FK180310 cruise report
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Figures provided by Benedetto Barone, Sara Ferron, John Ryan, and Sam Wilson

Location of the expedition. The majority of the expedition was located in a cyclonic eddy to the north of Molokai, hereafter referred to as the 'Molokai' eddy. The reason for selecting a cyclonic eddy was to better understand the microbial community structure and dynamics associated with the deep chlorophyll maximum in an eddy with negative sea level anomaly. The deep chlorophyll maximum is uplifted by 20 to 40 m in a cyclonic eddy compared to its typical position in the water-column. The decision to target this particular cyclonic eddy targeted was made 1-2 days prior to departure from port. Eddies located closer to the Hawaiian Islands tend to be more dynamic and therefore we delayed making a final decision until the few days before departure. The only other cyclonic eddy with reasonable distance resulted in being more dynamic than the Molokai eddy (Figure 1). After sampling the cyclonic eddy during 14 March to 4 April, the expedition sampled a large anticyclonic eddy to the northwest in order to augment our increasing understanding of microbial biogeochemistry in eddies with contrasting polarity (Figure 2).

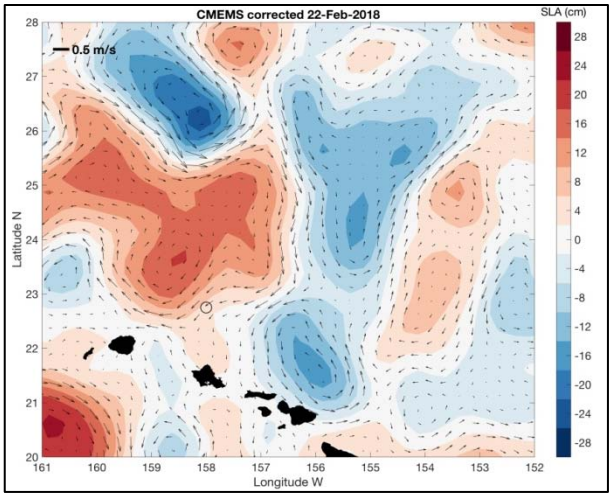

Figure 1. Sea level anomaly around the Hawaiian Islands two weeks prior to departure (February 22, 2018). Cyclonic eddies are shown in blue and anticyclonic eddies are shown in orange. At this point, we were still considering sampling the eddy located at 26 N 158 W, however it was more variable than the 'Molokai' eddy located at 22 N 156 W. The Molokai eddy ended up becoming our targeted feature.

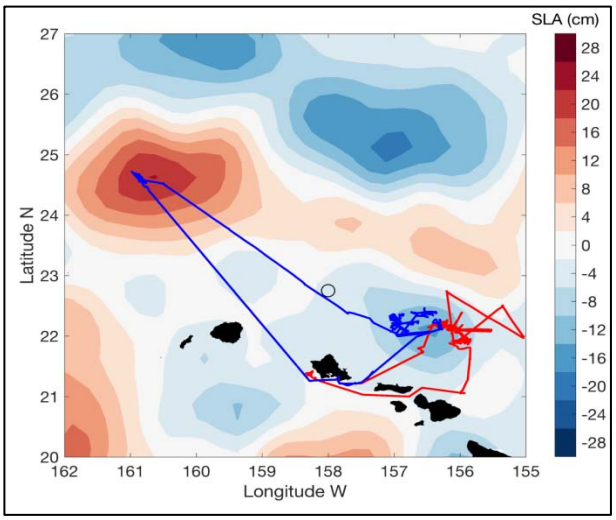

Figure 2. Sea level anomaly around the Hawaiian Islands overlain with the cruise tracks of Leg 1 (red line) and Leg 2 (blue line) of FK180310. The sea level anomaly data is taken from March 31, 2018, midway through the expedition.

The expedition was split into two legs in order to facilitate both engineering and scientific research objectives. The expedition participants for both Legs are listed at the end of the report.

Leg One (10-24 March 2018): The primary objective of Leg 1 of FK180310 focused on the testing of new MBARI designed, Long Range Autonomous Underwater Vehicles (LRAUV). These vehicles were designed to sample the microbial metabolic activity occurring over timescales of hours to days. More specifically, the LRAUVs can adaptively sample the water-column upon detecting changes in predetermined parameters (e.g. dissolved oxygen concentration, chlorophyll fluorescence, or vertical movement of isopycnals). During the Falkor expedition, the LRAUVs were pre-programmed to sample the deep chlorophyll maximum, which is situated between depths of 90-140 m. This sampling program matched the broader objectives of the expedition to understand the microbial temporal and spatial dynamics in a cyclonic eddy. Since the LRAUVs had never been deployed from a large research vessel in the open ocean, their inaugural ocean mission was preempted with a test in the typically calm waters off the west side of Oahu (Waianae Coast). However, during 10-12 March, the sea state was not particularly favorable and the initial deployment of a LRAUV was unsuccessful. Following several changes, further deployments and recoveries were successful and the ESP was determined to have 90% success in its initial short term testing of a few cartridges. The Falkor subsequently transited to the cyclonic eddy and two LRAUVs were deployed in the center of the eddy field for a 5 day period.

In addition to the LRAUV operations, the ship also conducted a hydrographic survey of the eddy field using an underway CTD mounted on the backdeck in order to facilitate location of the eddy center. Two Surface Velocity Program (SVP) drifters were deployed at the center of the eddy: a surface drifter which was centered at 15 m and a custom-made deep drifter which was centered at 120 m. The drifters were deployed in order to conduct Lagrangian sampling during the expedition and the two depths of the drifters were to determine any differences in current speed and direction between the upper and lower euphotic zone. The Falkor also deployed Seagliders (2), Waveglider (1), Wirewalker (1), and free-drifting sediment trap arrays (2). All of these profiling and sampling devices were left in the water when the ship returned to Honolulu on the 24 March to continue recording data when the ship was in port. To facilitate tracking the many Lagrangian instruments and autonomous vehicles, we used a web-based tool developed by Lance Fujieki at the University of Hawaii, website: http://hahana.soest.hawaii.edu/hot/trackmap/TrackMap.html.

Leg Two (28 March-10 April): Leg 2 of the expedition focused on the scientific research objectives. These included: (1) Determine the hydrographic structure of mesoscale eddies, their variability over timescales of weeks to months, and the associated biophysical interactions; (2) Quantify how phytoplankton and microbial community composition, diversity, productivity, and biogeochemical cycling vary between eddies of different types, and along eddy fronts, and (3) Determine how mesoscale eddies influence model predictions of ocean productivity, and carbon and energy export to the ocean's interior. The expedition greatly benefited from the eddy characterization conducted during Leg One and also the familiarization with the LRAUVs. Experiments and measurements were conducted to elucidate linkages between the diel periodicity of microbial activities and biogeochemical processes. To achieve our research objectives, we deployed a wide range of scientific equipment including incubation arrays (productivity, N_2 fixation, sediment traps), bio-optical profiles, and trace metal clean seawater sampling,

in addition to the vehicles and equipment mentioned under Leg One. CTD casts were conducted at sunrise, midday, and sunset, and at other times of the day as needed. On 4 March, the ship retrieved the scientific equipment and transited from the cyclonic eddy to a large coherent anticyclonic eddy located 24.5 N, 161 W (Figure 2). The ship sampled the anticyclonic eddy for a period of 3 days and then returned to port.

Preliminary research findings: During the Falkor expedition, the cyclonic eddy which played host to our measurements remained a coherent and stable mesoscale feature. The intensity of the eddy decreased slightly throughout the expedition as shown by a monitoring of its sea level anomaly (Figure 3). There was a contrast in weather and sea state conditions between Leg One and Leg Two. During Leg Two when the majority of scientific observations were conducted, the sea state was calm with low wind speeds (Figure 4), which facilitated deployment and recovery of the oceanographic equipment.

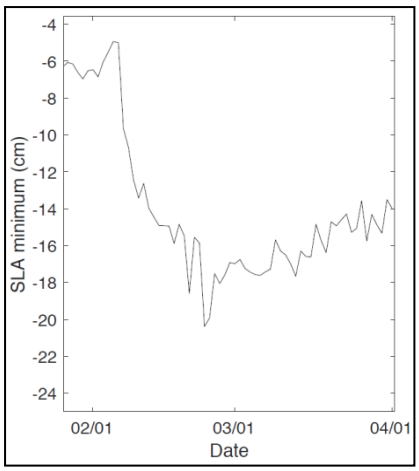

Figure 3. Sea level anomaly (cm) associated with the cyclonic eddy in the months prior to the expedition and during the initial phase of the expedition. The cyclonic eddy significantly strengthened in February which made it a viable sampling location for our expedition. During the period of observations, the eddy began to weaken but remained coherent.

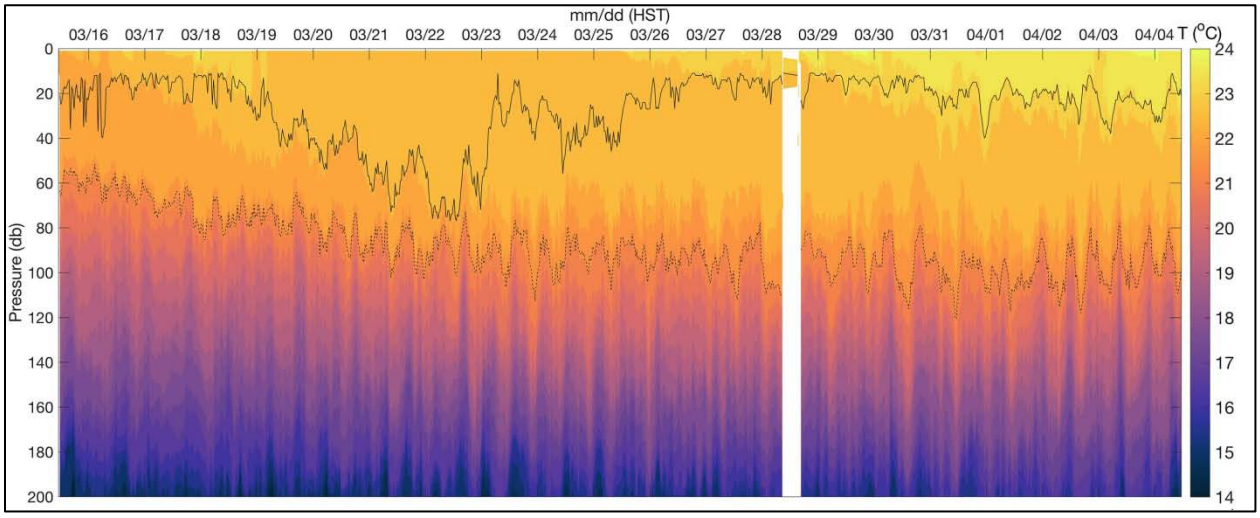

Figure 4. Contour plot of temperature between depths of 0-200 m from the Wirewalker instrument which conducted fifty profiles per day. The mixed layer depth is shown by the upper black solid line. The mixed layer increased in depth due to an increase in wind speed between 19-23 March. In comparison,

during Leg Two of the Falkor expedition, the low winds and calm sea state kept the mixed layer shallower than 40 m.

One of the main objectives specifically for the LRAUVs was to detect and continuously track the deep chlorophyll maximum. During Leg Two of the Falkor expedition, one of the LRAUVS accomplished this goal, by autonomously detecting and sampling the deep chlorophyll maximum for a 4 day period (Figure 5).

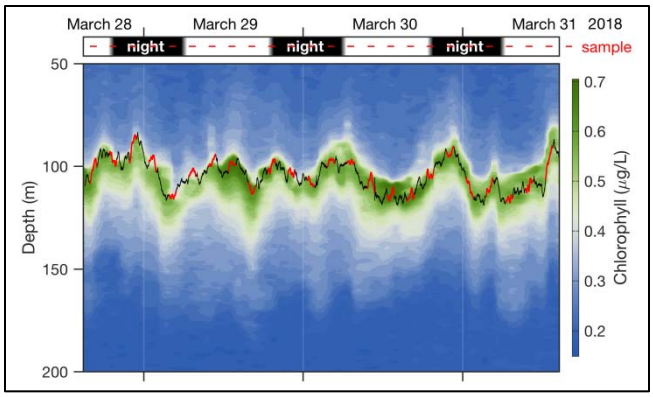

Figure 5: Time-series measurements of chlorophyll profiles during an ESP/LRAUV drift. The solid black line represents drift depth, as controlled by AUV autonomous isotherm tracking. ESP sampling events are shown by the red line segments. Times of discrete measurements conducted by shipboard CTD sampling for comparative purposes are shown by solid black circles.

The biogeochemical measurements conducted during the expedition revealed ecosystem changes in the lower euphotic zone during Leg Two of the expedition. One of the major changes was a decrease in the intensity of the deep chlorophyll maximum, which was a primary focus of the expedition (Figure 6). The extent to which the changes in fluoresence match up with changes in the eddy instensity remain to be determined. Two of the free-drifting arrays that were deployed conducted incubations of productivity (Figure 7) and nitrogen fixation (Figure 8).

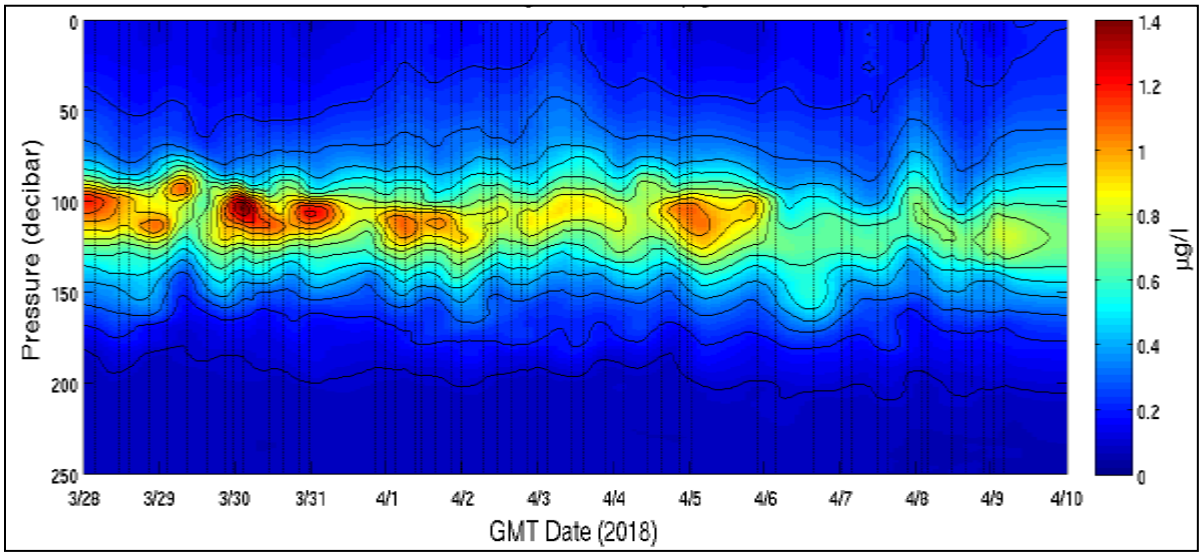

Figure 6. Contour plot in pigment concentrations during Leg Two of the Falkor expedition.

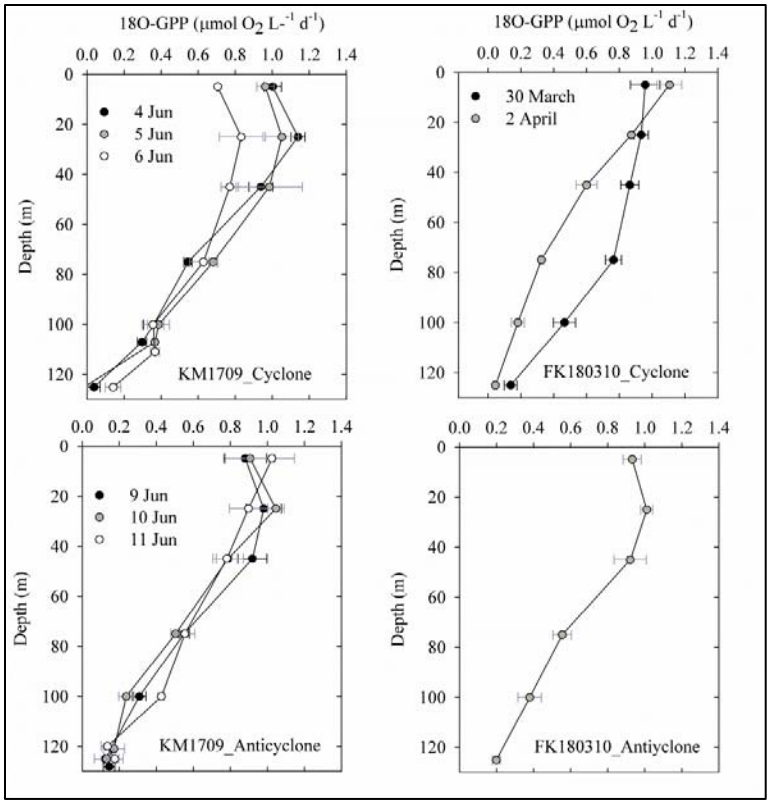

Figure 7. Vertical profiles of gross primary production as measured by ^{18}O assimilation during a 12 h period. The values from the 2018 Falkor expedition are shown alongside the 2017 MESOSCOPE expedition for comparison. Of particular interest to the cyclonic eddy work conducted during the Falkor expedition, are the varying rates of productivity between the 30 March and 2 April in the lower euphotic zone.

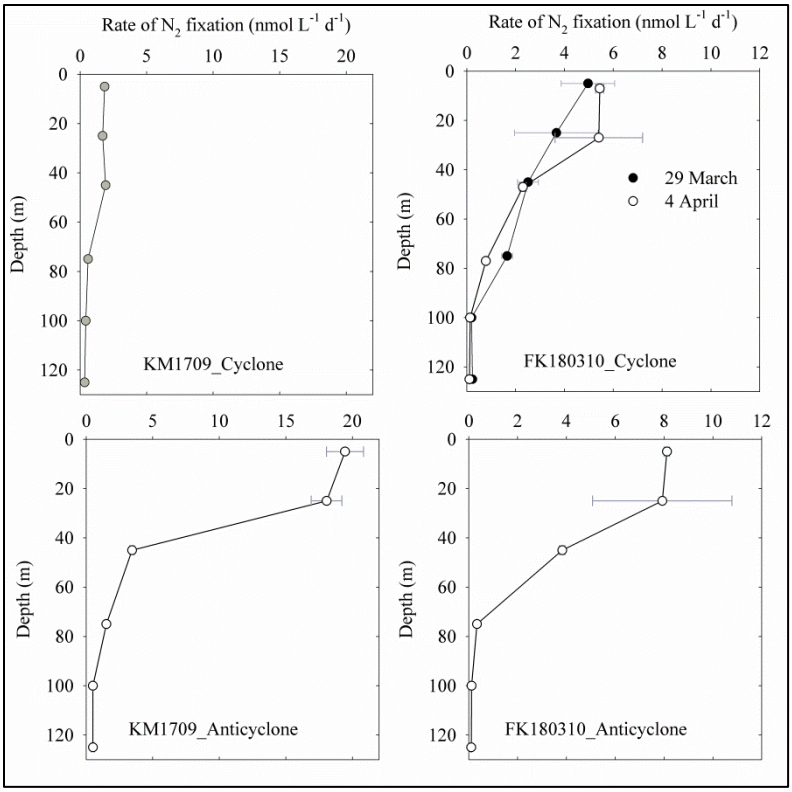

Figure 8. Vertical profiles of N_2 fixation as measured by ^{15}N assimilation during a 24 h period. The values from the 2018 Falkor expedition are shown alongside the 2017 MESOSCOPE expedition for comparative purposes. The vertical profiles conducted during the cyclone show a decrease as the cyclonic eddy decreased in strength, as per the productivity measurements (Figure 7).

Summary of equipment used during the expedition

Table 1. Summary of equipment used during the expedition

Description	Ship vs *in situ*	Person responsible	Leg 1 or 2
Falkor CTD-rosette	Ship	*SCOPE*	Leg 1 & 2
Underway CTD	Ship	*SCOPE*	Leg 1
Hyperpro	Ship	*Hendrikx/Dugenne*	Leg 2
Flow cytometer 'SeaFlow'	Ship	*Armbrust/SCOPE*	Leg 1 & 2
Transmissometer	Ship	*Hendrikx/Dugenne*	Leg 1 & 2
LRAUVs	In situ	*Poulos/Foreman*	Leg 1 & 2
Waveglider	In situ	*Poulos/Foreman*	Leg 1 & 2
Seaglider	In situ	*Poulos/Foreman*	Leg 1 & 2
Surface Velocity Program (SVP) drifters	In situ	*Wilson*	Leg 1 & 2
Drifting Bio-Argo float	In situ	*Hendrikx*	Leg 1 & 2
Drifting profiling Wirewalker systems	In situ	*SCOPE*	Leg 2
Sediment trap array	In situ	*Karl/SCOPE*	Leg 2
Productivity array	In situ	*Karl/SCOPE*	Leg 2
N2 fixation array	In situ	*Karl/Zehr*	Leg 2
Incubation array (x3)	In situ	*Church*	Leg 2
Incubation array	In situ	*Becker/Weisenbach*	Leg 2

Shipboard observations

- CTD & rosette operations (*Falkor*): Vertical profiles of temperature, conductivity and depth were made with an instrument package consisting of a Sea-Bird CTD attached to a 24-place rosette with 12 liter Niskin sampling bottles. Water samples for biogeochemical measurements will be collected on each cast. Additional CTD channels will be used for the following sensors: secondary temperature, secondary salinity, oxygen SBE43 sensor, Seapoint fluorometer, Wetlab fluorometer, c-star transmissometer, and scalar PAR sensor.

- Underway CTD: An underway CTD (Oceansciences) was deployed from the stern of the ship during the cruise. The instrument used a free-fall, internal-logging probe tethered to the ship by a high strength line that is loaded on a special tail spool before every cast. As the probe fell through the water, the line on the tail spool was paid out at the same time as line was paid out from the winch on the ship, similar to the operation of an XBT or XCTD, but with the probe being recovered after each cast. The uCTD winch is used to recover the probe. The web link to the instrument is http://www.teledynemarine.com/underwayctd?BrandID=13. It is a different model to the Teledyne rapidCAST.

- HyperPro: Daily deployments of Satlantic radiometer to characterize irradiance and radiance. The Hyperpro is a profiling unit with one up-looking and one down-looking hyperspectral radiometer, a WET Labs ECO- BB2F triplet (measuring Chlorophyll-a fluorescence and backscattering in the blue and red wavelengths), temperature and conductivity sensors. This instrument also incorporates a ship mounted surface radiometer.

Shipboard instrumentation sampling from uncontaminated seawater supply

- Flow cytometer 'SeaFlow': This instrument provides continuous measurements of cell abundance and cell size distributions will be used to generate hourly estimates of *Prochlorococcus* and other picophytoplankton growth and loss rates.

- Transmissometer: This instrument is configured to auto-sample whole water for 50 mins and 0.2 μm filtered seawater for 10 mins at hourly intervals from the ship's underway system.

***In situ* autonomous vehicles**

- Long Range Autonomous Underwater Vehicles: LRAUVs are 2.5 m in length, weigh 120 kg, and can support an 8 W sensor payload when travelling at 1 m/sec. The vehicles are based off the MBARI Tethys AUV design

- Waveglider: A Waveglider (Liquid Robotics) sat at the surface, equipped with sensors to conduct its own independent operations, and also act as a communication relay or 'mule' between one of the deployed LRAUVs and the R/V Falkor.

- Seaglider: Two Seagliders were deployed during the cruise to survey the region of interest.

Free drifting floats, nets, and arrays

- SVP Drifters: We deployed two Surface Velocity Program (SVP) drifters that comprised of a spherical surface float (equipped with a solar LED) and a "holey-sock" drogue. One drifter was centered at 15 m below the surface and the other at 120 m below the surface. The drifter transmitted its position using iridium and drift along with the surface.

- APEX float: One Bio-Argo APEX-style profiling float was deployed.

- Drifting profiling systems: Two wave-powered drifting profiling systems (Wirewalker, Del Mar Oceanographic) were deployed in the first days of the cruise and recovered after 10-15 days.

- Sediment trap arrays, Productivity array, and Incubation arrays: Free-drifting incubation arrays will be deployed multiple times during the cruise, for 12, 24 and 72 hours deployments.

SCOPE Science activity: PI (with cruise participant indicated in brackets)

- Church (*Vick-Majors, Wear*) Rates of nitrification in the lower euphotic zone using in situ arrays. Mesoscale variability in dissolved organic matter concentrations and turnover
- DeLong (*Den Uyl, Romano*) Diel transcriptomics in/above the DCM alongside the LRAUV measurements. Microbial diversity associated with mesoscale eddy fields
- John (*Hawco*) Vertical profiles of dissolved iron and iron enrichment experiments at the DCM
- Karl (*Linney/Terlouw*): Production/consumption of dissolved DNA. Gross production, net production, community respiration, export, nitrogen fixation
- Lindell *(Weissenbach*) Viral production and decay over the diel cycle using in situ arrays and deckboard experiments. Vertical profiles of viruses across the deep chlorophyll maximum
- Van Mooy (*Becker*) Lipidomics over the diel cycle
- White (*Henderikx, Dugenne*): Underway optical instruments to obtain estimates of community production. Vertical profiles of bio-optics for particles and phytoplankton
- Zehr (*Gradoville, Maria Cabello*) Cell division and transcriptional activity of UCYNA across the diel cycle. Vertical profiles of cell-specific rates of nitrogen fixation in the euphotic zone using in situ arrays
- Samples collected for Armbrust (via SeaFlow), Dyhrman (eddy profiles), Caron (eddy profiles), Ingalls (eddy profiles)

Science personnel for FK180310

Leg1

Name	**Institute**
Tim Burrell	University of Hawaii
Tara Clemente	University of Hawaii
Brett Hobson	MBARI
Roman Marin	MBARI
Tom O'Reilly	MBARI
Steve Poulos	University of Hawaii
Chris Preston	MBARI
Hans Ramm	University of Hawaii
Anna Romano	University of Hawaii
Brent Roman	MBARI
Eric Shimabukuro	University of Hawaii
Ryan Tabata	University of Hawaii
Gabe Foreman	University of Hawaii
Blake Watkins	University of Hawaii
Fernanda Henderikx	OSU
Angel White	OSU
Elisha Wood-Charlson	University of Hawaii
Yanwu Zhang	MBARI

Leg2

Name	**Institute**
Kevin Becker	WHOI
Tim Burrell	University of Hawaii
Tara Clemente	University of Hawaii
Paul Den Uyl	University of Hawaii
Mathilde Dugenne	OSU
Gabe Foreman	University of Hawaii
Rosie Gradoville	UCSC
Fernanda Henderikx	OSU
Nick Hawco	USC
Morgan Linney	University of Hawaii
Brian Kieft	MBARI
Ana Maria Cabello	UCSC
John Ryan	MBARI
Gerianne Terlouw	University of Hawaii
Tristy Vick-Majors	University of Montana
Emma Wear	University of Montana
Julia Weissenbach	Technion
Sam Wilson	University of Hawaii