

MESO-SCOPE 2017 cruise report

Benedetto Barone and Tara Clemente, Chief Scientists

July 2017

1. Introduction

The MESO-SCOPE (Microbial Ecology of the Surface Ocean - Simons Collaboration on Ocean Processes and Ecology) expedition collected oceanographic observations in the region north of the Hawaiian Islands with the aim of identifying the impact of mesoscale eddies on the ecosystem of the North Pacific Subtropical Gyre. The expedition was funded by the Simons Collaboration on Ocean Processes and Ecology (SCOPE) and hosted on the research vessel Kilo Moana between June 26 and July 15 2017, leaving from and returning to the port of Honolulu.

Scientists from eight countries, representing eleven SCOPE laboratories, participated in the MESO-SCOPE expedition and contributed their expertise in research areas as ocean biogeochemistry, molecular biology, bio-optics, plankton taxonomy, microbiology, and ecology.

Mesoscale eddies affect the variability of ocean ecosystem through different dynamics, but an exhaustive description of their influence on the plankton community is still missing, partly due to the complex physical-biological interaction taking place inside the eddies. One of the most well known effects of mesoscale eddies is the vertical displacement of water in their interior due to the geostrophic balance with the eddy circular motion. Since eddies of different polarity displace water in opposite directions, their impact on pelagic ecosystems is postulated to be very different. Based on this information, one of the objectives of the MESO-SCOPE expedition was to study a mesoscale dipole, i.e. a system composed of adjacent cyclonic and anticyclonic eddies.

Investigations into the ecological impact of mesoscale eddies with different polarities included understanding:

1. Horizontal variability of the hydrographical and biogeochemical characteristics
2. Changes in diel ecosystem physiology
3. Ecological effects of inorganic and organic nutrient additions
4. Horizontal variability of particle export
5. Ecological and biogeochemical transitions across the deep chlorophyll maximum

These lines of investigation were addressed by using different sampling and observational strategies during different phases of the MESO-SCOPE expedition, as synthesized in Figure 1 below.

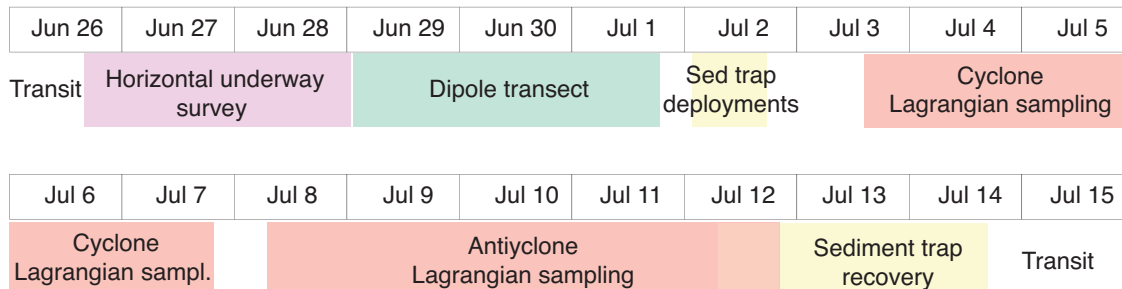


Figure 1: Structure of the MESO-SCOPE expedition showing the timing of the different phases of the cruise based on Hawaiian local time (GMT -10 hours).

The horizontal variability of hydrography and biogeochemistry was characterized during the underway horizontal survey, and the dipole transect phases of the cruise. Diel sampling and incubations to study the effects of nutrient addition took place during the cyclonic and anticyclonic Lagrangian sampling periods. Sediment trap arrays to study export variability were deployed around the middle of the cruise and recovered at the end. High vertical resolution sampling across the depth of the chlorophyll maximum was conducted at eddy centers and at a frontal station identified based on thermal gradients.

The choice of the mesoscale dipole to be sampled was based on the analysis of satellite observations of sea surface height (SLA from CMEMS), and sea surface temperature (SST from NOAA) for weeks before the beginning of the expedition. One week before the start of the cruise, on June 19, there were several eddies north of Hawaii (Figure 2a,b) and they were labeled either with an A (Anticyclone) or with a C (Cyclone) based on their polarity. Considering the distance from Hawaii and the characteristics of the available eddies, the most interesting dipole was formed by eddies C1 and A1. This dipole contained relatively strong eddies that had been observed for a while, and the SST field showed mesoscale stirring consistent with the circulation predicted from the SLA field (warm water had been drawn in the front between C1 and A1). Based on these observations, a track for the initial characterization of the mesoscale field was proposed. This track would transit across eddies C1 and A1 after passing through a third eddy, A3, that was on the way to the dipole (Figure 2, dashed black line). The MESO-SCOPE cruise started by collecting underway observations along the proposed track, and the expedition ended up focusing on eddies C1 and A1 during all the phases of the cruise.

The next sections of this document describe the different sampling and experimental efforts of the MESO-SCOPE expedition.

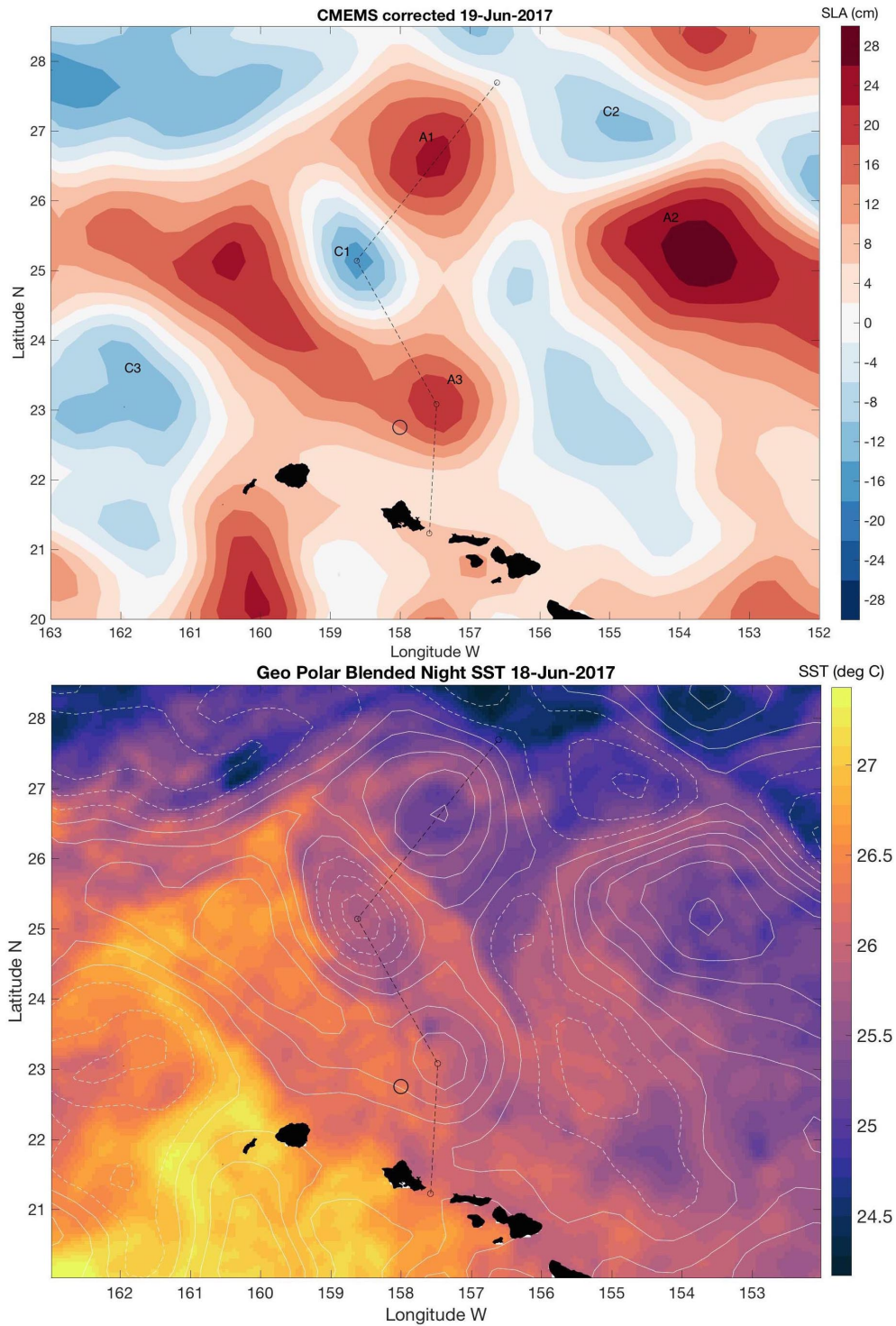


Figure 2: Satellite observations for the region north of the Hawaiian archipelago used before the MESO-SCOPE expedition to define the optimal study area. Top panel is Sea Level Anomaly (SLA) showing several eddies labeled with a C or an A to indicate cyclones and anticyclones, respectively. Bottom panel is sea surface temperature (SST) showing stirring of the temperature field by mesoscale eddies according to a clockwise circulation around the anticyclone and an anticlockwise circulation around the cyclone. White lines in the bottom panel are contours of SLA; the dashed black line depicts the proposed track for the underway survey as of June 19, 2017; the open black circle is Station ALOHA.

2. Underway survey

The initial characterization of mesoscale eddies was done from June 26 to June 28 by using underway instruments while the ship was transiting north (Figure 3). Observations were collected using instruments measuring the properties of the underway flow-through seawater including a thermosalinograph (Sea-Bird SBE 45 MicroTSG), a chlorophyll fluorometer (Turner10-AU-005), a Seaflow flow cytometer (Armbrust lab, University of Washington), a suite of bio-optical sensors and an Imaging Flow Cytobot (White lab, Oregon State University).

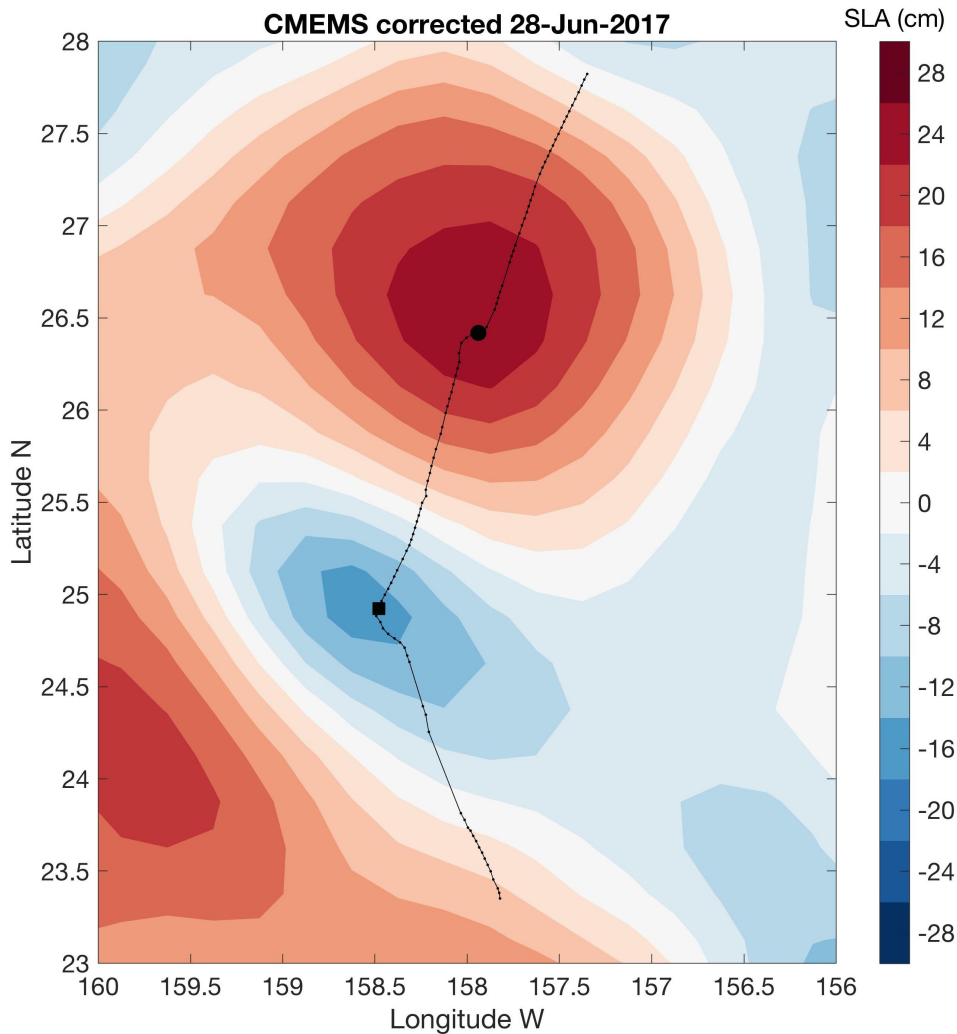


Figure 3: Trajectory of the ship during the underway survey. Black dots are the sites of deployment of the underway CTD used to plot the contours in Figure 4. Black square is the site of deployment of drifter UOH-0002 defined as the cyclone center. Black circle is the site of deployment of drifter UOH-0003 defined as the anticyclone center.

In addition to measurements of the properties of surface seawater, the hydrographic characteristics of the upper 300 meters of the water column were measured using an underway CTD (Teledyne) deployed from the back deck while the ship was transiting at

a speed between 8 and 10 knots. A total of 148 underway CTD deployments were made starting from the edge of anticyclone A3, to the center of cyclone C1m across the center of anticyclone A1, and beyond till getting outside of this last eddy (Figure 2a). A subset of these measurements taken along the track in Figure 3 shows the structure of eddies C1 and A1 (Figure 4).

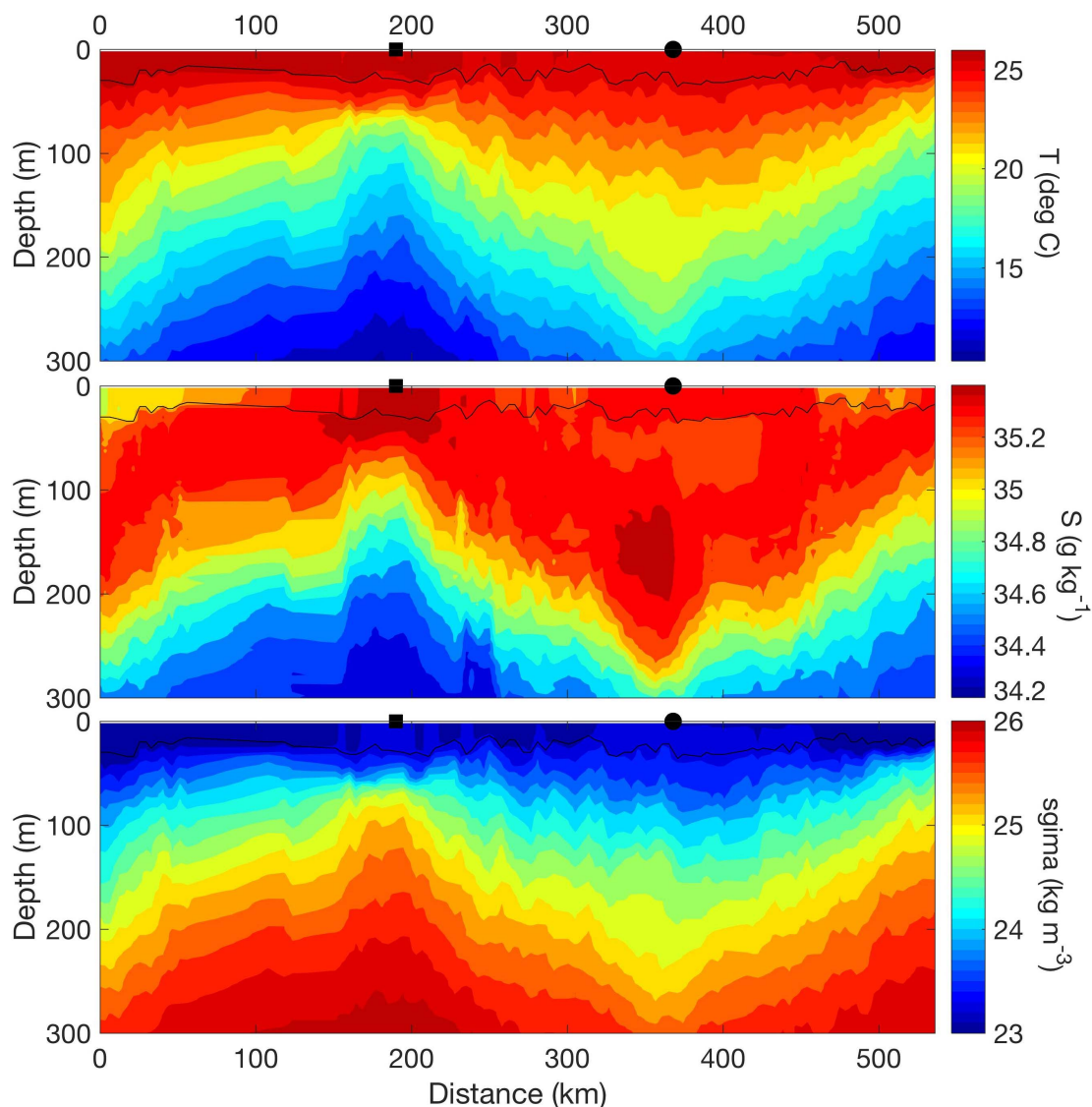


Figure 4: Hydrographic observations collected along the track in Figure 3 with an underway CTD. Top panel is temperature, central panel is absolute salinity, and bottom panel is potential density anomaly. Data from left to right run south to north along track in Figure 3. Solid black line depicts the depth of the base of the mixed layer. Black square and circle are the centers of the cyclone and of the anticyclone, respectively, consistent with the symbols in Figure 3.

Underway CTD measurements were used to verify that the vertical structure associated with eddies reflected the uplifting and down lifting of deep layers within cyclones and anticyclones, respectively. Changes in the vertical position of deep layers are evident in

the hydrographic observations of temperature, salinity and density, with isopycnal surfaces vertically separated by as much as ~150 meters between the cyclone and the anticyclone (Figure 4).

The current velocity and direction was continuously measured by using two RDI acoustic doppler current profilers (ADCPs) working at frequencies of 38 kHz and 300 kHz. The average currents in a 50-meter thick layer close to the sea surface shows that the circulation of water within the dipole was consistent with clockwise and anticlockwise circulation around eddies (Figure 5).

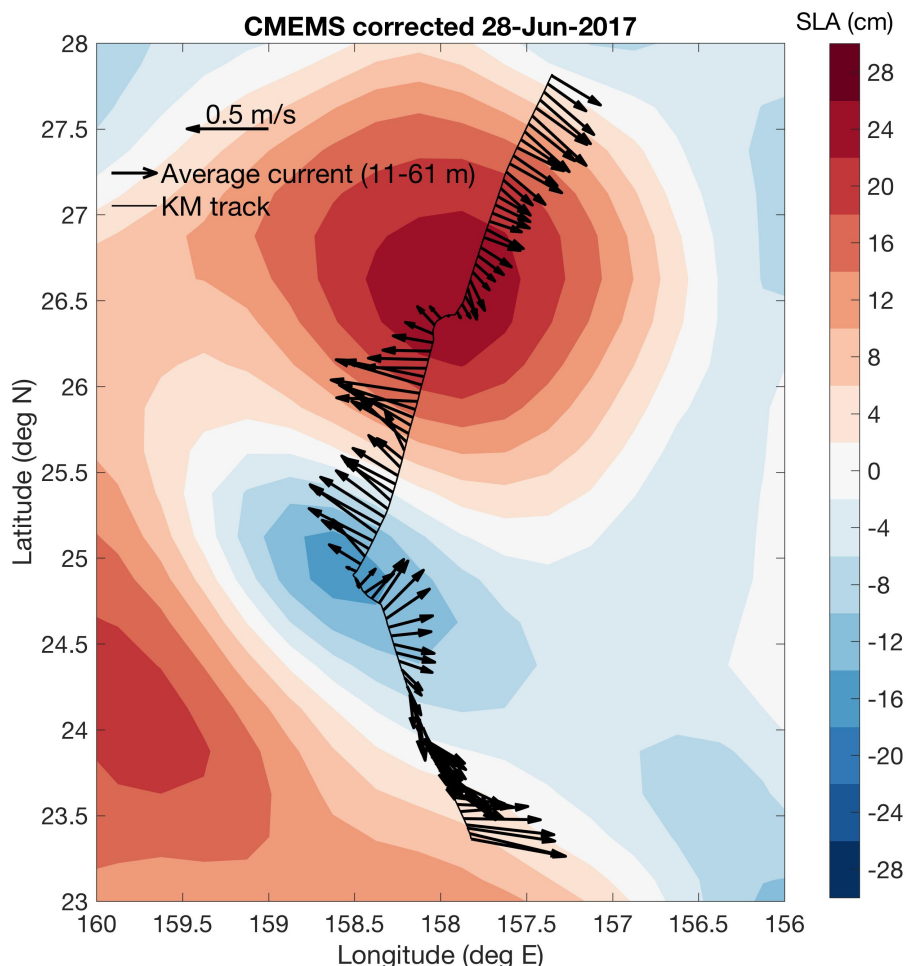


Figure 5: Average current velocity and direction from the 38 kHz ADCP along the ship track. The period of the observations is same as in Figure 3.

Lastly, an attempt was made to deploy a towfish from the starboard side of the ship for continuous sampling of trace metal clean seawater. The towfish was successfully deployed using an aluminum boom that kept the towfish far from the side of the ship. Unfortunately, a failure in the pump pulling water to the ship from the towfish ended this operation, and the boom and the towfish were brought back on board.

3. Dipole transect

The underway survey ended north east of the dipole and from there we started the dipole transect, a line composed by 11 sampling stations, from Station 4 to Station 14 (Figure 6). Every transect station was sampled by several CTD casts and one trace metal clean CTD cast. This phase of the cruise was aimed at characterizing the horizontal structure of the mesoscale dipole by measuring changes in organic matter in dissolved and particulate forms, trace elements, chlorophyll a, ATP, lipids, inorganic nutrients, cell abundance, diazotroph abundance, genes, transcripts, and metabolites.

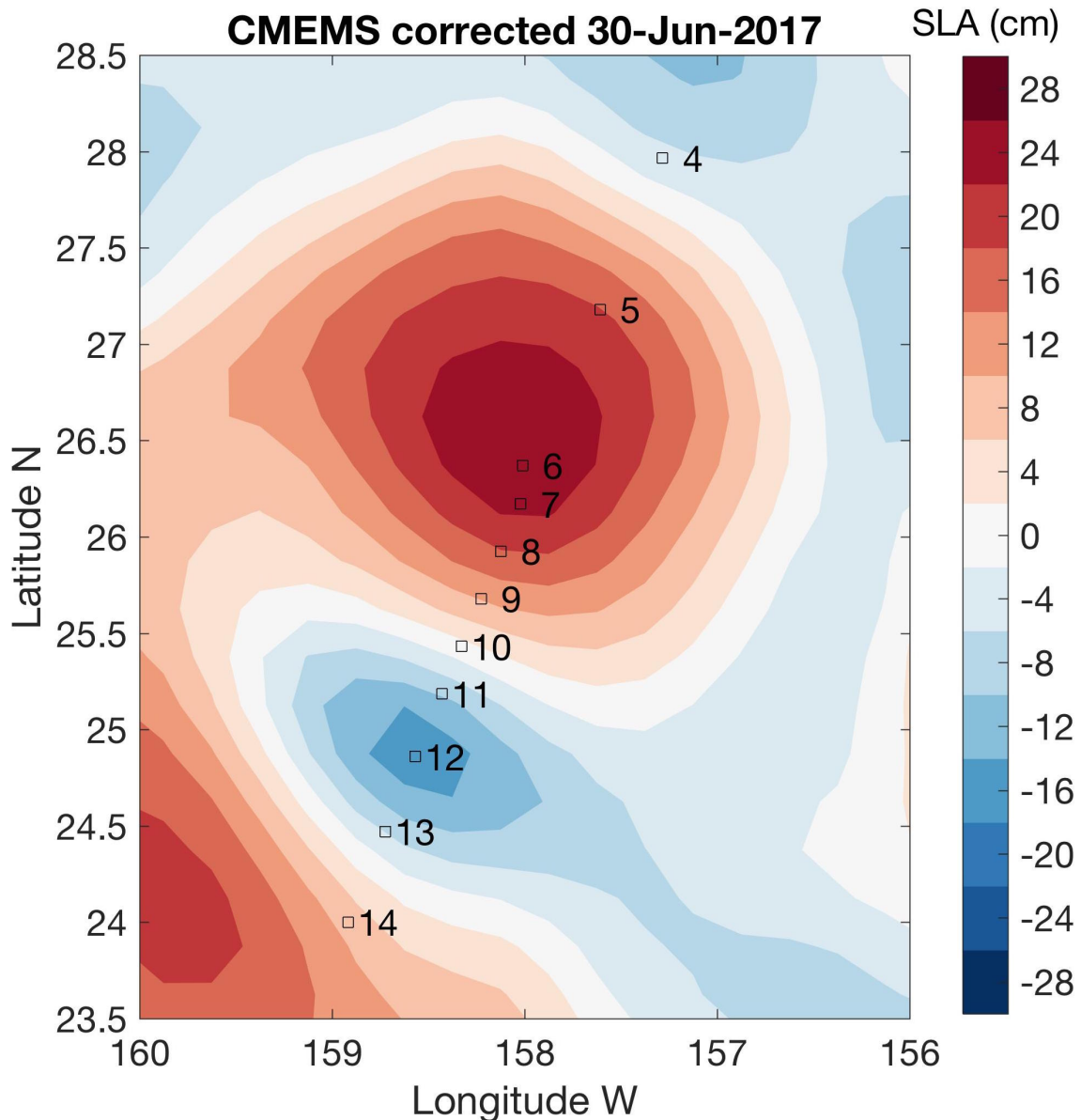


Figure 6: Sampling stations during the dipole transect. Station location was planned based on the SLA reconstruction from June 28 while this map shows the SLA from the central day of the transect (June 30).

The dipole transect also provided an opportunity to characterize the mesoscale variability using the suite of auxiliary sensors attached to the CTD system. These sensors include a chlorophyll fluorometer (Seapoint SCF), a transmissometer (WetLabs c-star), and an oxygen sensor (Sea-Bird SBE 43). CTD data are still being processed, but from the available measurements we were able to observe an increase of chlorophyll and oxygen below the surface mixed layer in the cyclone (Figure 7).

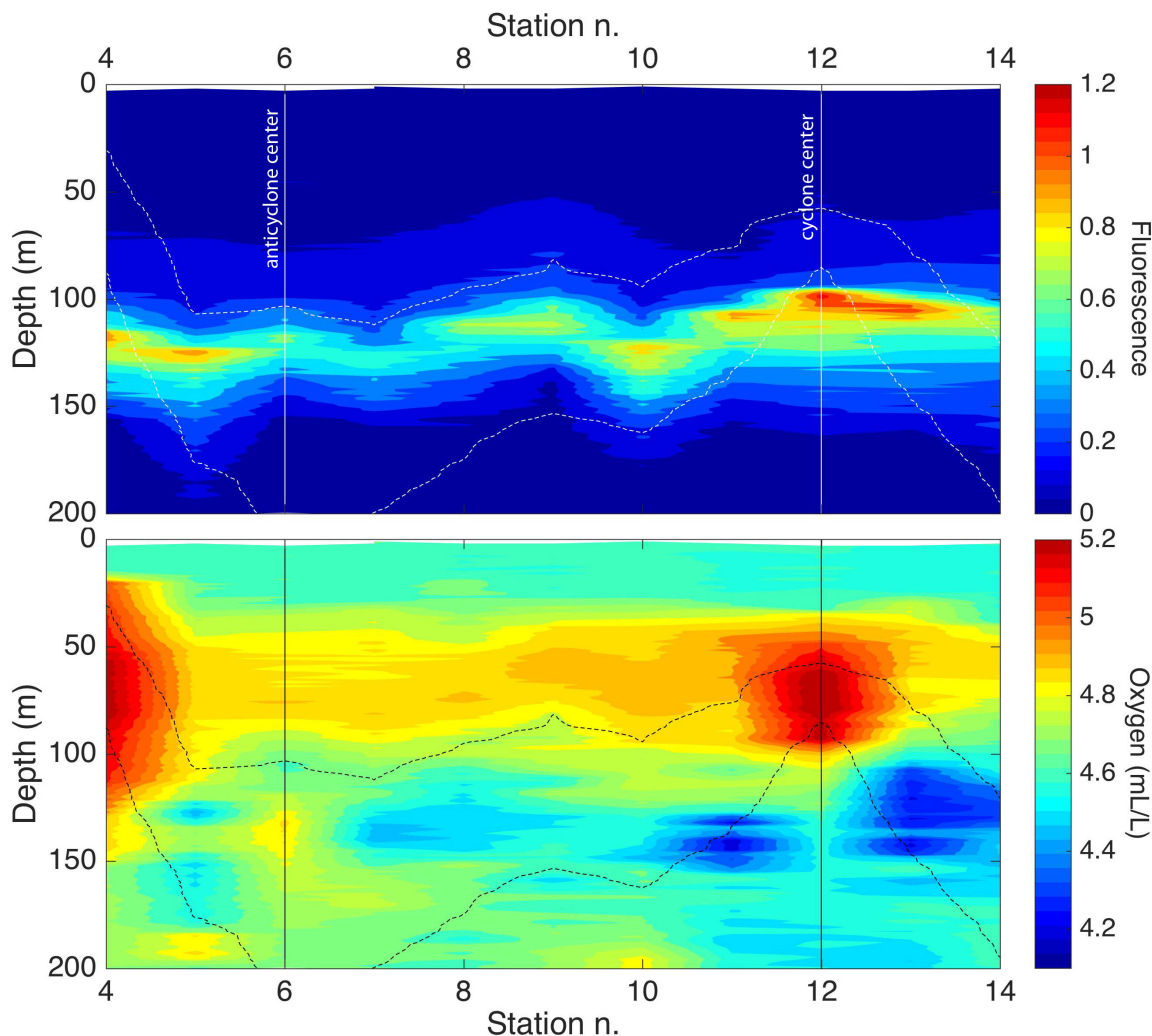


Figure 7: Preliminary reconstruction of the uncalibrated concentration of chlorophyll fluorescence (top panel), and oxygen (bottom panel) from profiling sensors attached to the CTD system at the 11 Stations of the dipole transect. Data from left to right run northeast to southwest tracking station deployments in Figure 6. The observations show increased chlorophyll at around 100 meter depth in the cyclone, and higher concentrations of oxygen just above it. Dashed lines depict the depth of two isopycnal surfaces.

During the dipole transect, two drifting profilers (WirewalkerTM, Del Mar Oceanographic) were deployed in the eddy centers close to Stations 6 and 12. These profilers drifted and collected data for about 12 days before being recovered at the end of the MESO-SCOPE expedition. Besides CTD measurements, the profilers measured downwelling light, particle scattering and attenuation, dissolved oxygen concentration, and the fluorescence by both chlorophyll and colored dissolved organic matter.

4. Lagrangian sampling in the cyclone

From July 3 to July 7 the expedition focused on studying the center of the cyclonic eddy in a Lagrangian sampling effort. Lagrangian sampling was achieved by following the position of a SVP drifter (UOH-0004) that was transported by the currents close to the sea surface (Figure 8) by means of a holey sock drogue centered at 15 m depth.

Lagrangian CTD sampling stations were named with the prefix L1 followed by the cast number. Many of these CTD casts were dedicated to the diel sampling effort whereby water was collected every 4 hours for 3 days to characterize the ecosystem diel periodicities in terms of particles, ATP, chlorophyll, pH, DIC, organic and inorganic phosphorus stocks, inorganic nutrients, lipids, genes, transcripts, and metabolites. Diel sampling took place on two different layers: 15 m to represent the surface mixed layer ecosystem, and a deeper isopycnal surface that tracked the displacement of an ecosystem close to the deep chlorophyll maximum. The isopycnal to be sampled was defined by the potential density at the chlorophyll maximum observed during the casts before the start of the diel sampling. Isopycnal density was $\sigma_{\theta} = 25.24 \text{ kg m}^{-3}$.

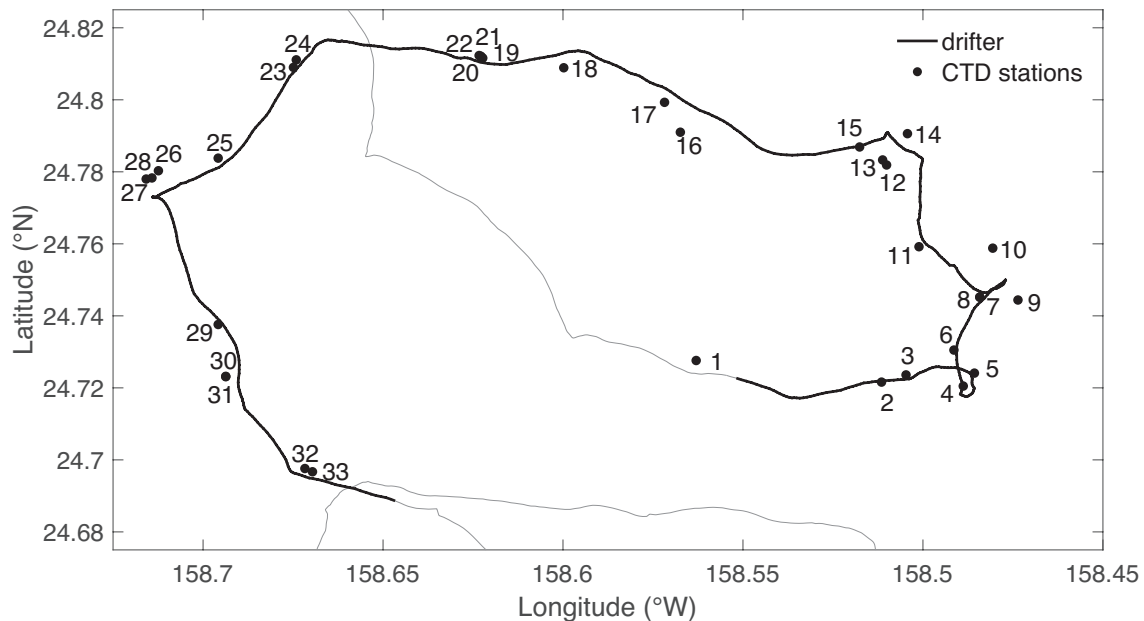


Figure 8: Anticlockwise trajectory of drifter UOH-0004 (solid black line) and position of L1 sampling stations (black dots) during Lagrangian sampling in the cyclone. Gray line depicts the trajectory of the drifter before or after the period when R/V Kilo Moana was following it.

Besides diel sampling, a substantial effort was devoted to incubation experiments, both on deck (with temperature and light controlled incubators), and in situ using drifting arrays (Table 1). Some of these incubations were used to measure rates of photosynthesis, respiration, bacterial production, phosphorus assimilation, ATP turnover, or ammonium oxidation. Other incubations were used to measure the

ecosystem response following addition of inorganic and organic nutrients, or trace elements.

Table 1: Deployment, recovery, and drift duration of incubation arrays in the cyclone center. Time is in local Hawaiian time (GMT-10 hours), and it refers to the beginning of the deployment or recovery.

Array	deployment day	deployment time	recovery day	recovery time	duration (hours)
L1-iron1	7/4/17	3:08	7/7/17	00:30	69.4
L1-Diazo	7/4/17	4:19	7/6/17	3:46	47.5
L1-PP1	7/4/17	5:20	7/4/17	19:23	14.1
L1-PP2-meso	7/5/17	5:04	7/5/17	19:10	14.1
L1-Nfix	7/6/17	4:26	7/7/17	5:45	25.3
L1-PP3	7/6/17	5:15	7/6/17	19:25	14.2
L1-iron2	7/7/17	4:20	7/7/17	19:30	15.2

Meteorological observations of wind speed and photosynthetically available radiation (PAR) at the sea surface measured sunny days with light to fresh breezes (Figure 9).

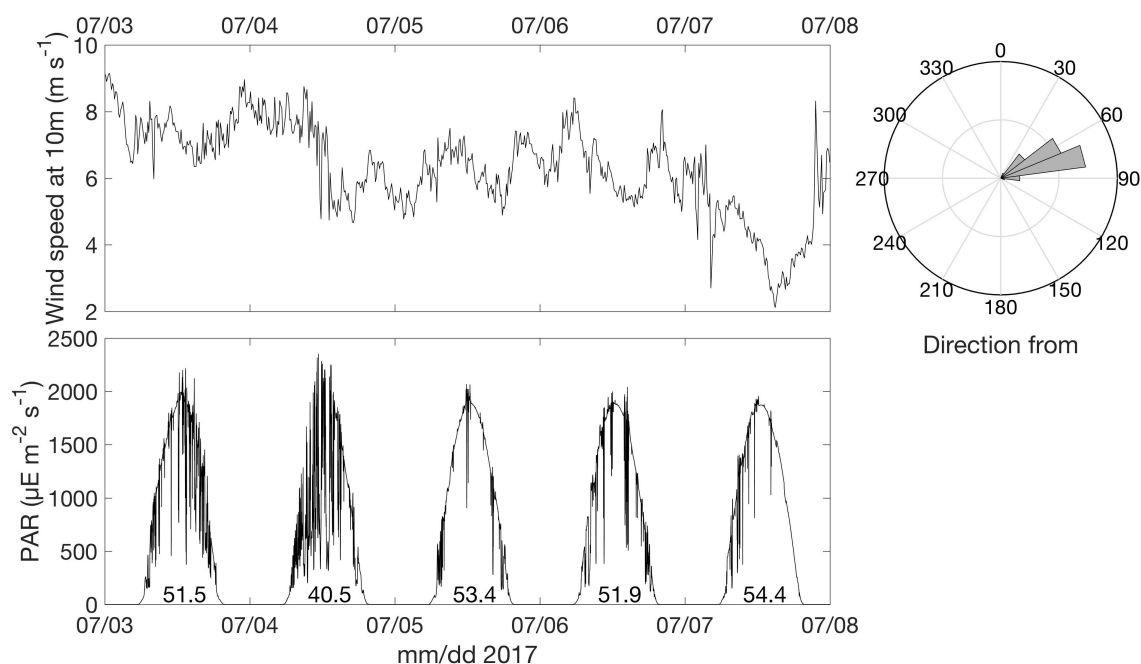


Figure 9: Meteorological observations during Lagrangian sampling in the cyclone. Top panels depict wind speed and wind direction from the measurements of a RM Young Wind Monitor 5016-5 MA. Bottom panel is photosynthetically available radiation from a LI-190 sensor (LI-COR); numbers at the bottom of each day are daily integrals in $E m^{-2} d^{-1}$.

5. Lagrangian sampling in the anticyclone

The center of the anticyclonic eddy was studied with a Lagrangian sampling between July 8 and 12 by following the position of SVP drifter UOH-0005 (Figure 10). Similarly to what was done in the cyclone, Lagrangian casts were named using the prefix L2, and most of these casts were dedicated to diel sampling. Diel sampling took place at 15 m to represent the surface mixed layer ecosystem, and at the chlorophyll maximum isopycnal surface that in this case was at $\sigma_{\theta} = 24.43 \text{ kg m}^{-3}$, much less dense than the one sampled in the cyclone.

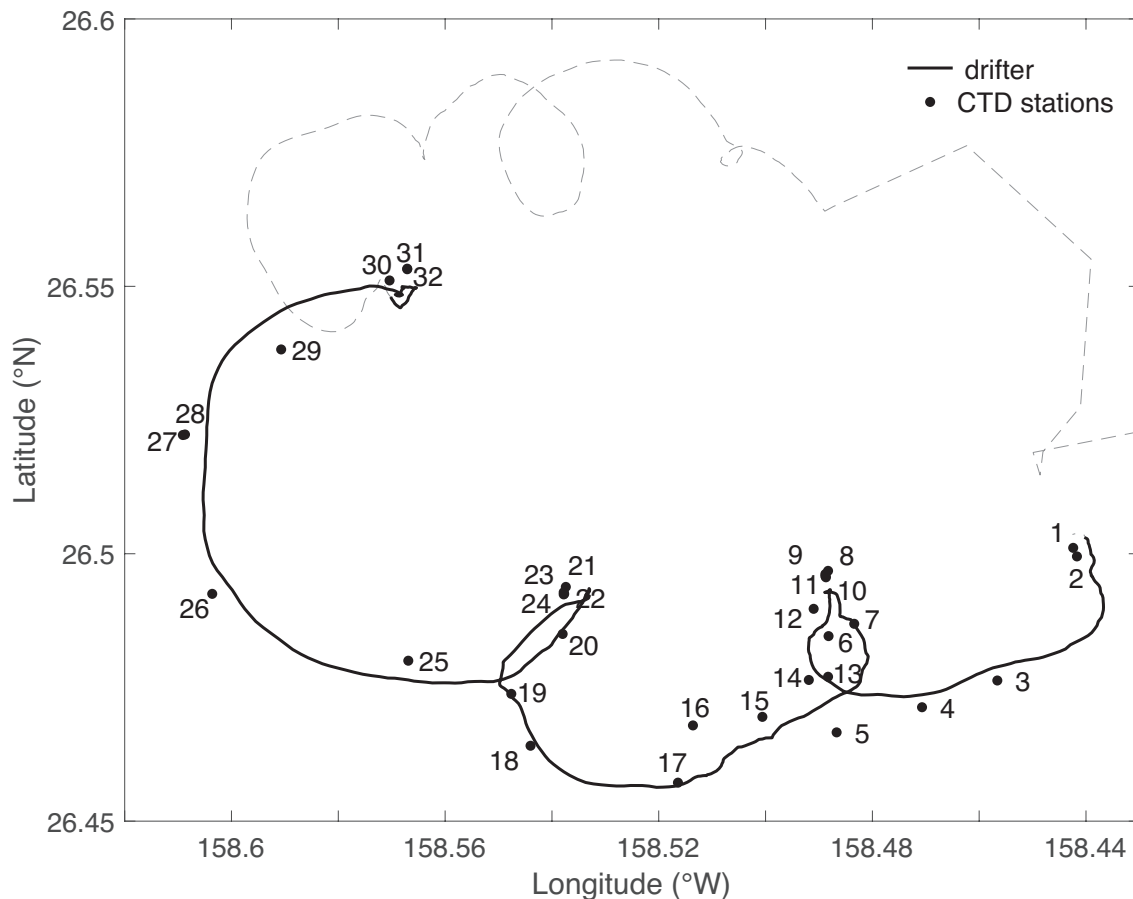


Figure 10: Clockwise trajectory of drifter UOH-0005 (solid black line) and position of L2 sampling stations (black dots) during Lagrangian sampling in the anticyclone. Gray line depicts the trajectory of the drifter before or after the period when R/V Kilo Moana was following it.

The anticyclone center was studied by doing the same kind of incubations as in the cyclone, both on deck and in situ (Table 2). Meteorological observations measured sunny days with light to fresh breezes (Figure 11).

Table 2: Deployment, recovery, and drift duration of incubation arrays in the anticyclone center. Time is in local Hawaiian time (GMT-10 hours), and it refers to the beginning of the deployment or recovery.

Array	deployment day	deployment time	recovery day	recovery time	duration (hours)
L2-iron1	7/9/17	3:17	7/12/17	00:05	68.8
L2-Diazo	7/9/17	4:21	7/11/17	3:55	47.6
L2-PP1	7/9/17	5:14	7/9/17	19:23	14.2
L2-PP2-meso	7/10/17	4:55	7/10/17	20:05	15.2
L2-Nfix	7/11/17	4:18	7/12/17	5:50	24.5
L2-PP3	7/11/17	5:05	7/11/17	19:35	14.5
L2-iron2	7/12/17	4:40	7/12/17	20:56	16.3

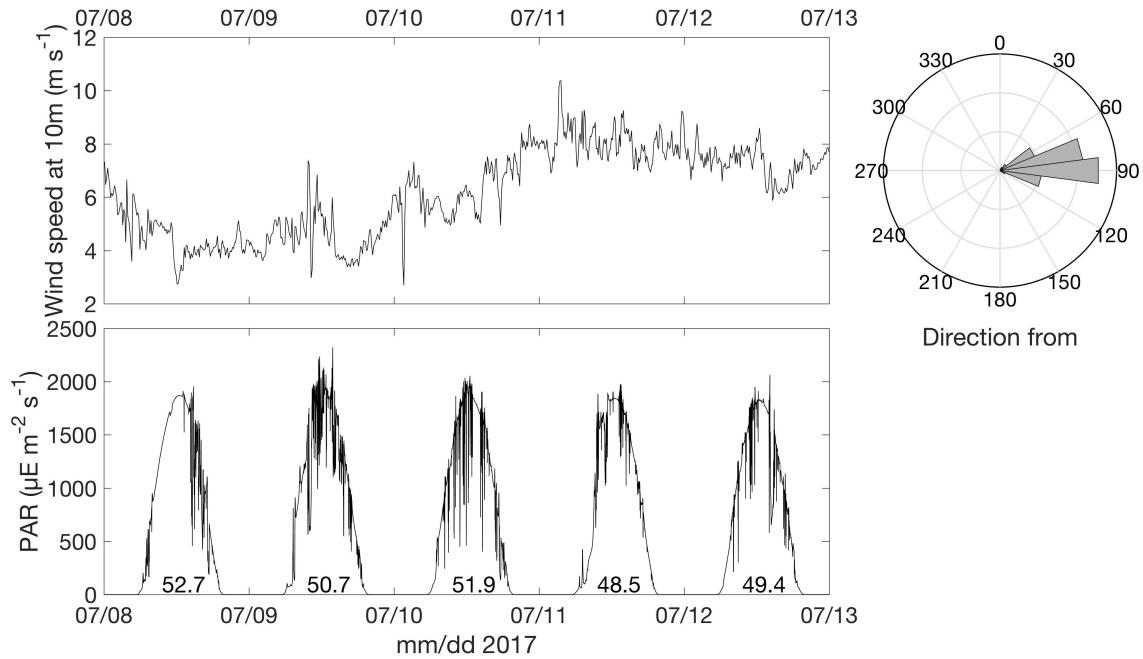


Figure 11: Meteorological observations during Lagrangian sampling in the anticyclone. Top panels depict wind speed and wind direction from the measurements of a RM Young Wind Monitor 5016-5 MA. Bottom panel is photosynthetically available radiation from a LI-190 sensor (LI-COR); numbers at the bottom of each day are daily integrals in $\text{E m}^{-2} \text{d}^{-1}$.

6. Horizontal variability in particle export

A large-scale deployment of 12 sediment trap arrays was used to assess the horizontal variability in the flux of particles exported below the surface layer to a depth of 150 m. The 12 arrays were equipped with 12 particle interceptor traps each that were processed upon recovery by different research groups to measure spatial changes in: elemental composition, energy density, microscopic characteristics, lipids, genes, transcripts, and metabolites.

The arrays were deployed along a line connecting the center of the anticyclone and the center of the cyclone (Table 3), and they started drifting in a clockwise or anticlockwise fashion following the anticyclonic or the cyclonic circulation, respectively (Figure 12).

Table 3: Deployment, recovery, and drift duration of the sediment trap arrays. Time is in local Hawaiian time (GMT-10 hours), and it refers to the beginning of the deployment or recovery.

Sed. trap #	deployment day	deployment time	recovery day	recovery time	duration (days)
1	7/2/17	2:05	7/14/17	15:20	12.55
2	7/2/17	3:33	7/14/17	10:08	12.28
3	7/2/17	5:00	7/13/17	22:48	11.74
4	7/2/17	6:19	7/13/17	19:43	11.56
5	7/2/17	7:37	7/13/17	16:35	11.37
6	7/2/17	9:00	7/13/17	10:03	11.04
7	7/2/17	10:19	7/13/17	02:17	10.67
8	7/2/17	11:40	7/12/17	17:30	10.24
9	7/2/17	13:00	7/12/17	12:44	9.99
10	7/2/17	14:15	7/12/17	9:35	9.81
11	7/2/17	15:37	7/12/17	11:10	9.81
12	7/2/17	16:38	7/12/17	14:25	9.91

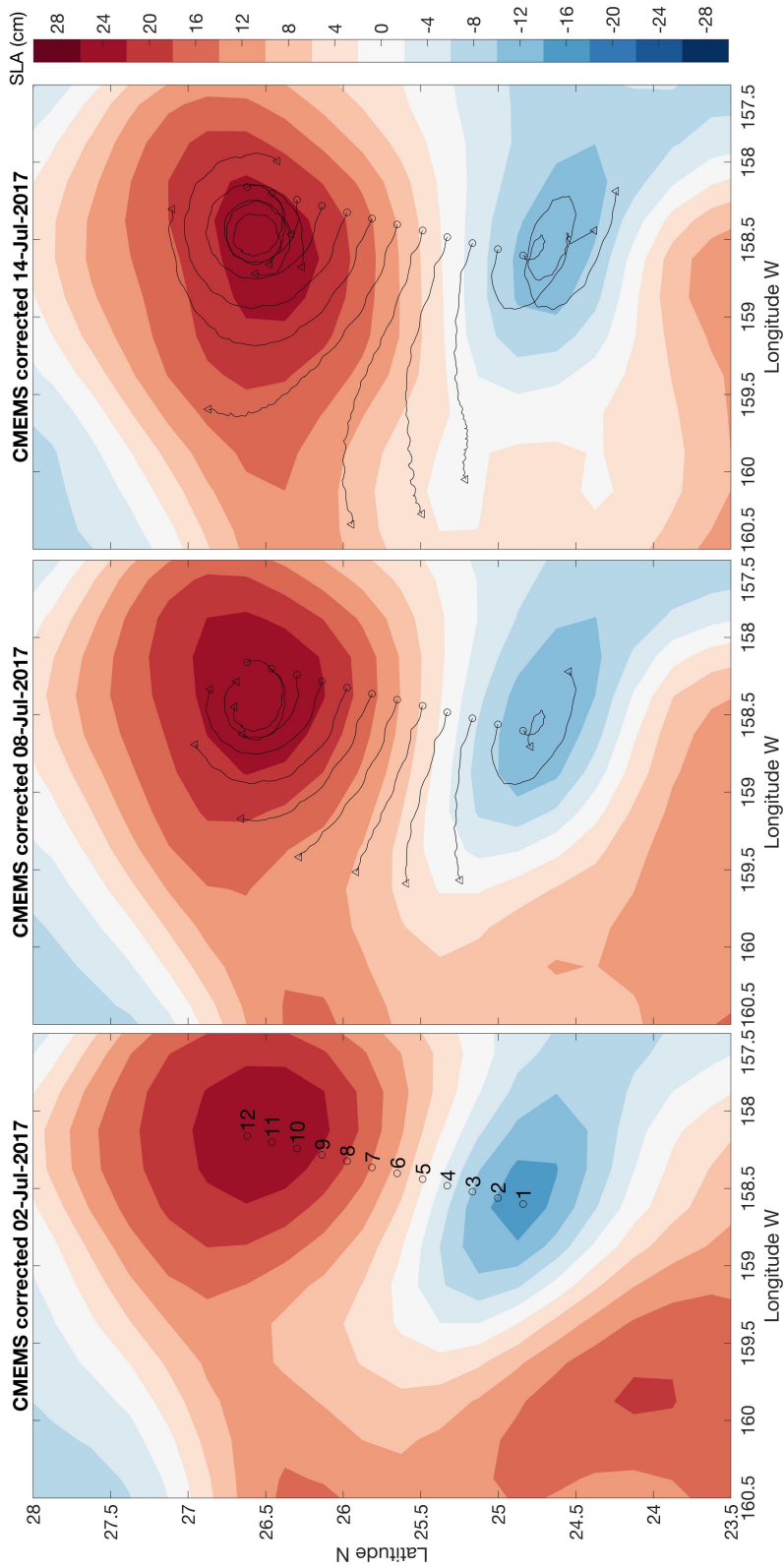


Figure 12: Position and trajectory of sediment trap arrays at time of deployment (left/bottom panel), after 6 days of drift (middle panel), and at the time of recovery (right/top panel). Solid black lines depict array trajectories, black circles are deployment sites, and triangles are location as of July 8 (middle panel) or at recovery (right panel). Contours depict SLA on three different days.

7. High vertical resolution sampling

The ecological and biogeochemical change across the depth of the chlorophyll maximum was characterized by sampling at high vertical resolution on 15 depth levels and at three sites including two eddy centers and Station 15, a location selected based on thermal gradient measurements from satellite. Besides the depth of the chlorophyll maximum, we sampled on 6 depth levels above it, and 8 levels below it, with a vertical spacing of 5 m between consecutive levels. The average chlorophyll maximum depth was 106 m in the cyclone, 123 m in the anticyclone, and 109 m at Station 15.

This sampling effort included sampling for inorganic nutrients, chlorophyll, dissolved and particulate organic matter, cell counts, genes, transcripts, metabolites, and diazotroph abundances.

Appendix 1: Daily reports

June 26 We left the Honolulu harbor in the early morning and our first operation was a deployment to test the ship rosette and CTD system close to the south shore of Oahu to a final depth of 100 m. This cast served two purposes: a) we made sure that the scientific equipment provided by the OTG group functioned correctly; and b) we trained the cruise participants with less experience at sea in rosette preparation and deployment.

We started transiting north from the east side of Oahu and aimed toward the center of anticyclone A3 (Figure 2). At a latitude of ~22 degrees N we started transiting at a lower speed of 8 kts to start conducting underway CTD deployments at a rate of 1 cast every ~15 minutes. We had also planned to start deploying the tow-fish at this time, but the preparation took longer than expected because of the need to splice a weak link in the line in case that something gets entangled in the tow-fish. This is a safety measure so that the drag due to the entangled material breaks the line rather than causing stress on the boom, possibly causing a hazard for the people and the ship. Things were ready for deployment around 7pm, but after discussing it with the captain we agreed that it would be safer to do the deployment in the early morning of the next day with both the daylight and rested personnel.

Just before midnight we reached a latitude of 23.2 north, the reconstructed center of anticyclone A3. There we deployed a first SVP drifter (UOH-0001) so to later understand the coherency of this eddy, and possibly use it as a backup sampling region. Then we stopped the ship to have a first sampling station.

June 27 The two CTD casts planned within the 'backup anticyclone' A3 station could not be used to collect water due to a problem with bottle numbering on the OTG rosette system. We had previously alerted the OTG about a problem with the rosette carousel, but the attempted software fix to the problem had been made ineffective by a crash of the computer used to communicate with the rosette. Since then we adopted another solution to this problem whereby we changed the bottle number using tape and a marker.

In the anticyclonic station, the trace metal free rosette cast was successful and was used as training for the people that will be involved in this operation.

Overall, having a first sampling station outside of the dipole transect was useful because it made us solve some problems before they could affect the sampling in more important phases of the cruise. After the first station, we started transiting toward the center of cyclone C1 (as from Figure 2).

In the late afternoon, we deployed a Seaglider (s/n 512) south of the center of the cyclonic eddy, and we did a CTD cast to calibrate the measurements of oxygen and pigment concentrations from optical sensors on the underwater vehicle. The Seaglider was piloted by Hans Ramm and Steve Poulos (UH) and the plan was to use it to explore the region around the cyclonic eddy, so to possibly find interesting features that could be targeted by the ship.

The boom and the tow-fish for trace metal sampling were deployed out of the

starboard side of the ship. Lots of people participated in this activity and they could put on a functional underway system that we hoped to use for the entire duration of the survey phase of the cruise. Since this was the first time mounting the boom on the ship, the bridge needed to test its response at different speeds and headings. We started from 2 kts and made our way up to 8 kts, and this took some additional time. Everything seemed to go well for a while, but then the pumping system failed, so we stopped and recovered the equipment.

To get back on schedule, in the evening we accelerated from 8 to 9 kts, so to try and start the next phase of the cruise as originally planned.

June 28 We spent the day transiting and deploying the underway CTD to characterize the hydrography of the dipole.

When close to the centers of the eddies, we deployed two SVP drifters in the cyclone (UOH-0002), and in the anticyclone (UOH-0003). The site of deployment was chosen based on the information from real-time current observations (ADCP), and by directing the ship orthogonal to the currents.

The science party had a meeting to discuss the next phase of the cruise, the dipole transect, starting at midnight. Before the meeting, the locations of the sampling stations of the dipole transect were decided based on the most recent altimetric map. During the science meeting, we had a little debate on the choice of having two different sampling depths during the dipole transect and the diel sampling, at 25 m and 15 m, respectively. We eventually agreed, almost unanimously, that it would have been better to have one consistent sampling depth, and 15 meters was chosen to represent the mixed layer.

June 29 We sampled at 3 of the 11 stations of the dipole transect, where we deployed both the 'normal' rosette, and the smaller rosette for trace metal clean sampling. The transit distance between these stations was longer than originally planned so that we accumulated a couple of hours of delay with respect to the schedule drafted before the start of the cruise.

In the morning, we deployed and recovered one drifting profiler (Wirewalker 003) so to make sure that it was working properly and collecting data. We later deployed the same profiler close to the center of the anticyclonic eddy.

We kept having some problems at the CTD console station, and the marine technicians tried different solutions to make the console setting work properly.

June 30 The day was spent sampling at other 4 stations on the dipole transect with deployments of both rosettes.

July 1 After three days, we completed phase two of the expedition by sampling the 11 stations of the dipole transect. Besides this, we deployed the second Wirewalker and another SVP drifter (UOH-0004) inside the cyclone trying to improve on the position of the first SVP drifter deployed in the same eddy (UOH-0002).

- July 2* The day was dedicated to the deployment of 12 sediment trap arrays. The operations went faster than predicted, and by 5:30 pm the SCOPE team led by Tara Clemente had already deployed all of the 12 arrays. At this stage, we already had 19 objects drifting or gliding in the water, with no incubation arrays deployed yet. Since we had gained some time due to the fast deployments, we decided to add a frontal station at a location where satellites indicated the presence of relatively strong thermal front. There was a first deployment of the Scripps plankton camera (Caron's lab) that went well.
- July 3* We arrived in the center of the cyclone in the early afternoon and we started Lagrangian sampling some hours later by following drifter 4, the one that was tracking the eddy center more closely. One Wirewalker and a sediment trap array (#1) are also following a similar circular trajectory. To identify the CTD casts done during Lagrangian sampling we decided to use the prefix L1 (Lagrangian 1) instead of the common S# used for sampling Stations. In the early morning, before reaching the eddy center, we had several CTD casts at a frontal station, Station 15, where we measured rates and we conducted high vertical resolution sampling around the depth of the chlorophyll maximum. The Ingalls' lab also sampled for proteomics at 15 meters and the DCM, so to add another sampling point to the two eddy centers. not far away from where we are now. Later, and before reaching the location of drifter 4, we had another science meeting to make sure that everyone was on the same page about the activities that would take place during Lagrangian sampling. In particular, this meeting was meant to communicate the need to make deployments as fast as possible because there were not many holes in the schedule that could act as buffers in case of delays. During the meeting we also informed the captain and the other bridge personnel our requirements during Lagrangian sampling: first we needed to keep a reasonable distance from the drifter (we agreed on 500m), and second we requested that the tanks were emptied away from the center of the eddy, rather than toward it.
- July 4* The first day of diel sampling went as planned, without big delays or problems. We did several CTD casts and trace metal free CTD casts; we deployed net tows; we deployed three arrays, and recovered one; we deployed an optical package, the Scripps plankton camera, and the hyperspectral profiler. For the diel sampling, we have been collecting water every 4 hours to measure several parameters, from bulk element concentrations all the way to the concentration of single compounds. We sampled on two vertical layers: 15 meters to represent the mixed layer, and an isopycnal layer (25.24 kg m^{-3}) to represent the deep chlorophyll maximum. Sampling on an isopycnal layer

is a bit more complicated than sampling at a fixed depth, but it is the only way to get rid of the variability due to internal waves and isolate the temporal dynamics of a community.

At 8pm, the crew brought the expired emergency flares to the back deck and we fired them to celebrate the fourth of July, US Independence Day.

July 5 The second day of the cyclonic diel went as planned. The primary production array was deployed with a mesopelagic array attached to its bottom. They were both recovered in the evening, but when in the water we once more reached our impressive number of 22 objects simultaneously deployed.

July 6 The third day of diel sampling in the cyclonic eddy went as planned. We deployed an array to measure nitrogen fixation with two different methods to be compared, by the Karl lab and by the White lab. Array deployments and recoveries have been the routine in this Lagrangian phase of the cruise, and it is easy to forget that these operations require tightly coordinated efforts from the bridge and the scientific party. The SCOPE team has been very efficient in these deployments, 6 in 3 days without delaying the other operations in the schedule.

The captain communicated us that today they temporarily lost power to the port shaft while maneuvering to recover one of the arrays. The power came back soon after, but they were not sure what caused it, so they planned to troubleshoot it in the night.

July 7 It was the last day of activity in the cyclonic eddy. The last CTD cast of the diel sampling came out of the water around 3 am, but we stayed near the cyclone center until after sunset, when we recovered the last incubation array (for the iron limitation experiment).

In the morning we sampled the upper water column at a high-vertical resolution to study the sharp ecological transition that happens near the depth of the chlorophyll maximum. We had already done this kind of sampling in a frontal station, and we planned to repeat it the next day in the center of the anticyclone around 8am.

The daily schedule was not too busy because we wanted to have a more relaxed day between the two Lagrangian sampling periods. Anyway, two unexpected events changed our daily plan and lead us in different directions. The first of this event was the news of a problem with Seaglider 512 that was transiting in the cyclone and characterizing its structure. Steve Poulos noticed a problem with the salinity measurements and asked us to check the status of the vehicle. Since the glider was 2 hours away from our location, we transited there and deployed the recovery boat to pick up the Seaglider. Tara Clemente and I (Benedetto Barone) were part of the 4-people crew that went to the rescue. It was a fun trip, and we got the glider back. Unfortunately, we did not notice any visible problem with the vehicle so we decided to bring the Seaglider on the Kilo Moana and end its mission, at least for the time being.

The second event happened while transiting to the Seaglider location, when we noticed a very high abundance of *Trichodesmium* at the sea surface. This was surprising considering that high concentrations of nitrogen fixers are thought to happen almost only within anticyclonic eddies.

On our way back to the center of the cyclone, we briefly stopped to sample this apparent *Trichodesmium* bloom. We only had time for a net tow and some 'bucket sampling', but that should have been enough considering that the high concentrations appeared to be only at the very surface of the water. From a naked eye analysis, *Trichodesmium* was found mostly in tufts, with very few puffs.

July 8 We arrived in the anticyclone around 6:30 in the morning, and we spent the next hour looking for the best spot to deploy a Lagrangian drifter, as close as possible to the eddy center. We eventually deployed the SVP drifter (UOH-0005) and from the first few hours of observations we realized that we got closer to the eddy center than with drifter 3.

In the morning, we repeated the high vertical resolution sampling around the chlorophyll maximum, and the scientific party started preparing for the deployment of three arrays that would take place in the morning of the next day. We used the information from the first few CTD casts to establish which isopycnal surface to sample to represent the layer of the chlorophyll maximum. As expected, this isopycnal was less dense than the one sampled in the cyclone due to the vertical displacement of density surfaces generated by the circulation within the eddies.

July 9 First day of diel sampling in the anticyclone and things went according to the plan. All groups have been busy with different activities: some have been sampling and filtering every four hours for diel measurements; others have been busy incubating plankton in different conditions; others have been using net tows or optical instruments to characterize or try to culture planktonic organisms.

At eddy centers, we have been deploying an optical package with several optical instruments (put together by the White lab) to study the characteristics of the water in situ. One of the purposes of these deployments was to understand if what we measure on filters is the same as what we observe in situ. In the past, in situ optical measurements and concentrations on filters have shown some differences, in particular at the chlorophyll maximum of cyclones. The measurements from the optical package could help us understand the causes of this mismatch, but we have been having some issues with data logging, and it is yet unclear if the optical system is working properly.

July 10 The second day of anticyclonic diel sampling went as planned.

July 11 During the 10am diel CTD cast, we had a delay in our schedule because a chain broke in the CTD winch, and we had to wait for about 1 hour and a half

before it was repaired and we could recover the CTD from the water. This caused one of our diel data points to be moved in time, but we could avoid affecting other operations in the schedule apart from a net tow that had to be cancelled (because it was time sensitive).

July 12 We spent the day transiting and recovering the equipment deployed in the anticyclone. We recovered 4 sediment traps and one of the Wirewalkers, and the next in line are the sediment traps that were originally deployed in the frontal region that drifted for longer distances.

The transit time to recover the traps increased by several hours with respect to the first estimates done two days before because of the additional distance covered by the drifting arrays since those calculations.

Unfortunately, one of the arrays stopped sending its coordinates in the morning. The array was the one closest to the cyclone center, and it was likely following a trajectory similar to the Lagrangian drifter close to it

July 13 The recovery of the sediment trap arrays went as planned.

In the morning we had another science meeting where we discussed some logistical details for off loading the ship, and we had some preliminary discussions about the scientific activities of each group. We went around the table and everyone described the measurements and experiments that he or she had done during the cruise, with a brief introduction of the main objectives that motivated the work. It was a good discussion that helped to build future collaborations, and also made people aware of all the observations that would be available from this expedition.

July 14 The recoveries went according to the plan.

As the last operation of the day, we had planned to go and look for sediment trap 1, the one that had stopped sending its coordinates two days before. We were cautiously optimistic, but we knew that finding it would be a long shot. For the occasion, most of the scientific party was on the bridge looking for the array, someone with binoculars, others with their eyes only. We used a search pattern to explore a big square region of about 5 miles by 5 miles where we thought the array could be (based on the position of drifter 3). Eventually, after ~3 hours, when we had almost ran out of time and we were getting ready to aim back, Rachel Lundeen spotted an orange flag sticking out of the sea. It was the array. We recovered it and started aiming back toward Honolulu.

July 15 We arrived outside the Honolulu harbor before noon, and earlier than expected.

We started off loading the ship, but we completed this operation the day after.

Appendix 2: Science personnel

Participant	Gender	Citizenship	Title	Affiliation
Marianne Acker	F	France	Student	WHOI - Repeta
Lydia Babcock-Adams	F	USA	Student	WHOI - Repeta
Benedetto Barone	M	Italy	Postdoc	UH - Karl
Kevin Becker	M	Germany	Postdoc	WHOI - Van Mooy
Karin Björkman	F	Sweden	Scientist	UH - Karl
Timothy Burrell	M	New Zealand	Scientist	UH - SCOPE
Tara Clemente	F	USA	Scientist	UH - SCOPE
Paul Den Uyl	M	USA	Scientist	UH - DeLong
Mathilde Dugenne	F	France	Postdoc	OSU - White
Sara Ferrón	F	USA	Scientist	UH - Karl
Katie Harding	F	USA	Student	UCSC - Zehr
Matt Harke	M	USA	Postdoc	LDEO, CU - Dyhrman
Nick Hawco	M	USA	Postdoc	USC - John
Gwenn Hennon	F	USA	Postdoc	LDEO, CU - Dyhrman
Fiona Hopewell	F	USA	Student	WHOI - Van Mooy
Rachel Kelly	F	USA	Student	USC - John
Rachel Lundeen	F	USA	Postdoc	UW - Ingalls
Lisa Mesrop	F	USA	Scientist	USC - Caron
Alex Nelson	F	USA	Scientist	UH - Church
John Ranieri	M	USA	Scientist	FHLBS, UM - Church
Eric Shimabukuro	M	USA	Scientist	UH - SCOPE
Brittany Stewrt	F	USA	Scientist	UCSC - Zehr
Alice Vislova	F	Russia	Student	UH - DeLong
Ryan Tabata	M	USA	Scientist	UH - SCOPE
Katie Watkins-Brandt	F	USA	Scientist	OSU - White
Qin Wei	M	China	Postdoc	UW - Ingalls

(26 participants: 10 males, 16 females)