ship's crew, as many express great curiosity about what we do, how we do it, and why, and this tour served to open lines of communication with all interested members of the crew.

CCE-P1706 DAILY ACTIVITY SCHEDULE

(1 June – 2 July 2017) ***R/V Roger Revelle***

Listed are intended times; consult Event Log for actual times.

1 June

0800 Depart MARFAC
1400 CTD test cast
1600 Trace Metal rosette test
1700 Bongo test
1800 MVP test
1900 MOCNESS test
2030 Transit to Santa Barbara Basin

2 June – Santa Barbara Basin (34º 16.5'N, 120º 1.5' W)

0900 CTD cast
1000 Bongo tow
1100 Ring net tow
1200 TM rosette cast
1530 Transit to waypoint for beginning of Seasoar:
2000 Deploy Seasoar

3 June – SEASOAR - Waypoint 1: 34º 13.69'N, 120º 49.53' W
to Waypoint 2: 36º 34.70'N, 122º 16.10' W
connecting leg to Waypoint 3: 36º 27.26'N, 122º 34.42' W

4 June – SEASOAR - Waypoint 3: 36º 27.26'N, 122º 34.42' W
to Waypoint 4: 34º 6.25'N, 121º 7.32' W
connecting leg to Waypoint 5: 33º 58.84'N, 121º 25.06' W

5 June – SEASOAR - Waypoint 5: 33º 58.84'N, 121º 25.06' W
to Waypoint 6: 36º 19.82'N, 122º 52.72' W
connecting leg to Waypoint 7: 36º 12.4' N, 123º 10.57' W

6 June – SEASOAR - Waypoint 7: 36º 12.4' N, 123º 10.57' W
to Waypoint 8: 33º 51.54'N, 121º 43.08' W

1400 Recover Seasoar
1430 Ring net tow
1530 CTD cast – calibration
1900 Transit to Santa Barbara Harbor

7 June

0600 Personnel transfer, Santa Barbara harbor
0700 Transit to Cross-filament Transect
1600 Cross-filament underway survey start approx. 35º 15'N, 121º 00'W
end approx. 35º 23'N, 121º 16'W
1800 Return to survey start location

2000 Start: CTD-Bongo-TM **Transect 1** start approx. 35º 15'N, 121º 00'W
end approx. 35º 23'N, 121º 16'W

(11 stations, 2 nm intervals)

2000: T1- Sta. 1 - CTD, **TM rosette**, Vertical bongo
2115: T1- Sta. 2 - CTD, Vertical bongo, TM pole sample
2230: T1- Sta. 3 - CTD, Vertical bongo, TM pole sample
8 June 2345: T1- Sta. 4 - CTD, Vertical bongo, TM pole sample
0100: T1- Sta. 5 - CTD, Vertical bongo, TM pole sample
0215: T1- Sta. 6 - CTD, **TM rosette**, Vertical bongo
0330: T1- Sta. 7 - CTD, **TM rosette**, Vertical bongo
0445: T1- Sta. 8 - CTD, Vertical bongo, TM pole sample
0600: T1- Sta. 9 - CTD, Vertical bongo, TM pole sample
0715: T1- Sta. 10 - CTD, Vertical bongo, TM pole sample
0830: T1- Sta. 11 - CTD, **TM rosette**, Vertical bongo

8 June

1000 End: **Transect 1**
1200 MVP Transect #1 (return along axis of CTD-Transect 1)
1600 Steam to location of MVP Transect #2
1800 MVP Transect #2

9 June

0100 Sediment trap deployment, **begin CYCLE 1**
0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy driftarray #1
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tows, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #1 (start 2 nm downwind of driftarray)
1600 C Flux Explor-Calib deployments (N=2)
1800 CTD, thorium
1900 CTD, full dilution experiments
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230 MOCNESS – Night #1 (start 2 nm downwind of driftarray)

10 June

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0500 Recover driftarray #1/Deploy driftarray #2
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #2 (start 2 nm downwind of driftarray)
1600 Recover C Flux Explor-Calibs (N=2)
1900 C Flux Explor Deployments (N=2)
2000 CTD to 500m, copepod EPR – Bishop
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230 MOCNESS – Night #2 (start 2 nm downwind of driftarray)

11 June

0200 CTD, sampling & *in situ* experiments
0430 Recover driftarray #2/Deploy driftarray #3
0630 Pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1600 Deploy C Flux Explor-Calibs (N=2)
1800 Pump profile (Stukel and Kranz)
2030 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)

12 June

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover driftarray #3
0530 Recover C Flux Explor (N=2)
0630 Recover sediment trap, **END CYCLE 1**
0730 Recover C Flux Explor-Calibs (N=2)
0900 Steam to MVP Transect (waypoints tbd, but in vicinity of 35º 00' N, 122º 00' W)
1430 MVP test casts with new tow cable
(Vacate specified ops area for Vandenberg live fire)
1800 MVP Transect #3 across filament Start: 35º 16.3' N, 122º 14.1' W
End: 34º 41.5' N, 121º 40.0'W

5th VERSION OF TODAY'S SCHEDULE !

(We will NOT remain on location for Cycle 2 between 1300-1900 due to Vandenberg operations.)

13 June

0200 CTD, sampling & *in situ* experiments, **Begin CYCLE 2**
0300 Trace Metal cast – deck incubation experiments
0430 Deploy driftarray #4
0530 Trace Metal cast
0730 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0830 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 Vacate Cycle 2 area for Vandenberg live fire
1830 Sediment Trap deployment
1945 CTD, Thorium
2030 C Flux Explor deployments (N=2)
2115 CTD, Full dilution experiments
2200 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2300 MOCNESS – Night #1 (start 2 nm downwind of driftarray)

14 June

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover driftarray #4/Deploy driftarray #5
0600 Trace Metal cast
0730 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0830 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1000 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #1 (start 2 nm downwind of driftarray)
1600 C Flux Explor-Calib deployments (N=2)
1800 Pump tanks, burn (> 1.5 nm downwind of driftarray)
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230 MOCNESS – Night #2 (start 2 nm downwind of driftarray)

15 June

0200 CTD, sampling & *in situ* experiments
0430 Recover driftarray #5/Deploy driftarray #6
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics

1300 MOCNESS – Day #2 (start 2 nm downwind of driftarray)
1530 C Flux Explor-Calib recoveries (N=2)
2000 Thorium pumping (Stukel & Kranz)
2200 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)

16 June

0200 CTD, sampling & *in situ* experiments
0430 Recover driftarray #6/Deploy driftarray #7
0600 Trace Metal cast
0700 C Flux Explor-Calib deployments (N=2)
0800 Pump tanks (> 1.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1500 Deep CTD (3,500 m)
1800 Deep Trace Metal CTD (1,200 m)(
1900 Pump tanks, burn (> 1.5 nm downwind of driftarray)
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)

17 June

0000 Deploy sediment trap (to leave drifting at Cycle 2)
0200 CTD, sampling & *in situ* experiments
0400 Recover driftarray #7
0700 Recover C Flux Explor (N=2)
0830 Recover sediment trap – **END CYCLE 2**
1030 Recover C Flux Explor-Calibs (N=2)
1115 Steam to start of MVP Transect; Pump tanks

1400 Start: **MVP Transect** (NW -> SE) start: 35º 07.5' N, 122º 36.0' W
@ 11 kts. end: 34º 13.7' N, 122º 04.1' W
1900 End: MVP Transect

1930 Start: **CTD-Bongo-TM Transect 2** start: 34º 22.65' N, 122º 09.42' W
(SE -> NW) end: 35º 07.5' N, 122º 36.0' W

(11 stations, 5.0 nm intervals)
1930: T2- Sta. 1 - CTD, **TM rosette**, Vertical bongo
2145: T2- Sta. 2 - CTD, Vertical bongo, TM pole sample
2330: T2- Sta. 3 - CTD, Vertical bongo, TM pole sample
18 June 0100: T2- Sta. 4 - CTD, Vertical bongo, TM pole sample
0230: T2- Sta. 5 - CTD, Vertical bongo, TM pole sample
0415: T2- Sta. 6 - CTD, **TM rosette**, Vertical bongo
0600: T2- Sta. 7 - CTD, **TM rosette**, Vertical bongo

0745: T2- Sta. 8 - CTD, Vertical bongo, TM pole sample
0930: T2- Sta. 9 - CTD, Vertical bongo, TM pole sample
1045: T2- Sta. 10 - CTD, Vertical bongo, TM pole sample
1230: T2- Sta. 11 - CTD, **TM rosette**, Vertical bongo

1330 END **CTD-Bongo Transect 2**; Steam to MVP Transect

1630 Start: **MVP Transect** (N -> S) start: 34º 49.8' N, 123º 16.3' W
@ 11-12 kts. end: 34º 08.1' N, 123º 07.5' W
2130 End: MVP Transect

2130 Steam to CYCLE 3 location (tbd after MVP transect)

19 June

0000 Deploy sediment trap – **Begin CYCLE 3**
0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy driftarray #8
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #1 (start 2 nm downwind of driftarray)
1600 C Flux Explor deployments (N=2) [near driftarry]
1700 CTD, thorium [near driftarry]
1800 MVP Transect, driftarray to sediment trap
1900 C Flux Explor – Calib deployment (N=1) [near sediment trap]
2000 CTD, full dilution experiments [near driftarry]
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of sediment trap)
2300 MOCNESS – Night #1 (start 2 nm downwind of sediment trap)

20 June

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover driftarray #8/Reposition and Deploy driftarray #9 **near sediment trap**
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #2 (start 2 nm downwind of driftarray)
1600 C Flux Explor-Calib recovery (N=1)
1800 C Flux Explor recovery (~~N=2~~; N=1; shark attack)

2000 C Flux Explor-Calib deploy (N=2)
2100 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of sed trap)
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of sed trap)
2230 MOCNESS – Night #2 (start 2 nm downwind of sed trap)

21 June
0200 CTD, sampling & *in situ* experiments
0430 Recover driftarray #9/Reposition and Deploy driftarray #10 **near sediment trap**
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1500 C Flux Explor-Calib recovery (N=2)
1800 Pump profile (Stukel and Kranz)
2000 C Flux Explor-Calib deploy (N=2)
2100 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of sed trap)
2200 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of sed trap)

22 June
0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0400 Recover driftarray #10
0500 Recover sediment trap – **END CYCLE 3**
0600 Recover C Flux Explor (N=1)
0800 MVP Bow tie survey
1200 Vacate Navy ops area
1300 Deep CTD (3,500 m)
1800 **CTD-Bongo-TM Transect 3** start: 33º 49.408' N, 122º 42.893' W
(SW -> NE) end: 34º 13.246' N, 122º 27.287' W
(11 stations, 2.7 nm intervals)
1800: T3- Sta. 1 - CTD, **TM rosette**, Vertical bongo
1915: T3- Sta. 2 - CTD, Vertical bongo
2030: T3- Sta. 3 - CTD, Vertical bongo
2145: T3- Sta. 4 - CTD, Vertical bongo
2300: T3- Sta. 5 - CTD, Vertical bongo
23 June 0015: T3- Sta. 6 - CTD, **TM rosette**, Vertical bongo
0130 T3- Sta. 7 - CTD, Vertical bongo
0245: T3- Sta. 8 - CTD, Vertical bongo
0400: T3- Sta. 9 - CTD, Vertical bongo
0515: T3- Sta. 10 - CTD, Vertical bongo
0630: T3- Sta. 11 - CTD, **TM rosette**, Vertical bongo

0800 END **CTD-Bongo-TM Transect 3**

23 June

0800 Transit to **Cycle 2R** (Cycle 2-revisited; location of Cycle 2 sediment trap)
1200 MVP Survey
1800 End MVP Survey
1900 Deploy C Flux Explor (N=1)
2000 Deploy C Flux Explor-Calib (N=2)
2200 Deploy Sediment Trap – **Begin Cycle 4**

24 June - Cycle 4

0000 Recover Sediment Trap from Cycle 2R
0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy driftarray #11
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #1 (start 2 nm downwind of driftarray)
1600 C Flux Explor – Calib recovery (N=2)
1730 CTD, thorium
1900 C Flux Explor – Calib deployment (N=2)
2000 CTD, full dilution experiments
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2300 MOCNESS – Night #1 (start 2 nm downwind of driftarray)

25 June

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover driftarray #11/Deploy driftarray #12
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #2 (start 2 nm downwind of driftarray)
1325 SpaceX launch, Vandenberg
~~1600 C Flux Explor – Calib recovery (N=2)~~
1800 Pump cast (Stukel & Kranz)
2000 C Flux Explor – Calib deployment (N=2)
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2300 MOCNESS – Night #2 (start 2 nm downwind of driftarray)

26 June

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0400 Recover driftarray #12
0500 Recover sediment trap – **END CYCLE 4**
0630 Recover C Flux Explor (N=1)
0730 Recover C Flux Explor-Calib (N=2)
0830 Steam to beginning of **SEASOAR 2**
1300 Deploy Seasoar

26 June (1400) – **29 June** (2200) - **SEASOAR 2** survey across study region

28 June

1900 Science tour, all invited

29 June

2200 Recover Seasoar
2230 Steam to BBL Sta. 1

30 June – Benthic Boundary Layer (BBL) study

0200	BBL sta. 1	Cambria	35º	34.728'	121º	10.096'
0400	BBL sta. 2	Pt. Estero	35º	28.507'	121º	03.411'
0600	BBL sta. 3	Morro Bay	35º	21.621'	120º	55.541'
0800	BBL sta. 4	Shell Beach[prev. Line 77 sta. 49]	35º	05.090'	120º	46.250'
1000	BBL sta. 5	Vandenberg	34º	52.860'	120º	44.170'
1200	BBL sta. 6	Santa Ynez	34º	41.530'	120º	42.560'
1400	BBL sta. 7	Pt Arguello	34º	33.857'	120º	41.065'
1600	BBL sta. 8	Line 80 sta. 51	34º	27.735'	120º	31.250'
1800	BBL sta. 9	Gato	34º	25.351'	120º	24.443'

2100 Steam to Santa Cruz Basin, south of Santa Cruz Id
33 50' 119 40' 33 50' 119 15'
33 40' 119 40' 33 40' 119 15'

1 July – Santa Cruz Basin, MVP vs. UVP5 comparison

0645 Deploy MVP
0700 MVP line 1 - Start 33º 45.0' 119º 39.84' @ 10 kts SOG
0900 MVP line 1 - END 33º 45.0' 119º 15.26'

0915 CTD sta. 1 - to 300 m 33º 45.0' 119º 15.26'
1030 CTD sta. 2 - to 300 m 33º 45.0' 119º 20.0'
1130 CTD sta. 3 - to 300 m 33º 45.0' 119º 25.0'
1230 CTD sta. 4 - to **1,000 m** 33º 45.0' 119º 30.0'
1415 CTD sta. 5 - to 300 m 33º 45.0' 119º 35.0'
1515 CTD sta. 6 - to 300 m 33º 45.0' 119º 39.84'

1530 Deploy MVP
1545 MVP line 2 - Start 33º 45.0' 119º 39.84' @ 10 kts SOG
1815 MVP line 2 - END 33º 45.0' 119º 15.26'

1800 Group photo and live concert on the fantail
Steam to Pt. Loma

2 July
0800 Arrive MARFAC