CTD-associated variables, bottle salinity measurements, oxygen titrations, nutrient analyses, biogeochemical/biological variables, and DIC/Freon chemistry variables from R/V Roger Revelle cruise RR2004 along the 150W meridian from 30S to 60S

Website: https://www.bco-dmo.org/dataset/907028
Data Type: Cruise Results
Version: 1
Version Date: 2023-08-31

Project
» Collaborative Research: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean (Conditioning_SAMW)

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Abstract
These data are part of the NSF project "Collaborative Research: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean". Specifically, these are the discrete bottle data from cruise RR2004 aboard R/V Roger Revelle, which sailed from Honolulu, Hawaii on 26 December 2020 to the Southern Ocean and returned to Honolulu on 23 February 2021. The purpose of the project was to define the processes that condition Sub-Antarctic Mode Water (SAMW) formed at the Sub-Antarctic Front in the Southern Ocean. The cruise track was from 30 degrees South to 60 degrees South along the 150 degrees West meridian as well as an investigation of frontal boundaries and eddies further east (from 45S to 57S by ~145W). Bottle data were collected from CTD casts with tripped Niskin bottles on the CTD Rosette. Trace-metal-clean casts were performed using Niskin-X bottles suspended on Kevlar line and a trace-metal-clean block. The data reported herein fall into several categories, A) CTD-associated variables, B) bottle salinity measurements, C) oxygen titrations and nutrient analyses, biogeochemical/biological variables, and D) DIC/Freon chemistry variables. Regarding the specific data, we first report CTD variables (salinity, temperature, potential temperature, density, dissolved oxygen, sound velocity, pressure, depth, conductivity, SeaBird-probe-derived oxygen concentrations, chlorophyll fluorescence, beam transmittance (660nm; %), backscattering, CTD PAR, and surface PAR reference. Next, results from bottle samples for salinity, lab oxygen titration, and nutrient concentrations (nitrate, phosphate, silicate, nitrite, and ammonium). The following biogeochemical and biological variables are presented: particulate organic carbon concentration (POC), particulate organic nitrogen (PON), and particulate inorganic carbon (PIC), concentration of detached coccoliths (given as birefringent singlets, doublets, triplets, or quadruplets, when viewed in a compound microscope with polarization optics), total coccolith concentration (the sum of singlets, doublets, triplets or quadruplets), concentration of birefringent plated coccolithophore cells, coccospheres or coccolith aggregates, planar area subtended by detached coccoliths or plated cells, concentration of biogenic silica, concentration of chlorophyll, phaeopigment and their sum. There are a suite of variables from FlowCAM measurements, mostly done on particles greater than 5 micrometers (um) in diameter: Particle size distribution function (PSDF) slope, standard error of PSDF slope, Y-intercept of the PSDF, R^2 of the PDF slope, F statistic of PSDF slope, total cell concentration per milliliter (mL), concentrations (in cells per mL) of small 0-4um diameter cells, 4-12um round cells, 4-12um diameter ovoid cells, dinoflagellates, ciliates, diatoms silicoflagellates, other unidentified cells, followed by percent of total cell concentrations and carbon biomass (using equations of Menden Deuer and Lessard) for

the same cell categories. Carbon fixation rates are then presented for: ratio of calcification/photosynthesis, photosynthesis, calcification, standard deviation of photosynthesis and calcification measurements, chlorophyll concentration within incubation bottles, chlorophyll normalized photosynthesis, and calcification. Finally, corrected salinity (based on bottle salinity), corrected SeaBird oxygen values based on lab oxygen titrations, dissolved inorganic carbon (DIC) concentrations, total alkalinity and concentration of CFC12 and CFC11 freons are presented.

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Coverage

Spatial Extent: **N**:-26.011 **E**:-137.022 **S**:-59.9983 **W**:-152.319
Temporal Extent: 2021-01-08 - 2021-02-09

Methods & Sampling

R/V Roger Revelle (cruise ID RR2004) departed Honolulu, Hawaii on 26 December 2020. The ship transited south along the great circle route from Honolulu to 30°S x 150°W.

Sampling Overview:
Hydrographic profiles were performed along the transect with the CTD (the "full-water cast"), sampling for Freons, dissolved oxygen, DIC, alkalinity (and all other parameters of the carbonate cycle using the CO2-SYS program), extracted chlorophyll, nutrients, POC, PIC, biogenic silica, coccolithophore counts and FlowCAM analyses (for enumerating and classification of nanoplankton and microplankton species). Each CTD full-water cast was alternated with a "trip-on-fly" water cast. The latter casts involved tripping bottles at 24 depths "on the fly" as they passed the following 24 depth targets: 1000 meters (m), 900m, 800m, 700m,600m 500m, 450m, 400m, 350m, 300m, 250m, 200m, 150m, 120m, 110m, 100m, 90m, 80m, 70m, 60m, 50m, 40m, 25m, 5m. These later casts were used only to sample full water properties at the surface only, as well as DIC and nutrients at eight depths. These trip-on-fly casts served to provide greater resolution in hydrographic sections across the features. Once per day, typically pre-dawn, CTD casts included samples drawn for primary productivity and calcification. These measurements involved the use of 14C-bicarbonate and all manipulations were done in a portable radioisotope van on deck.

Sampling for trace metals was performed daily using nine Niskin-X bottles clamped to nonmetallic Aracom line, hung at depths to ~1000m and tripped with nonmetallic messengers. All trace-metal-clean manipulations were performed in a trace-metal-clean laboratory or a plastic bubble built within the ship's wet lab. Five carboy experiments were performed over the cruise, which involved incubating surface, trace-metal-clean water collected by a "Big Jon" surface sampler (towed from the side of the ship at 1-3 knots (kts), which maintained a distance of 5-10m from the side of the ship as it pumped surface water into two 200-liter (L) plastic tanks within the wet lab bubble). For three of the carboy experiments, the investigators conducted triplicate incubations of untreated control water plus five treatments (three replicates each) in plastic, acid-cleaned cubitainers with a) 5% dilution with subsurface water, b) 20-micromoles (uM) trace metal-clean nitrate, (c) 20 uM trace metal-silicate, (d) 1 nanomole (nM) of iron and (e) 1 nM of iron+20 um of silicate 6. The cubitainers were then sampled approximately every other day for 4-5 days while being incubated under surface light conditions in an on-deck incubator, with temperature maintained at T0 in-situ surface conditions. The carboys were sampled about every two days by the Balch group for chlorophyll, nutrients, PIC, POC, biogenic silica, quantitative coccolithophore counts, and quantitative FlowCAM samples (for enumeration of algal classes, cell volumes, and slope of the particle-size distribution). Later in the cruise, for two of the carboy experiments, due

to time constraints with two simultaneous incubations, incubations could only be performed with a control and two treatments of (a) 5% subsurface water and (b) 2 nM iron).

Sampling Methods:
At sea collections: Water samples were collected using CTD casts from 103 stations encompassing Subtropical, Subantarctic and Polar waters in the Pacific Sector of the Southern Ocean. Discrete samples were taken from 10L Niskin bottles for the following measurements:

1. Chlorophyll - Water samples were filtered onto a 25-millimeter (mm) Millipore HA filter (mixed cellulose ester, 0.45-micrometer (µm) pore size). The filters were transferred to test tubes filled with chilled 90% acetone for extraction and vortexed until the filter dissolved. Tubes were stored in the dark in a freezer for 24 hours before analysis. Tubes were then re-vortexed and gently centrifuged (~1300g) for 5 minutes before being decanted into a glass cuvette for the fluorometer. A Turner Designs 10AU was used to read Fb of the sample and then, after adding 50 microliters (µl) of 10% HCL, to read Fa. The fluorometer was calibrated pre-cruise with a pure chlorophyll extract (Turner Designs part# 10-850) to determine Tau τ=(Fb/Fa pure chl a) and chlorophyll a was then calculated from: (Fb – Fa) * (τ/ τ-1) * (Vfiltered/Vextracted). Generally, all surface measurements were made in triplicate. The fluorometers (Turner 10-AUs) were calibrated using the calibration method defined by Turner Designs using standards purchased from Turner Designs. Additionally, for long cruises such as this cruise, a calibration was performed on the ship. References: Trees, et al.

2. Particulate organic carbon (POC) plus particulate organic nitrogen (PON) - Water samples were filtered onto 25 mm GF/F filters which were pre-combusted (450°, 5 hours). Filters were rinsed with filtered seawater (FSW) and then stored in individual petri-plates and dried (60°) for storage. Prior to analysis, the plates were opened and placed overnight in a sealed container like a dessicator with saturated HCL fumes to remove any particulate inorganic carbon (PIC). These samples were run by the Bigelow Laboratory Analytical Facility. The filters were packed into pre-combusted nickel sleeves and analyzed on a Perkin Elmer 2400 Series II CHNS/O for C, N, and H. The analyzer was calibrated using tin capsules as blanks and acetanilide to calibrate instrument response to carbon and nitrogen. NIST-certified check standards consisting of either low organic content soil or sediment are analyzed to determine accuracy of carbon detection. NIST-certified organic check standards such as corn flour or rice flour were analyzed to determine the accuracy of nitrogen detection. If values varied by more than 4% from stated values, the instrument was examined, any problems were addressed and the instrument was recalibrated and checked standards rerun until the error was within acceptable limits. Duplicate samples were run during each sample run to ensure results were reproducible. If duplicates could not be run on actual samples, as in the case of filter samples, duplicate check standards were analyzed. Duplicate samples typically varied less than 2%. One instrument blank was analyzed for every 12 samples run. One acetanilide standard was analyzed for every 15 samples run. If blank or acetanilide values differed significantly from previous values, a new series of standards and blanks were analyzed to recalibrate the instrument. The actual minimum detection limit (3 times the standard error) determined from the standard error of the instrument blanks is 2 micrograms for carbon and 4 micrograms for nitrogen. References: JGOFS (1996).

3. PIC (Particulate Inorganic Carbon) - Water samples were filtered through a 25mm, 0.4 µm pore size polycarbonate filter. The dry filter was rinsed with Potassium tetraborate (6.11 grams per liter $K_2B_4O_7 \cdot 4H_2O$) buffer while still in the filter tower to remove as much seawater salt and also to maintain a high pH (~8.1) during sample storage and to preserve the $CaCO_3$ on the filter. Filters were placed into trace metal clean polypropylene centrifuge tubes and dried at approximately 60°. For analysis, the filters were sent to (a) the Sawyer Environmental Chemistry Laboratory at the University of Maine or to (b) the Department of Earth Sciences at Boston University. Filters were digested in a 5% nitric acid solution for 12 hours to dissolve all $CaCO_3$ and the solution was analyzed by ICP-AES (Inductively Couple Plasma – Atomic Emission Spectrometry) for Ca concentration. Filter and dissolution blanks were run as well as QC standards run with each batch of samples. The investigators also used the concentration of dissolved Na in the digestate to correct for any Ca present in sea salts left on the filter. PIC concentrations were calculated using the volumes of water filtered and the volume of the digestions, and assuming all Particulate Inorganic Carbon was in the form of $CaCO_3$.

4. Biogenic Silicas - To determine reactive silicate, 200 milliliters (mL) of seawater sample is filtered onto a 25 mm, 0.4um pore size polycarbonate filter. Filters are folded and placed in a super clear polypropylene centrifuge tube and dried in a drying oven at 60° Celsius (C) for 24 hours then tightly capped and stored until analysis. On shore, 0.2N NaOH is added and the sample is placed in a 95°C water bath. The digestions are then cooled and neutralized with 1N HCl. After centrifuging, the supernatant is transferred to a new tube and diluted with MilliQ water. Molybdate reagent is added and then a reducing agent is added to reduce silicomolybdate to silicomolybdous acid. The transmission at 810 nanometers (nm) is read on a Hitachi U-3010 spectrophotometer (SN 0947-010). Reactive silicate is calculated using a silicate standard solution standard curve prepared at least every 5 days or whenever new reagents are prepared. Readings are corrected using a

reagent blank run at the same time as the standard curve and three tube blanks interspersed in each batch. References: Brzezinski & Nelson (1989); JGOFS (1996); Strickland & Parsons (1972).

5. Freon analysis - Sampling for the freons, CFC11 and CFC12, as well as analytical methods for their measurement were described previously (Bullister & Weiss, 1988; Bullister & Wisegarver, 2008), along with the equation of solubility of CFC11 and CFC12 as a function of temperature and salinity (Fine, 2011). A look-up table (Bullister, 2015) was used to convert CFC partial pressures measured in the Southern Hemispheric to the year of equilibration; the initial table covered up to the year 2015. The look-up table was extended to 2021 (M. Warner (Univ. Washington), personal communication).

6. Dissolved Inorganic Carbon and Total Alkalinity Measurements - The analytical method followed standardized protocols (Bates et al., 1996; Bates et al., 2001; Dickson et al., 2007; Knap et al., 1993). Samples for DIC and TA were collected in 250ml borosilicate glass bottles according to standard JGOFS methods. Milli-Q cleaned bottles were rinsed out 3 times, bottom filled using silicone tubing, allowed to overflow at least 1X the bottle volume, ensuring no bubbles were in the sample and that it was sealed with a small headspace to allow for water expansion. Water samples were collected from all depths the CTD-rosette sampled on full casts and from eight depths on the "trip-on-fly" casts. Two samples were collected from each Niskin bottle on the full casts. The first sample was poisoned with 100µl saturated mercuric chloride solution for analysis ashore. The second sample was not spiked and stored in the dark for no longer than 12 hours (to minimize any biological activity altering the sample) before being run aboard the ship, DIC first then TA. In addition to sampling from the rosette, samples were also collected and analyzed on board from the underway system. Both the underway and carboy samples were unpreserved, stored in the dark and analyzed on board the ship. Samples were processed at sea using a highly precise (0.02%; 0.4 millimoles per kilogram (mmoles kg-1)) VINDTA system (Bates, 2007; Bates et al., 1996; Bates & Peters, 2007). TA was measured on the VINDTA 3S by titration with a strong acid (HCl). The titration curve shows 2 inflection points, characterizing the protonation of carbonate and bicarbonate respectively, where consumption of acid at the second point is equal to the titration alkalinity. DIC was measured on the AIRICA by the extraction of total dissolved inorganic carbon content from the sample by phosphoric acid addition. The liberated CO_2 flowed with a N_2 carrier gas into a Li-Cor non-dispersive IR gas analyzer where the CO_2 levels were measured. For both instruments, within bottle replicates were run consecutively on start-up to check the precision, continuing once the instrument precision was ±2 micromoles per kilogram (µmol kg-1) or better. These were followed by a combination of Certified Reference Materials (CRMs) produced by the Marine Physical Laboratory at UCSD and low nutrient surface water from the Bermuda Atlantic Time Series (BATS) site, which were run every 20-24 samples on the VINDTA and every 6 samples on the AIRICA, to determine the accuracy and precision of the measurements and to correct for any discrepancies. The TA system CRM values did not vary more than 2 millimoles (mmol) within each batch of HCl acid. The AIRICA was more susceptible to drift and was affected by the lab temperature which is why CRMs were run much more often on the AIRICA, the system did not drift much and the lab temperature did not vary markedly. Both of the DIC and TA methods had a precision and accuracy of ~1 mmol kg-1 (precision estimates were determined from between-bottle and within-bottle replicates, and accuracy assessed using CRMs. The values for DIC and TA were used to calculate other parameters of the carbonate system using the software CO2sys (Lewis and Wallace, 1998). The calculated parameters were: pH, fCO_2, pCO_2, [HCO3-], [CO3=], [CO2], alkalinity from borate; hydroxide ion; phosphate and silicate, Revelle Factor, plus the saturation states of calcite and aragonite.

7. Nutrients - Analyses of phosphate, silicate, nitrate+nitrite, nitrite, and ammonia were performed on a Seal Analytical continuous-flow AutoAnalyzer 3 (AA3). The methods used were described by Gordon et al. (1992), Hager et al. (1972), and Atlas et al. (1971). Details of modification of analytical methods used in this cruise are also compatible with the methods described in the nutrient section of the GO-SHIP repeat hydrography manual (Hydes et al., 2010).

8. Coccolithophore enumeration - Polarized microscopy was used to determine the concentration of coccolithophores and detached coccoliths in samples collected in the SW Pacific during the R/V Roger Revelle cruise from December 2020 to February 2021. A volume of 200mL was filtered onto 0.4µm-pore size, 25mm diameter polycarbonate filter and then processed according to Balch & Utgoff (2009).

9. Enumeration of major algal classes - A shipboard Yokogawa Fluid Imaging Technologies FlowCam imaging cytometer was used to enumerate the major microalgal classes and estimate the particle size distribution function. The instrument was keyed on particle backscattering and fluorescence properties. Samples were first filtered through 100um Nitex mesh to make sure the 100um diameter flow chamber did not clog. The instrument was run with a 10X objective in order to reliably count particles bigger than 4-5um diameter. Samples were processed according to Poulton and Martin (2010). Concentrations (per mL), percent contribution with respect to total particles, and biomass are presented. Carbon biomass was determined based on Menden-Deuer & Lessard (2000) method.

10. Primary Production and Calcification Carbon rates - Samples were also taken for measuring photosynthesis and calcification rates from 21 morning, full-CTD stations over the course of the trip (here called Productivity Stations). For these measurements, Niskin bottles were tripped at specific light depths throughout the euphotic zone (0.56%, 3.86%, 7.10%, 23.4%, 42.2% and 73.6%). During casts where there was sufficient light to measure PAR throughout the euphotic zone, these depths were calculated assuming a constant diffuse attenuation coefficient. For samples taken during the nighttime, estimation of those light depths was performed based on the assumption that the fluorescence maximum was located at the 1% light depth (Poulton et al., 2017). Water samples for incubation were transferred from Niskin bottles to incubation bottles, typically inside the ship's enclosed hanger, under subdued light conditions. Water samples were pre-filtered through 120mm nitex mesh to remove large grazers. Incubations were performed in 70 mL polystyrene tissue culture bottles that were previously acid-cleaned, rinsed with ethanol, reverse-osmosis water, then rinsed 5x with each sea water sample prior to filling. Photosynthesis and calcification were measured using the microdiffusion technique (Paasche & Brubak, 1994) with modifications by Balch et al. (2000) (see also Fabry (2010)). 14C bicarbonate (~30 mCi) was added for each water sample. Incubations were performed in triplicate (with an additional 2% buffered formalin sample (final concentration) used as a killed control) in simulated in situ conditions on-deck, corrected for both light quantity (extinction using bags made of neutral-density shade cloth) and quality (spectral narrowing) using blue acetate bag inserts. Bottle transfers between the incubators and radioisotope van were always done in darkened bags to avoid light shock to the phytoplankton. Deck incubators consisted of blue plastic tubs open to sky light, chilled using surface seawater from the ship's flowing seawater system. Calibration of those light levels in the bag were previously made using a Biospherical OSR2100 scalar PAR sensor inserted into each bag relative to a scalar PAR sensor outside the bag. All filtrations were performed using 0.4 mm pore-size polycarbonate filters. Following sample filtration, polycarbonate filters were rinsed three times with filtered seawater, then carefully given a "rim rinse" to make sure that all 14C-HCO3 in interstitial seawater in the filters was rinsed out. Filters and sample "boats" were placed in scintillation vials with 7mL of Ecolume scintillation cocktail. Samples were counted using a high-sensitivity Beckman Tricarb liquid scintillation counter with channel windows set for 14C counting. Counts were performed for sufficient time to reach 1% precision or 25 minutes for samples with lower counts. Blank 14C counts were always run for scintillation cocktail as well as the phenethylamine CO_2 absorbent. Standard equations were used for calculating primary production and calcification from the 14C counts with a 5% isotope discrimination factor assumed for the physiological fixation of 14C-HCO3 as opposed to 12C-HCO3. Specific intrinsic growth rates of organic matter were calculated by dividing daily photosynthetic carbon estimates by the concentration of POC. Carbon-specific intrinsic growth rates for PIC were calculated by dividing the calcification rate by the concentration of PIC.

Known Problems or Issues:
The investigators discovered the calcification blanks during the cruise had consistently higher DPMs than the photosynthesis blanks. They ran an extra experiment on the formalin blanks to see whether the buffer in the buffered formalin used to kill the cells, was causing the artificially high blanks. This experiment was performed using highly oligotrophic, 0.2mm filtered water found north of the Subtropical front in which there was no measurable phytoplankton fluorescence. The investigators filled 10 productivity bottles with this water, and added buffered formalin (buffered to pH 8.8) to half of them (leaving the other five bottles "live" despite the fact that all particles >0.2mm diameter had been filtered out), then incubated all bottles with 30uCi 14C bicarbonate in the dark for 24h. All 10 bottles were subsequently filtered onto 0.4um polycarbonate filters and subjected to the microdiffusion technique. The calcification blanks for the filtered, non-killed samples had radioactivity that was 46% lower than the blank samples "killed" with buffered formalin. Given the state of oligotrophy in the original water samples, and that they were incubated in darkness, the investigators conclude that the buffered formalin-killed calcification blanks caused a small chemical artifact. That is, that the buffer injected with the formalin into the incubation bottles was driving the carbonate equilibrium to precipitate a small amount of the 14C-bicarbonate, which was then caught on the filters for the killed blanks. For this reason, for all calcification blanks, the investigators subtracted the blank formalin values from filters that were acidified prior to counting (which drove off any residual 14C-carbonate precipitate (artifact) or residual 14C bicarbonate solution left in the interstices of filters).

BCO-DMO Processing Description

- Imported original file "rr2004_masterData_v8 for BCO-DMO.csv" into the BCO-DMO system.
- Re-named fields to comply with BCO-DMO naming conventions.
- Removed the original "yyyy-mm-ddThh:mm:ss" field, which was mostly empty.
- Created the ISO_Date_UTC column using the Month, Day, and Year fields as input.
- Saved the final data file as "907028_v1_rr2204_bottle.csv".

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Data Files

File
907028_v1_rr2204_bottle.csv (Comma Separated Values (.csv), 1.36 MB) MD5:a6a329b9bb478f847ca87474b96fc8ba Primary data file for dataset ID 907028, version 1.

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Parameters

Parameter	Description	Units
Sample	unique sample number	unitless
Type	four types of sampling: CTD, EXP, NX, UW. CTD = discrete Niskin bottle samples from CTD cast; EXP = Carboy Experiment sampling; NX = Niskin X cast using trace metal-clean Niskin X bottles hung from Kevlar cable; UW = surface underway sample taken from ship's non-toxic seawater line.	unitless
Station	station number (between 1 and 103)	unitless

Event	sequential operation during station	unitless
Cast	sequential attempted sampling operation for a given event	unitless
Niskin	numbered Niskin bottle tripped on CTD casts	unitless
Trip_on_Fly	code for trip-on-fly cast: 0 if "no" and 1 if "yes"	unitless
Incubation	letter A-E designating results from each of five experiments	unitless
Timepoint	numbered sampling of carboy experiment	unitless
Elapsed_Time_hours	number of hours after start of carboy incubation	hours
Treatment	description of carboy treatment	unitless
Cubitainer	number of incubation cubitainer	unitless
Underway_Number	unique number of underway sample	unitless
Salinometer_Sample_Number	sequentially numbered salinometer sample	unitless
Lab_O2_Sample_Number	sequentially numbered oxygen sample for Winkler titration O2 sample	unitless
Nutrient_Sample_Number	sequentially numbered nutrient sample number	unitless
CTD_Sample_Number	sequentially numbered CTD sample	unitless
Balch_Sample_Number	sequentially numbered sample from Balch lab	unitless
Freon_Sample_Number	sequentially numbered freon sample number	unitless
Month	number month of year	unitless
Day	number day of month	unitless
Year	year	unitless
Trip_Time	time (GMT) bottle tripped	unitless
Latitude	decimal degrees of latitude of sample location, negative values = South	degrees North
Longitude	decimal degrees of longitude of sample location; negative values = West	degrees East
Sal00	salinity of water sample as estimated by conductivity probe 0	PSU (Practical Salinity Units)
Sal11	salinity of water sample as estimated by conductivity probe 1	PSU (Practical Salinity Units)
Sigma_E900	density anomaly of seawater calculated from salinity derived from conductivity probe 0	metric tonnes per cubic meter
Sigma_E911	density anomaly of seawater calculated from salinity derived from conductivity probe 1	metric tonnes per cubic meter
Sbeox0_mL_per_L	Oxygen concentration derived from Sea Bird oxygen probe on CTD	milliliters per liter (mL L-1)

Oxsol_mL_per_L	Estimated 100%-saturated concentration of oxygen for given temperature and salinity conditions	milliliters per liter (mL L-1)
Bottle_O2_Flag	possible suspect bottle oxygen datum as indicated by analist for various reasons; 0 =no flag; 1=flag	unitless
Potemp090C	Potential temperature ITS-90 (primary temperature probe)	degrees Celsius
Potemp190C	Potential temperature ITS-90 (secondary temperature probe)	degrees Celsius
SvCM	Sound Velocity [Chen-Millero 1977] based on temperature & salinity probes #1	meters per second (m/s)
SvCM1	Sound Velocity [Chen-Millero 1977] based on temperature & salinity probes #2	meters per second (m/s)
PrDM	water pressure	decibars
Depth_m	water depth	meters
T090C	CTD temperature (ITS-90) probe 1	degrees Celsius
T190C	CTD temperature (ITS-90) probe 2	degrees Celsius
C0_S_per_m	Conductivity based on conductivity probe 0	Siemens per meter (S/m)
C1_S_per_m	Conductivity based on conductivity probe 1	Siemens per meter (S/m)
Sbeox0V	SeaBird oxygen probe 0	volts
FlECO_AFL	Chlorophyll Fluorescence; WET Labs ECO-AFL/FL sensor 0	Volts DC
FlECO_AFL1	Chlorophyll Fluorescence; WET Labs ECO-AFL/FL sensor 1	Volts DC
CStarTr0	Beam transmission WetLabs Cstar	percent
TurbWETbb0	Turbidity; WET Labs ECO BB	per meter (m-1)
Par	Photosynthetically Available Radiation measured at depth	microEinsteins per square centimeter per second (uE/(cm2·sec))
Spar	Surface photosynthetically available radiation measured at the surface	microEinsteins per square centimeter per second (uE/(cm2·sec))
Cpar	fraction of photosynthetically available radiation measured at depth	percent
V5_WET_Labs_ECO_BB_Volts	backscattering measured with a WET Labs ECO-BB	volts
Scan	number of the CTD scan in which measurements were made	unitless

Lab_Salinity	lab-derived salinity	PSU (Practical Salinity Units)
Lab_Salinity_Flag	possible suspect lab salinity datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
Lab_O2__mL_per_L	Oxygen concentration	milliliters per liter (mL/L)
Lab_O2_Flag	possible suspect oxygen datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
NO3_umol_per_L	concentration of nitrate	micromoles per liter (umoles/L)
PO4_umol_per_L	concentration of phosphate	micromoles per liter (umoles/L)
SIL_umol_per_L	concentration of silicate	micromoles per liter (umoles/L)
NO2_umol_per_L	concentration of nitrite	micromoles per liter (umoles/L)
NH4_umol_per_L	concentration of ammonia	micromoles per liter (umoles/L)
Nutrient_Flag	possible suspect nutrient sample datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
POC_ug_per_L	concentration of particulate organic carbon	micrograms per liter (ug/L)
POC_Flag	possible suspect POC datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
PON_ug_per_L	concentration of particulate organic nitrogen	micrograms per liter (ug/L)
POC_umol_per_L	concentration of particulate organic carbon	micromoles per liter (umoles/L)
PON_umol_per_L	concentration of particulate organic nitrogen	micromoles per liter (umoles/L)
PON_Flag	possible suspect PON datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
PIC_umol_per_L	concentration of particulate inorganic carbon	micromoles per liter (umoles/L)
PIC_ug_per_L	concentration of particulate inorganic carbon	micrograms per liter (ug/L)
PIC_mol_per_cubic_m	concentration of particulate inorganic carbon	moles per cubic meter (mol/m3)

PIC_Flag	possible suspect PIC datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
Single_Lith_count_per_mL	concentration of birefringent particles-singlets	numbers per milliliter (mL)
Double_Lith_count_per_mL	concentration of birefringent particles-doublets	numbers per milliliter (mL)
Triple_Lith_count_per_mL	concentration of birefringent particles-triplets	numbers per milliliter (mL)
Quadruple_Lith_count_per_mL	concentration of birefringent particles-quadruplets	numbers per milliliter (mL)
Tot_Lith_count_per_mL	concentration of birefringent particles-all	numbers per milliliter (mL)
Cell_plus_Agg_count_per_mL	concentration of birefringent plated cells; coccospheres and aggregates	numbers per milliliter (mL)
Lith_Area_square_um_per_mL	total area subtended by by detached coccoliths	square micrometers per milliliter (um^2 per mL)
Cell_plus_Agg_Area_square_um_per_mL	total area subtended by by plated coccolithophores; coccospheres and aggregates	square micrometers per milliliter (um^2 per mL)
Cell_Count_Flag	possible suspect cell count datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
BSi_umol_per_L	concentration of biogenic silica	micromoles per liter (umoles/L)
BSi_Flag	possible suspect biogenic silica datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
Avg_Corr_Chl_a_ug_per_L	concentration of chlorophyll a	micrograms per liter (ug/L)
Avg_Corr_Phaeo_ug_per_L	concentration of phaeopigments	micrograms per liter (ug/L)
Avg_Corr_Chl_a_plus_Phaeo_ug_per_L	concentration of chlorophyll a plus phaeopigments	micrograms per liter (ug/L)
Chl_Flag	possible suspect chlorophyll datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless

PSD_Slope_logABD_grthan_point_75	PDF Slope logABD>0.75 (only particles >5um); Particle size Distribution Function slope of the plot of log cell abundance (particles per mL) versus Area Based Diameter (micrometers) calculated for particles of >5 micrometers diameter using a Yokogowa FlowCAM. Area Based Diameter (ABD) is defined as the diameter measured by the number of grey scale pixels of the binary image converted to a circle with the same number of pixels	unitless
Std_Err_of_PSD_Slope_logABD_grthan_point_75	Std Err of PDF Slope logABD>0.75 (for particles >5um); Standard error of the above particle size distribution slope for only particles of 5 micrometers diameter or larger using a Yokogowa FlowCAM	unitless
Y_int_of_PSD_Slope_logABD_grthan_point_75	Y-int of PDF Slope logABD>0.75 (only particles >5um); the Y intercept of above PDF for only particles of ~5um diameter or larger using a Yokogowa FlowCAM	unitless
R2of_PSD_Slope_logABD_grthan_point_75	R-squared value of PDF Slope logABD>0.75(only particles >5um); squared correlation coefficient of above PDF for only particles of >5um diameter or larger using a Yokogowa FlowCAM	unitless
F_statistic_of_PSD_Slope_logABD_grthan_point_75	F-statistic of PDF Slope logABD>0.75 (only particles >5um); the F statistic of of above PDF for only particles of >5um diameter or larger using a Yokogowa FlowCAM	unitless
Total_cells_per_mL	Concentration of total particles measured by Yokogowa measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Small_0_4um_cells_per_mL	Concentration of small particles with diameters of 0 to 4 micrometers measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Round_4_12um_cells_per_mL	Concentration of round particles with diameters of 4 to 12 micrometers measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Ovoid_4_12um_cells_per_mL	Concentration of ovoid particles with diameters of 4 to 12 micrometers measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Dinoflagellates_cells_per_mL	Concentration of dinoflagellates measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Ciliates_cells_per_mL	Concentration of ciliates measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)

Diatoms_cells_per_mL	Concentration of diatoms measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Silicoflagellates_cells_per_mL	Concentration of silicoflagellates measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Other_Cells_cells_per_mL	Concentration of other unidentified cells as measured by Yokogowa FlowCAM imaging cytometer	cells per milliliter (cells/mL)
Small_0_4um_pcnt	Percent of total particles contributed by small (0-4 um) particles as measured by Yokogowa FlowCAM imaging cytometer	unitless
Round_4_12um_pcnt	Percent of total particles contributed by round (4-12 um) particles as measured by Yokogowa FlowCAM imaging cytometer	unitless
Ovoid_4_12um_pcnt	Percent of total particles contributed by ovoid (4-12 um) particles as measured by Yokogowa FlowCAM imaging cytometer	unitless
Dinoflagellates_pcnt	Percent of total particles contributed by dinoflagellates as measured by Yokogowa FlowCAM imaging cytometer	unitless
Ciliates_pcnt	Percent of total particles contributed by ciliates as measured by Yokogowa FlowCAM imaging cytometer	unitless
Diatoms_pcnt	Percent of total particles contributed by diatoms as measured by Yokogowa FlowCAM imaging cytometer	unitless
Silicoflagellates_pcnt	Percent of total particles contributed by silicoflagellates as measured by Yokogowa FlowCAM imaging cytometer	unitless
Other_Cells_pcnt	Percent of total particles contributed by unidentified other cells as measured by Yokogowa FlowCAM imaging cytometer	unitless
Total_C_Biomass_Menden_Deuer_ug_per_L	Total carbon biomass (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Small_0_4um_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of small 0-4um cells (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Round_4_12um_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of round 4-12um cells (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)

Ovoid_4_12um_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of ovoid 4-12um cells (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Dinoflagellates_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of dinoflagellates (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Ciliates_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of ciliates (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Diatoms_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of diatoms (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Silicoflagellates_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of silicoflagellates (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Other_Cells_C_Biomass_Menden_Deuer_ug_per_L	Carbon biomass of unidentified other cells (based on Menden-Deuer and Lessard, 2000) for total particles measured by Yokogowa FlowCAM imaging cytometer	micrograms per liter (ug/L)
Flowcam_Flag	possible suspect FlowCAM datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
Psy_Avg_C_to_P	Ratio of calcification to photosynthesis	unitless
Psy_Avg_P	Average photosynthesis rate	micromoles Carbon per liter per day (umol C/L/d)
Psy_Avg_C	Average calcification rate	micromoles Carbon per liter per day (umol C/L/d)
Psy_P_SD	standard deviation of photosynthesis rate	micromoles Carbon per liter per day (umol C/L/d)
Psy_C_SD	standard deviation of calcification rate	micromoles Carbon per liter per day (umol C/L/d)
Psy_Avg_Chl_a_ug_per_L	chlorophyll concentration in productivity sample	micrograms per liter (ug/L)

Psy_Avg_Pmb_ug_C_per_ug_chl_d	chlorophyll-normalized primary production rate	micrograms Carbon per micrograms chlorophyll per day (ugC/ugchl/d)
Psy_Avg_Cmb_ug_C_per_ug_chl_d	chlorophyll-normalized calcification rate	micrograms Carbon per micrograms chlorophyll per day (ugC/ugchl/d)
Psy_Flag	possible suspect productivity or calcification datum as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
Freon_Flag	possible suspect freon sample as indicated by analist for various reasons; 0 = no flag; 1 = flag	unitless
Sal_corrected	salinity corrected for bottle salinity measured aboard ship	PSU (Practical Salinity Units)
Sbeox_corrected_mL_per_L	Seabird oxygen concentration corrected for lab oxygen concentration measured aboard ship	milliliters per liter (mL/L)
DIC_umol_per_kg	dissolved inorganic carbon concentration	micromoles per kilogram (umol/kg)
TA_umol_per_kg	Total akalinity	micromoles per kilogram (umol/kg)
F12_pM	concentration of CFC-12	picomolar (pM)
F11_pM	concentration of CFC-11	picomolar (pM)
ISO_Date_UTC	Date (UTC) in ISO 8601 format	unitless

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Instruments

Dataset-specific Instrument Name	VINDTA 3S
Generic Instrument Name	Automatic titrator
Generic Instrument Description	Instruments that incrementally add quantified aliquots of a reagent to a sample until the end-point of a chemical reaction is reached.

Dataset-specific Instrument Name	Biospherical OSR2100 scalar PAR sensor
Generic Instrument Name	Biospherical PAR sensor
Generic Instrument Description	Unspecified Biospherical PAR. An irradiance sensor, designed to measure Photosynthetically Active Radiation (PAR).

Dataset-specific Instrument Name	CTD Sea-Bird SBE911plus
Generic Instrument Name	CTD Sea-Bird SBE 911plus
Generic Instrument Description	The Sea-Bird SBE 911 plus is a type of CTD instrument package for continuous measurement of conductivity, temperature and pressure. The SBE 911 plus includes the SBE 9plus Underwater Unit and the SBE 11plus Deck Unit (for real-time readout using conductive wire) for deployment from a vessel. The combination of the SBE 9 plus and SBE 11 plus is called a SBE 911 plus. The SBE 9 plus uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 plus and SBE 4). The SBE 9 plus CTD can be configured with up to eight auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorescence, light (PAR), light transmission, etc.). more information from Sea-Bird Electronics

Dataset-specific Instrument Name	Perkin Elmer 2400 Series II CHNS/O
Generic Instrument Name	Elemental Analyzer
Generic Instrument Description	Instruments that quantify carbon, nitrogen and sometimes other elements by combusting the sample at very high temperature and assaying the resulting gaseous oxides. Usually used for samples including organic material.

Dataset-specific Instrument Name	Li-Cor non-dispersive IR gas analyzer
Generic Instrument Name	Gas Analyzer
Generic Instrument Description	Gas Analyzers - Instruments for determining the qualitative and quantitative composition of gas mixtures.

Dataset-specific Instrument Name	ICP-AES (Inductively Couple Plasma - Atomic Emission Spectrometry)
Generic Instrument Name	Inductively Coupled Plasma Optical Emission Spectrometer
Generic Instrument Description	Also referred to as an Inductively coupled plasma atomic emission spectroscope (ICP-AES). These instruments pass nebulised samples into an inductively-coupled gas plasma (8-10000 K) where they are atomised and excited. The de-excitation optical emissions at characteristic wavelengths are spectroscopically analysed. It is often used in the detection of trace metals.

Dataset-specific Instrument Name	Beckman Tricarb liquid scintillation counter
Generic Instrument Name	Liquid Scintillation Counter
Generic Instrument Description	Liquid scintillation counting is an analytical technique which is defined by the incorporation of the radiolabeled analyte into uniform distribution with a liquid chemical medium capable of converting the kinetic energy of nuclear emissions into light energy. Although the liquid scintillation counter is a sophisticated laboratory counting system used the quantify the activity of particulate emitting (ß and a) radioactive samples, it can also detect the auger electrons emitted from 51Cr and 125I samples.

Dataset-specific Instrument Name	Polarized microscopy
Generic Instrument Name	Microscope - Optical
Generic Instrument Description	Instruments that generate enlarged images of samples using the phenomena of reflection and absorption of visible light. Includes conventional and inverted instruments. Also called a "light microscope".

Dataset-specific Instrument Name	Niskin-X and 10L Niskin bottles
Generic Instrument Name	Niskin bottle
Generic Instrument Description	A Niskin bottle (a next generation water sampler based on the Nansen bottle) is a cylindrical, non-metallic water collection device with stoppers at both ends. The bottles can be attached individually on a hydrowire or deployed in 12, 24, or 36 bottle Rosette systems mounted on a frame and combined with a CTD. Niskin bottles are used to collect discrete water samples for a range of measurements including pigments, nutrients, plankton, etc.

Dataset-specific Instrument Name	Seal Analytical continuous-flow AutoAnalyzer 3 (AA3)
Generic Instrument Name	Nutrient Autoanalyzer
Generic Instrument Description	Nutrient Autoanalyzer is a generic term used when specific type, make and model were not specified. In general, a Nutrient Autoanalyzer is an automated flow-thru system for doing nutrient analysis (nitrate, ammonium, orthophosphate, and silicate) on seawater samples.

Dataset-specific Instrument Name	incubation bottles, deck incubators
Generic Instrument Name	Shipboard Incubator
Generic Instrument Description	A device mounted on a ship that holds water samples under conditions of controlled temperature or controlled temperature and illumination.

Dataset-specific Instrument Name	Hitachi U-3010 spectrophotometer (SN 0947-010)
Generic Instrument Name	Spectrophotometer
Generic Instrument Description	An instrument used to measure the relative absorption of electromagnetic radiation of different wavelengths in the near infra-red, visible and ultraviolet wavebands by samples.

Dataset-specific Instrument Name	Turner Designs 10AU fluorometer
Generic Instrument Name	Turner Designs Fluorometer 10-AU
Generic Instrument Description	The Turner Designs 10-AU Field Fluorometer is used to measure Chlorophyll fluorescence. The 10AU Fluorometer can be set up for continuous-flow monitoring or discrete sample analyses. A variety of compounds can be measured using application-specific optical filters available from the manufacturer. (read more from Turner Designs, turnerdesigns.com, Sunnyvale, CA, USA)

Dataset-specific Instrument Name	Yokogowa FlowCAM imaging cytometer
Generic Instrument Name	Yokogawa Fluid Imaging Technologies FlowCam VS particle imaging system
Generic Instrument Description	Imaging cytometers are automated instruments that quantify properties of single cells, one cell at a time. They combine some aspects of flow cytometry with particle imaging capabilities in an automated device to classify small particles, including phytoplankton and protozoa. They can measure a variety of properties: cell size, cell granularity, cell aspect ratio, equivalent spherical diameter (ESD) and area-based diameter (ABD) [to estimate bio-volume, which is used to estimate cell carbon biomass]. Particle images are digitally recorded and sorted into different classes according to training libraries using a support vector machine (supervised learning methods). The instruments particle-size is calibrated using different sizes of latex beads. The FlowCam VS series are automated imaging-in-flow instruments that generate high-resolution digital images for measuring size and shape of microscopic particles. The sample introduced in the system is attracted by a peristaltic or a syringe pump into a flow cell (or flow chamber) with known dimensions, located in front of a microscope objective which is connected to a camera video. The benchtop model is ideally suited to a typical laboratory environment with applications in oceanographic research, municipal water, biopharmaceutical formulations, chemicals, oil and gas, biofuels, and many other markets. FlowCam VS is available in four models, from the imaging-only VS-I (i.e. without excitation wavelength or fluorescence emission wavelengths) to the top-of-the-line VS-IV with two channels of fluorescence measurement and scatter triggering capabilities. The instrument can measure particles between 2µm and 2mm; can analyse in vivo or fixed samples; has a flow rate between 0.005 ml/minute and 250 ml/minute (dependant upon magnification, flow cell depth, camera frame rate, efficiency desired, etc.). It can produce either 8-bit Grayscale (Monochrome Camera) or 24-bit Colour (Colour Camera) images, depending on the model.

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Deployments

RR2004

Website	https://www.bco-dmo.org/deployment/904213
Platform	R/V Roger Revelle
Start Date	2020-12-26
End Date	2021-02-23
Description	See more information at R2R: https://www.rvdata.us/search/cruise/RR2004 Description of Cruise (provided by Chief Scientist Barney Balch): This cruise departed Honolulu, Hawaii on 26 December 2020 (following two weeks of strict quarantine/isolation for Covid plus 4 days of loading of the ship within the Revelle's Covid "bubble"). The ship transited south along the great circle route from Honolulu to 30°S x 150°W. We targeted this meridian for several reasons. First, Sub-Antarctic Mode Water (SAMW) is formed in the Southern Ocean at high rates in the vicinity of this meridian (Cerovečki et al., 2013). This water is subsequently subducted and gets carried northward at depths of 500-700 meters (m), where it is brought closer to the surface in about 40 years' time in the equatorial regions, influencing the productivity of these waters as well as those further into the northern hemisphere (Sarmiento et al., 2004). Second, ocean color satellite data over the last 23 years has shown elevated reflectance from the Great Calcite Belt between the latitudes of 40°S to 50°S but this region is extremely remote and few actual observations exist to confirm this (Balch et al., 2016). Third, ocean color imagery has also revealed regions of elevated coccolithophore-like reflectance further south than 50°S latitude along this meridian, but these waters have temperatures well below the preferred temperature range of the common coccolithophore species of the Southern Ocean, Emiliana huxleyi, hence we suspected another particle type likely is responsible. There is strong topographic steering of the currents along the subantarctic front, the polar front, and the southern Antarctic Circumpolar current by the Pacific Antarctic Ridge and its associated Udintsev and Eltanin Fracture Zones. Fourth, this region has elevated frequencies of eddy formation, with trapped high-reflectance waters, which provide opportunities to follow these semi-enclosed parcels and their trapped populations in space and time. A meridional transect along 150°W provided an opportunity to track the formation of SAMW and its age using Freon measurements (to be performed ashore by the laboratory of Dr. Rana Fine (Rosenstiel School of Marine and Atmospheric Sciences, Miami, FL) (Fine, 1993, 2011; Fine et al., 2002; Fine et al., 2008). Knowing the age of SAMW allows determination of the rates that SAMW is being conditioned by diatoms, coccolithophores, and other classes of phytoplankton on its trek to the north. We began the meridional transect (with CTD casts at 0.5° latitude resolution at 30°S-47°S), and we switched to a higher resolution of sampling from 47°S to 60°S (so-called "enhanced" meridional transect at 0.33° latitude resolution), plus the addition of Video Plankton Recorder (VPR) tows, in order to better define mesoscale features that we encountered (with both satellite and ship data) along the 150°W meridian. The enhanced meridional transect was done in 180-240 nautical mile segments along 150°W, which allowed for more flexible scheduling of the VPR transects during good weather days, allowing safer VPR deployment and recovery, whereas the CTD stations could be performed safely on the many more inclement days with higher sea states when the VPR could not be deployed safely. Five carboy experiments were performed during the trip to investigate factors limiting to the phytoplankton production. After completion of the meridional transect (both reduced-resolution and enhanced resolution), we headed east for the first crossing of the polar front which was shown through altimetry to be topographically-steered through the Udintsev Fracture Zone. Moreover, satellite remote sensing of this feature showed it to be of high reflectance. After crossing the Polar Front the first time, we surveyed a mesoscale eddy that contained waters with elevated reflectance around the edge (hereafter referred to as "Eddy A") performing two radial surveys with complete VPR and hydrographic sections. Two productivity and trace-metal casts were performed in Eddy A along with a carboy experiment, as well. The ship then transited south and east to perform a cross frontal VPR and hydrographic survey (which crossed the same polar frontal boundary crossed earlier during the meridional transect, as well as during the transit to Eddy A; this transect was called the "Cross Frontal Transect"). At this point of the cruise, French Polynesia announced that the ports in Tahiti would be closed for the ship to disembark scientists at the end of February. This meant that the ship would have to return to Honolulu at cruise end, which, in turn, meant that we would lose about one week of science time for the long transit back to Honolulu. Therefore, we devised a streamlined cruise plan for the remainder of the cruise in order to achieve all of our objectives. The ship then visited a small mesoscale eddy (Eddy C) which contained a highly focused, high-reflectance core that we had observed in satellite imagery for several weeks. We performed one VPR tow and one

	hydrographic survey along one diameter across the small eddy and left Eddy C with VPR in tow, to do a repeat crossing of Eddy A, then onward to a high-reflectance meander of the SubAntarctic Front for collection of water for the fourth experiment and documentation of the conditions of the SAF. We then headed for the portion of the meridional survey where we had seen low levels of coccolithophores three weeks prior. This region had remained cloud-covered for weeks, thus we had little idea of what awaited us. Shortly after leaving the Meander station, the estimates of acid-labile backscattering (an optical proxy for PIC) began rising and for the next 400 nautical miles saw PIC concentrations three times higher than anything we had seen previously along the 150°W meridian (or elsewhere for that matter). References: Fine, R. A. (2011), Observations of CFCs and SF 6 as ocean tracers, Annual Review of Marine Science, 3, 173-195, doi:10.1146/annurev.marine.010908.163933.

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Project Information

Collaborative Research: Biogeochemical and Physical Conditioning of Sub-Antarctic Mode Water in the Southern Ocean (Conditioning_SAMW)

NSF Award Abstract:
Cold surface water in the southern Indian Ocean sinks to about 500 meters and travels in the dark for thousands of miles before it resurfaces some 40 years later near the equator in the other ocean basins. This major water mass is named the Sub-Antarctic Mode Water (SAMW). Nutrients it contains when it warms and rises into the sunlit subtropical and tropical waters are estimated to fuel up to 75% of the microscopic plant growth there. Before it sinks, the chemical properties of the SAMW are modified by the growth and distinct physiology of two common phytoplankton; diatoms with shells made of silica, and coccolithophores with carbonate shells. Local physical dynamics influence where and how fast these two phytoplankton classes grow. Consequently, differing nutrient and trace chemical fingerprints are established at the point of SAMW formation. This project is an exceptionally detailed field and modeling effort that will document and quantify the remarkable, interconnected processes that chemically connect two important oceanic ecosystems half a world apart. The scientists leading the project will study the complexity of the biological and chemical conditioning of the SAMW and thus provide critical data about the large-scale oceanic controls of the biological carbon pump that removes atmospheric carbon dioxide to the deep ocean over millennial timescales. Scientific impact from this project will stem from significant peer-reviewed publications and improved predictive models. Societal benefits will develop from training of a range of scholars, including high school, undergraduate, and graduate students, as well as technical and post-doctoral participants. A high school teacher and science communication specialist will go to sea with the project and share experiences from the ship with students on shore via social media and scheduled web interactions.

To examine how SAMW formation and subduction controls the productivity of global waters well to the north, two January expeditions to the SE Indian Ocean will identify, track, and study the unique mesoscale eddies that serve as discrete water parcels supporting rich populations of either coccolithophores or diatoms plus their associated microbial communities. The eddies will be tracked with Lagrangian Argo drifters and observations will be made of exactly how SAMW is chemically conditioned (i.e. Si, N, P, Fe, and carbonate chemistry) over time scales of months. Using data obtained on the feedback between ecological processes and nutrient, trace metal, and carbonate chemistry in these eddies and on related transect cruises, the project will have three main goals: (1) determine the rates at which SAMW coccolithophores and diatoms condition the carbonate chemistry plus nutrient and trace metal concentrations, as well as assess taxonomic and physiological diversity in the study area with traditional methods plus next-generation sequence DNA/RNA profiling, (2) explore growth limitations by iron, silicate and/or nitrate in controlling algal assemblages and genetic diversity, and (3) combine these findings with the Ekman- and eddy-driven subduction of SAMW to examine biogeochemical impact on a basin scale, using both observations and global numerical models. A meridional survey from 30 to 60 degrees south latitude will be used to characterize the larger-scale variability of carbonate chemistry, nutrient distributions, productivity, genetics and biomass of various plankton groups as SAMW is subducted and proceeds northward.

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