1-decibar binned CTD data from 103 stations collected during R/V Roger Revelle cruise RR2004 along the 150W meridian from 30S to 60S

Website: https://www.bco-dmo.org/dataset/908342
Data Type: Cruise Results
Version: 1
Version Date: 2023-09-22

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

Contributors	Affiliation	Role
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Abstract
This dataset includes the processed CTD data from 103 stations collected during R/V Roger Revelle cruise RR2004, which sailed from Honolulu, Hawaii on December 26, 2020 to the Southern Ocean and returned to Honolulu on February 23, 2021. Data have been binned by pressure into 1-decibar bins.

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Coverage

Spatial Extent: **N**:-29.997 **E**:-137.022 **S**:-59.9983 **W**:-150.004
Temporal Extent: 2021-01-08 - 2021-02-09

Methods & Sampling

These data were collected during cruise RR2004 on the R/V Roger Revelle using a Sea-Bird SBE911plus CTD. This cruise departed Honolulu, Hawaii on December 26, 2020 and the ship transited south along the great circle route from Honolulu to 30°S x 150°W, returning to Hawaii on February 23, 2021. CTD casts were performed at 103 stations, encompassing Subtropical, Subantarctic, and Polar waters in the Pacific Sector of the Southern Ocean.

Hydrographic profiles were performed along the transect with the CTD (the "full-water cast"), sampling for Freons, dissolved oxygen, DIC, alkalinity, extracted chlorophyll, nutrients, POC, PIC, biogenic silica, coccolithophore counts and FlowCAM analyses. 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. These trip-on-fly casts served to provide greater resolution in hydrographic sections across the features.

Evaluation and calibration of CTD conductivity and oxygen sensors

Salinity:
For the first 62 stations of RR2004, there was a consistent salinity offset of 0.016 ± 0.033 between conductivity sensors. There was a 0.013 ± 0.006 difference in salinity estimated from the salinometer and conductivity sensor 1, and a -0.004 ± 0.034 difference for conductivity sensor 2. The large standard deviations in the offset for conductivity sensor 2 were due to casts 32 and 33, where the pump for CTD 2 became disconnected. Removing these stations reduces the salinometer/conductivity sensor 2 offset to -0.0005 ± 0.006. Given the high agreement of conductivity sensor 2 with the salinometer, conductivity sensor 1 was replaced for stations 63 through the end of the cruise. After switching out the sensor, the difference between salinities between conductivity sensor 1 and 2 was reduced to 0.004 ± 0.002 (see Figure S1 Supplemental File), with a difference between the salinometer and CTD 1 0.0001 ± 0.0233 and a difference between the salinometer and CTD 2 of -0.0039 ± 0.0233. The difference between CTD 1 and the salinometer and CTD 2 and the salinometer was statistically significant (Student's t-test, t = -49.9, 95% confidence interval: -0.0041 – -0.0038, $p < 0.001$, 452 degrees of freedom), and so the salinometer measurements are significantly better represented by salinities measured by CTD 1 than CTD 2 for stations 63 onwards.

To summarize, users of salinities from RR2004 conductivity sensors should consider:
1) applying a correction factor of ~0.01 to conductivity sensor 1 salinities, at least for stations 32 and 33 where conductivity sensor 2 was not operational;
2) using salinities from conductivity sensor 2 for stations 1-62, except stations 32 and 33; and
3) using salinities from conductivity sensor 1 for stations 63 onward.

Oxygen:
Systematically low measurements recorded by CTD oxygen sensor during casts 1 and 2 led to its replacement for the remainder of the cruise. For stations 3 and onward, there was good agreement between the O2 sensor and the oxygen measurements made in the Hydrolab (see Figure S2 Supplemental File), with

2 = 1.0079[CTD O2] + 0.0643

which has $R^2 > 0.99$. For stations 1-2, the calibration is

O2 = 1.5205[CTD O2] + 0.9017

which has $R^2 = 0.91$.

Data Processing Description

Data were processed using Seasave V 7.26.7.121. Processing included binning into 1-decibar bins. For the full processing steps, see the attached Supplemental File containing the complete Seabird header from one cast (station 00101).

BCO-DMO Processing Description

- Imported the original downcast .cnv files (103 total; one per cast) into the BCO-DMO system.
- Marked "-9.990e-29" as the missing data identifier. In the final CSV file, missing values are blank/empty.
- Captured the starting latitude, starting longitude, starting date/time, and station number from the Seabird headers as columns.
- Corrected station numbers in files d03701, d07801, and d09401.
- Concatenated the separate files into one dataset.
- Converted starting latitude and longitude to decimal degrees and rounded values to 5 decimal places.
- Converted starting date/time to ISO8601 format.
- Renamed fields to comply with BCO-DMO parameter naming conventions.
- Saved the final file as "908342_v1_RR2004_CTD.csv".

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Data Files

File
908342_v1_RR2004_CTD.csv (Comma Separated Values (.csv), 23.13 MB) MD5:b2039f0fdfc915959258a7a445c9fdba Primary data file for dataset ID 908342, version 1.

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Supplemental Files

File
Figure S1 filename: Fig_S1.png (Portable Network Graphics (.png), 47.30 KB) MD5:6c116316f782dddc57255c780973fe9a Supplemental file for dataset ID 908342, version 1. Figure S1. Differences between salinities for conductivity sensor 1 and conductivity sensor 2, and between conductivity sensor 1 and the salinometer.
Figure S2 filename: Fig_S2.png (Portable Network Graphics (.png), 31.51 KB) MD5:6e5875b65353b3cb9e03c8db9604f4e4 Supplemental file for dataset ID 908342, version 1. Figure S2. Agreement between the Hydrolab O2 measurements and the CTD oxygen sensor.
RR2004_d00101_Sea-Bird_CTD_Header.txt (Plain Text, 13.66 KB) MD5:b076bcb785aa0a8099887177f3b36905 Supplemental file for dataset ID 908342, version 1. Example of a CTD header file extracted from the original .cnv file named "d00101.cnv"
RR2004_processed_CTD.zip (ZIP Archive (ZIP), 28.47 MB) MD5:579afa760b3e83e76ef8be953a3ab6b7 Supplemental file for dataset ID 908342, version 1. This .zip folder contains the original (processed) CTD data, where each cast has one .asc file, one .btl file, one .ros file, and three .cnv files (one for the upcast, denoted by "u" in the file name; one for the downcast, denoted by "d" in the file name; and one for the full (up+down) cast). The downcast files have been concatenated by BCO-DMO into one single .csv file named "908342_v1_RR2004_CTD.csv", which is the primary data file for this dataset.

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Parameters

Parameter	Description	Units
Station	Station identifer	unitless
cnv_file_name	Name of the original .cnv file	unitless
Ship	Name of the cruise	unitless
Lat_Start	Latitude at start of cast; negative values = South	decimal degrees
Lon_Start	Longitude at start of cast; negative values = West	decimal degrees
ISO_DateTime_UTC_Start	Date and time (UTC) at start of cast in ISO 8601 format	unitless
prDM	Pressure, Digiquartz	decibars (db)
t090C	Temperature (ITS-90)	degrees Celsius
t190C	Temperature, 2 (ITS-90)	degrees Celsius
c0S_m	Conductivity	Siemens per meter (S/m)
c1S_m	Conductivity, 2	Siemens per meter (S/m)
sbeox0V	Oxygen raw, SBE 43	volts (V)
flECO_AFL	Fluorescence, WET Labs ECO-AFL/FL	milligrams per cubic meter (mg/m^3)
flECO_AFL1	Fluorescence, WET Labs ECO-AFL/FL, 2	milligrams per cubic meter (mg/m^3)
CStarTr0	Beam Transmission, WET Labs C-Star	percent
turbWETbb0	Turbidity, WET Labs ECO BB	per meter-stearadian (m^-1/sr)
par	PAR/Irradiance, Biospherical/Licor	micromoles photons per square meter per second (umol photons/m^2/sec)
spar	SPAR, Biospherical/Licor	micromoles photons per square meter per second (umol photons/m^2/sec)
cpar	CPAR/Corrected Irradiance	percent
v5	Voltage for the Wetlabs Turbidity sensor	volts (V)
sal00	Salinity, Practical	PSU
sal11	Salinity, Practical, 2	PSU
sigma_e00	Density (sigma-theta)	kilograms per cubic meter (kg/m^3)
sigma_e11	Density, 2 (sigma-theta)	kilograms per cubic meter (kg/m^3)
sbeox0ML_L	Oxygen, SBE 43; WS = 2	milliliters per liter (ml/L)
oxsolML_L	Oxygen Saturation, Garcia & Gordon	milliliters per liter (ml/L)
flag	Flag	unitless

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Instruments

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

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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
	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

Description	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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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1735664
NSF Division of Ocean Sciences (NSF OCE)	OCE-1735783
NSF Division of Ocean Sciences (NSF OCE)	OCE-1735846
NSF Division of Ocean Sciences (NSF OCE)	OCE-1736375
NSF Division of Ocean Sciences (NSF OCE)	OCE-1735436

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