VPR images and log files from cruise RR2004 in the Pacific Sector of the Southern Ocean and cruise TN376 in the South Indian Ocean (Jan 2020 to Feb 2021)

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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
VPR images and log files from R/V Roger Revelle cruise RR2004 in the Pacific Sector of the Southern Ocean along 150W from Jan-Feb of 2020 and R/V Thomas G. Thompson cruise TN376 in the South Indian Ocean from Jan-Feb of 2021.

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Methods & Sampling

Location:

R/V Thomas G. Thompson cruise TN376: South Indian Ocean
R/V Roger Revelle cruise RR2004: Pacific Sector of the Southern Ocean along 150W|

Methods & Sampling:

To assess the large microplankton and small mesoplankton community alongside fine-scale measurements of temperature, salinity, and fluorescence, a Video Plankton Recorder II (VPR, from SeaScan Inc.) was towed behind the ship across the shelf break. The VPR consists of a towed body, containing a Seabird Electronics Inc. CTD (SBE 49 FastCat), oxygen sensor (SBE 43), fluorometer (ECO FLNTU-4050), ECO Triplet (ECO BBFL2-123), PAR (photosynthetically active radiation; Biospherical Instruments Inc. QCP-200L), and a synchronized video camera and xenon strobe (Davis et al., 2005). The VPR was towed at 10 knots (5.1 m s-1), undulating between depths as shallow as 5m and as deep as 120m approximately every 6 minutes. This provided a minimum horizontal resolution of 1.8 km throughout the tow.

Description of package contents within the "Data Files" and "Supplemetnal Files" sections:

VPR data presented in two types: images (tif format, *.tif) and log files for the hydrographic, bio-optical and navigation data (text format, *.combo). The images come in at 30 frames per second and the log files are 1 second averages. So there is not 1-to-1 mapping.

Each VPR tow (vpr1, vpr2, vpr3, etc.) has subdirectories called d### (year day #), then h## (hour), then the roi tifs collected during that hour and the ctd.dat file of corresponding physical data.

Example relative storage path within a tif image file zip:
RR2004/vpr/rois/vpr1/d362/h23/roi3.8594409700.tif
<cruise_id>/vpr/rois/d<year day #>/h<hour>/roiN.timestamp.tif

ROI naming convention is roiN.timestamp.tif where timestamp is milliseconds since midnight.
Tif file name example: roi0.4565601000.tif

N is the thread number in the processing stream, taking on values 0 through 3. This is a remnant from a prior incarnation of the software, not relevant to science use. Please ignore.

File name format: mmddhhminss.combo where mmddhhminss is VPR tow start date/time.

Data Processing Description

Calibrations:
* column numbers are relative to .combo files.

Column 11 fluorescence (ug / L)
TN376: fluo=6*((fluo/1000)-0.068); %SN FLNTURD-4050 Cal 2015-07-27
RR2004: fluo=6*(fluo/1000-0.073);%SN FLNTURTD-4050 Cal 2020-05-15

Column 12 PAR
light=sqrt(counts)*0.02;

Column 13 turbidity (NTU)
TN376: obs=2*(obs/1000-0.067); %SN FLNTURD-4050 Cal 2015-07-27
RR2004: obs=2*(obs/1000-0.069);%SN FLNTURTD-4050 Cal 2020-05-15

Column 18 Eco-triplet Bb
TN376: Bb=(lambda-66)*0.000007738;%TN376
RR2004 Bb=4.098e-06*(lambda-68);%SN BBFL2-123 Cal 2020-05-15

Column 20 Eco-triplet fluorescence
TN376: ecochl=(ecochl_counts-67)*0.0119;%%TN376
RR2004: ecochl=0.0109*(ecochl_counts-65);%SN BBFL2-123 Cal 2020-05-06

Column 22 Eco-triplet CDOM
TN376: cdom=(cdom_counts-61)*0.2207;%TN376
RR2004: cdom=0.1536*(cdom_counts-69);%SN BBFL2-123 Cal 2020-05-06

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Related Publications

Davis, C. S., Thwaites, F. T., Gallager, S. M., & Hu, Q. (2005). A three-axis fast-tow digital Video Plankton Recorder for rapid surveys of plankton taxa and hydrography. Limnology and Oceanography: Methods, 3(2), 59–74. Portico. https://doi.org/10.4319/lom.2005.3.59
Methods

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	Video Plankton Recorder II (VPR II, from SeaScan Inc.)
Generic Instrument Name	Video Plankton Recorder
Dataset-specific Description	Environmental data (temperature, salinity, turbidity, fluorescence, irradiance, dissolved oxygen) collected by sensors mounted on the Video Plankton Recorder (VPR).
Generic Instrument Description	The Video Plankton Recorder (VPR) is a video-microscope system used for imaging plankton and other particulate matter in the size range from a few micrometers to several centimeters. The VPR is essentially an underwater microscope. It consists of four video cameras (with magnifying optics) synchronized at 60 fields per second (fps) to a red-filtered 80 W xenon strobe (pulse duration = 1 microsecond). The current lens on each camera can be adjusted to provide a field of view between 5 mm and 10 cm. Use of higher magnification lenses is currently being explored for viewing protozoans (less than 1 micrometer resolution). The four cameras are set for concentric viewing fields so that a range of up to four magnifications can be viewed simultaneously, allowing a wide size range of plankton to be sampled. Depth of field is adjusted by the lens aperture setting, and the volume sampled in each video field ranges from about 1 ml to 1 liter, depending on lens settings. The cameras have been configured for stereoscopic viewing as well.A strobe on the other arm illuminates the imaged volume and flashes 60 times per second, producing 60 images per second of the particles and plankton in the water. The images are then saved internally on a computer hard disk and later plotted. Deployment: Most commonly, the VPR is mounted in a frame and lowered into the water from the stern of the ship. Sometimes, a CTD also is mounted next to the VPR to collect depth, temperature, and salinity information at the same time as each video image. The instrument is lowered down through the water to a maximum depth of 350 meters to generate a profile of plankton/particle abundance and taxon group along with temperature and salinity. In addition to the towed configuration for mapping plankton distributions, it is possible to deploy the VPR in a fixed position (on a mooring) for viewing plankton swimming behaviors in two or three dimensions. The VPR instrument system has been used in both configurations, and deployment on ROVs has been proposed. This definition was taken from the WHOI Ocean Instruments Web site and from a US GLOBEC Newsletter.

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Deployments

TN376

Website	https://www.bco-dmo.org/deployment/904210
Platform	R/V Thomas G. Thompson
Start Date	2020-01-25
End Date	2020-03-03
	See more information at R2R: https://www.rvdata.us/search/cruise/TN376 Description of Cruise (provided by Chief Scientist Barney Balch): Due to the ship breakdown early into the cruise and the need to divert to Durban, SA, for engine repairs, we divided the cruise into five legs, as defined by our revised cruise plan, then pre- and post-diversion engine repairs in Durban, SA. We present a summary below of each of the legs and associated measurements. Leg 1: Transit from Cape Town, South Africa (S.A.), zonal transect through Agulhas meander system, and sampling of a coccolith-rich filament; CTD stations 1-17, VPR tows 1-7; trace metal casts 1, 3, 5, 6, 7, 8, 12 and 17; 0800h, 25 January to 0222h, 4 February, 2020. For this leg, we transited across the Agulhas Meander system, beginning with a station in the Agulhas Retroflection eddy (station 2), criss-crossing the Agulhas, Southern Subtropical Fronts with

Description	Video Plankton Recorder (VPR) and underway bio-optical systems running, and performed full CTD water casts (stations 2-4). This line of stations crossed into the end of our filament of interest, which showed (with the Acoustic Doppler Current Profiler (ADCP), cyclonic circulation around a zero-velocity core of this frontally-embedded eddy. Station 35 was situated in the western interior side of this eddy. This was where we collected water for our first carboy experiment and also performed a trace metal cast consisting of nine Niskin X samplers deployed on a Kevlar line. After collecting seawater for the carboy experiment, the VPR was deployed and towed for the entire west-to-east section, then north-to-south section through the center of the eddy. The same sections were then visited (in reverse) for CTD casts. Daily productivity casts to measure photosynthesis and calcification, plus trace metal casts were run at stations 1, 3, 4, 5, 6, 7, 8, 12, and 17. The carboy experiment for this feature was run from surface water taken at station five. Measurements of photosynthetic photophysiological variables were made underway and at stations 1-17. These included photosynthetic efficiency and rapid light curve data. An imaging PAM system (PSI, Cz) was also used to obtain cell type-specific photosynthetic efficiency data. Filter/freeze/transfer (FFT) preparations were made for qualitative viewing of surface and fluorescence maxima phytoplankton assemblages (400x magnification bright-field, polarized microscopy, and epi-fluorescence using 480nm and 530nm excitation) viewing at stations 5,6,7,8, 12, and 17. Barite precipitation measurements were performed at station 5 in this feature. Leg 2: Transit to eddy feature and its survey; CTD stations 18-25; VPR tows 8-9; trace metal casts 18, 20, and 23; 0222h, 4 Feb. to 1400h, 8 Feb., 2020. This leg of the cruise involved sampling a cyclonic eddy roughly centered at 35° 53'S and 37° 38'E. We first did a full 195-kilometer east-to-west VPR survey, and towed it from the east end of the eddy to the northern end of the eddy followed by a complete VPR section (163 kilometers) from north to south. The area of this PIC-enhanced, elliptical eddy was about 25,000 km². Productivity and trace metal casts were performed at stations 18, 20, and 23 and the water for a second carboy experiment was collected from station 18 (eddy interior). Measurements of photosynthetic variables were made underway and at stations 18-25. FTF preparations were made for semi-quantitative viewing of surface and fluorescence maxima phytoplankton assemblages (400x magnification bright-field, polarized microscopy, and epi-fluorescence microscopy using 480nm and 530nm excitation wavelengths) viewing at stations 18, 20, and 23. Barite precipitation measurements were performed at station 18 in this feature. A 10m-sock drogue equipped with a satellite Argos transmitter was deployed in the eddy center prior to our departure for Durban as a means to track the feature in our absence. Leg 3: science stopped and ship diverted for engine repair; 1400h, Feb. 8, with science sampling resumed at 1726h, 16 February. All overboard sampling at Leg 2 stopped on 8 February for the steam back to the port of Durban for engine repairs. Only the carboy experiments were sampled during the two-day transit to the port but given that we had a temperature-controlled seawater incubator, the carboy experiments could be maintained at their in situ temperatures for the duration of the multi-day experiment. The engine repair work in Durban was completed by the evening of 13 February, after which the ship sailed for station 26 to resample the first filament that we had sampled in Leg 1. Leg 4: Re-sampling the meander filament and transit to first deep CTD; CTD Stations 26-53; VPR tows 10-12; trace metal casts 28 and 39; 0347h,16 Feb. to 0418h, Feb. 20, 2020. The ship proceeded to re-sample the meander filament by performing three east-to-west, VPR sections across the feature, followed by three CTD sections made immediately afterward across the same lines, from west-to-east. Those sections were made zonally at 41°30', 40°30'S and 39°30'S and had lengths of 222km, 222km, and 167km, respectively, such that they adequately sampled the cross-section of the feature. Beginning with station 27, we alternated each CTD full-water cast with a "trip on the fly" water cast. These later casts were used only to sample DIC and nutrients and served to provide greater resolution sections across the features. This pattern of CTD sampling was continued for the remaining feature surveys. Following the completion of each VPR and CTD zonal leg, the VPR was towed to the next zonal leg. Productivity/TM casts were made at stations 28, 39, and 50, near the mid-points of the filament. The carboy experiment in this feature was run using water from station 28. Measurements of photosynthetic variables were made underway and at stations 26, 28, 30, 32, 34, 35, 37, 39, 41, 43, 44, 46, 48, 50, and 52. Filter-Transfer-Freeze (FTF) preparations were made for semi-quantitative microscopy viewing at stations 28, 29, 30, 39, 42, and 50. Barite precipitation measurements were performed at station 28 in this feature. Leg 5: Re-sampling Eddy 3, Deepwater casts, transit to Mauritius; CTD Stations 54-73; VPR tows 13-14; trace metal casts 50, 56, and 70; 0418h, Feb. 20 to 0800h, March 3, 2020. From leg 4, we proceeded to re-sample the cyclonic eddy, originally sampled in leg 2. On the way, we made the first deep CTD cast to sample for nutrients, oxygen, and carbonate chemistry down to the sea floor (4500m). The eddy re-sampling consisted of a 163km west-to-east VPR tow followed by a 203km east-

	to-west CTD section. Heavy seas forced us to cancel the west-most CTD station. The ship then proceeded to the north eddy station with all weather decks secured. Again, heavy sea states made deployment of the VPR impossible, so we performed the north-to-south CTD section but had to call off some of the middle CTDs from that section due to heavy seas. The drogue had spiraled about 100km from the eddy center by this point, so the ship broke from the N-S line to recover it, after which the interior eddy stations (that had been skipped due to weather) were re-sampled under safer sea states, finally arriving at the southern eddy station, #71 at 1853h on 2/24/20. At this point, the VPR could finally be redeployed to tow the entire south-to-north eddy survey transect. Two productivity/trace-metal stations were run in the eddy at stations 56 and 70. (The carboy experiment was sampled at station 56. Measurements of photosynthetic variables were made underway and at stations 54, 56, 58, 60, 62, 64, 66, 68, 70 and 71. FTF preparations were made for semi-quantitative microscopy viewing at stations 56 (east eddy interior) and 70 (eddy center). Barite precipitation measurements were performed at station 56 in this feature. We performed a deep, 24-bottle, cast for nutrients, oxygen, and dissolved inorganic carbon chemistry 183km NE of the eddy (34.42°S x 38.04°E; depth 5217m), sampled to 5200m. The last station of the cruise was a 24-bottle deep cast at 27° 24.5'S 049°, 49.33'E for freons, nutrients, temperature, salinity, PIC, POC, biogenic silica, coccolithophore and coccolith abundance, dissolved oxygen and dissolved inorganic carbon chemistry. The purpose of this cast was to examine water ages of SAMW, examine the stoichiometry of the changes in the chemistry from assumed preformed levels, and to provide comparative values for the meridional transect to be performed in the following cruise on R/V Revelle.

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,

Description	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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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1736375
NSF Division of Ocean Sciences (NSF OCE)	OCE-1840381

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