Preliminary Cruise Report:	R/V Sally Ride
Cruise Number:	SR1812
Cruise Name:	NASA EXPORTS Survey Program
Chief Scientists:	Norman B. Nelson, Mary Jane Perry
Cruise Dates:	9 August 2018 – 13 September 2018
Port of Departure:	Seattle WA
Port of Return:	Seattle WA

Purpose of EXPORTS:

The goal of the EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) field campaign is to develop a predictive understanding of the export and fate of global ocean primary production and its implications for the Earth's carbon cycle in present and future climates. EXPORTS builds upon decades of NASA-supported research assessing global net primary production (NPP) from space and is designed to deliver science of significant societal relevance by better characterizing the fate of organic carbon in the ocean. < http://oceanexports.org/>

Objectives for the Survey Program:

The role of the Survey Ship R/V Sally Ride, in this two-ship operation, was to:

1) determine the horizontal and vertical spatial distribution of phytoplankton, particulate and dissolved organic carbon, dissolved nutrients, oxygen, optical properties and other chemicals;
2) determine the spatial distribution of thorium as a tool to quantify carbon flux from the euphotic zone; and
3) calibrate the autonomous platforms (floats and a glider) that will remain after the ship departs and develop proxies to interpret optical signals as biogeochemical parameters (in SI units).

Overview of Cruise Plan:

Cruise time on both the Sally Ride and the Revelle were divided into three epochs that were approximately eight days long. For each epoch, the ship carried out a small scale survey (30 x 30 km, with 17 stations) and a large scale survey (88 x 88 km, with 19 stations), which consisted of CTD casts at each station (Fig. 1). In addition to temperature and salinity, the CTD measured PAR (photosynthetically active radiation), chlorophyll fluorescence, optical backscattering, beam attenuation, LISST (Laser In-Situ Scattering and Transmissometery) for small particle size analysis, UVP (underwater vision profiler) for large particles, and a glider ADCP for zooplankton size and abundance. For Epochs 1 and 3, samples for (Th) thorium and DOC (dissolved organic carbon) were collected and thorium was measurement on board at all small scale survey stations; for Epoch 2, Th was sampled at all large scale survey stations. Four pumping stations, with large volume pumps at six to nine depths, were carried out during each Epoch; the timing of the pumping stations coincided with times when neutrally buoyant sediment traps were deployed from the Process Ship (*R/V Roger Revelle*). The filters were subsampled for Th, particulate carbon, nitrogen, inorganic carbon, silica, phosphorus, Pb, Po, Ba, other organics, lithogenic, particles, and phytoplankton pigments analyzed by HPLC (high performance liquid chromatography). Two optics CTD stations were occupied each day, every day, with sampling for IOPs (inherent optical properties), AOPs (apparent optical properties), and water samples for nutrients, particulate absorption spectra, phytoplankton taxa, CDOM (chromophoric dissolved organic matter), complete particle size spectrum, and VSF (volume scattering function).

Underway sampling from two near-surface seawater intakes was extensively sampled throughout the cruise. Scientists had the ship install a diaphragm pump that was plumbed to the lab; the ship's underway system with an impellor pump was sometimes used as well. Both systems had different issues and challenges. Three groups used one or the other or both systems to measure a variety of optical properties of phytoplankton, pH, nitrate, and ratios of Ar/O2 (argon/oxygen).

AUV (autonomous underwater vehicle) deployments included a Lagrangian float ballasted to track the water mass at the base of the euphotic zone; the float was used as the center of the Process Ship studies and for the various large and small scale surveys. Two Bio-Argo floats were deployed, one of which suffered an oil leak in the piston and had to be recovered. An OOI (Ocean Observatories Initiative) glider was deployed near Station P in support of the OOI program. Simultaneous profiles *of R/V Sally Ride* CTD and an AUV constituted an AUV calibration cast (AUVs = Lagrangian float, a previously deployed EXPORTS Seaglider, Bio-Argo float, and Wire Walker).

Station locations for each epoch:

EXPORTS EPOCH 1 SURVEY GRIDS Center 50.095 -145.050 Angle 30.000000

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Small Scale Survey
SS  1       50 5.70    -145 3.00
SS  2       50 3.33    -145 16.76
SS  3       50 7.07    -145 13.40
SS  4       50 10.81   -145 10.04
SS  5       50 14.54   -145 6.69
SS  6       50 12.39   -145 0.87
SS  7       50 8.65    -145 4.23
SS  8       50 4.91    -145 7.59
SS  9       50 1.17    -145 10.94
SS 10       49 59.01   -145 5.13
SS 11       50 2.75    -145 1.77
SS 12       50 6.49    -144 58.41
SS 13       50 10.23   -144 55.06
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SS 14	50 8.07	-144 49.24
SS 15	50 4.33	-144 52.60
SS 16	50 0.59	-144 55.96
SS 17	49 56.86	-144 59.31

Large Scale Survey

LS 1	50 5.70	-145 3.00
LS 2	50 4.30	-145 11.11
LS 3	50 1.51	-145 27.32
LS 4	49 58.72	-145 43.54
LS 5	49 53.95	-145 30.69
LS 6	49 49.18	-145 17.84
LS 7	49 44.41	-145 4.99
LS 8	49 39.64	-144 52.14
LS 9	49 50.06	-144 56.48
LS 10	50 0.49	-145 0.83

EXPORTS EPOCH 2 SURVEY GRIDS Center 50.343 -145.122 Angle 20.00

Large Scale Survey

LS 1	50 20.58	-145 7.33
LS 2	50 18.30	-145 14.93
LS 3	50 13.74	-145 30.15
LS 4	50 9.18	-145 45.37
LS 5	50 5.92	-145 31.42
LS 6	50 2.65	-145 17.48
LS 7	49 59.39	-145 3.53
LS 8	49 56.13	-144 49.59
LS 9	50 5.91	-144 56.68
LS 10	50 15.69	-145 3.78
LS 11	50 25.47	-145 10.87
LS 12	50 35.25	-145 17.97
LS 13	50 45.03	-145 25.06
LS 14	50 41.77	-145 11.12
LS 15	50 38.51	-144 57.18
LS 16	50 35.24	-144 43.23
LS 17	50 31.98	-144 29.29
LS 18	50 27.42	-144 44.50
LS 19	50 22.86	-144 59.72

Small Scale Survey

SS 1	50 34.59	-145 0.42
SS 2	50 28.12	-145 10.50
SS 3	50 32.44	-145 10.50
SS 4	50 36.75	-145 10.50
SS 5	50 41.07	-145 10.50
SS 6	50 41.07	-145 3.78
SS 7	50 36.75	-145 3.78
SS 8	50 32.44	-145 3.78
SS 9	50 28.12	-145 3.78
SS 10	50 28.12	-144 57.06
SS 11	50 32.44	-144 57.06
SS 12	50 36.75	-144 57.06
SS 13	50 41.07	-144 57.06

SS 14	50 41.07	-144 50.35
SS 15	50 36.75	-144 50.35
SS 16	50 32.44	-144 50.35
SS 17	50 28.12	-144 50.35

Extended Survey

ES 1	50 12.68	-144 22.46
ES 2	50 15.52	-144 30.74
ES 3	50 23.15	-144 42.62
ES 4	50 30.78	-144 54.49
ES 5	50 34.59	-145 0.42
ES 6	50 38.41	-145 6.36
ES 7	50 46.04	-145 18.23
ES 8	50 53.67	-145 30.10
ES 9	51 1.71	-145 40.63

EXPORTS EPOCH 3 SURVEY GRIDS Center 50.593 -144.870 Angle 45.000000

Small Scale Survey

SS 1	50 34.59	-145 0.42
SS 2	50 28.12	-145 10.50
SS 3	50 32.44	-145 10.50
SS 4	50 36.75	-145 10.50
SS 5	50 41.07	-145 10.50
SS 6	50 41.07	-145 3.78
SS 7	50 36.75	-145 3.78
SS 8	50 32.44	-145 3.78
SS 9	50 28.12	-145 3.78
SS 10	50 28.12	-144 57.06
SS 11	50 32.44	-144 57.06
SS 12	50 36.75	-144 57.06
SS 13	50 41.07	-144 57.06
SS 14	50 41.07	-144 50.35
SS 15	50 36.75	-144 50.35
SS 16	50 32.44	-144 50.35
SS 17	50 28.12	-144 50.35

Large Scale Survey

LS 1	50 35.58	-144 52.21
LS 2	50 35.58	-145 0.61
LS 3	50 35.58	-145 17.40
LS 4	50 35.58	-145 34.18
LS 5	50 28.84	-145 23.69
LS 9	50 19.40	-144 52.21
LS 10	50 30.19	-144 52.21
LS 11	50 40.98	-144 52.21
LS 12	50 51.77	-144 52.21
LS 13	51 2.56	-144 52.21
LS 14	50 55.82	-144 41.72
LS 15	50 49.07	-144 31.23
LS 16	50 42.33	-144 20.74
LS 17	50 35.58	-144 10.24
LS 18	50 35.58	-144 27.03
LS 19	50 35.58	-144 43.82

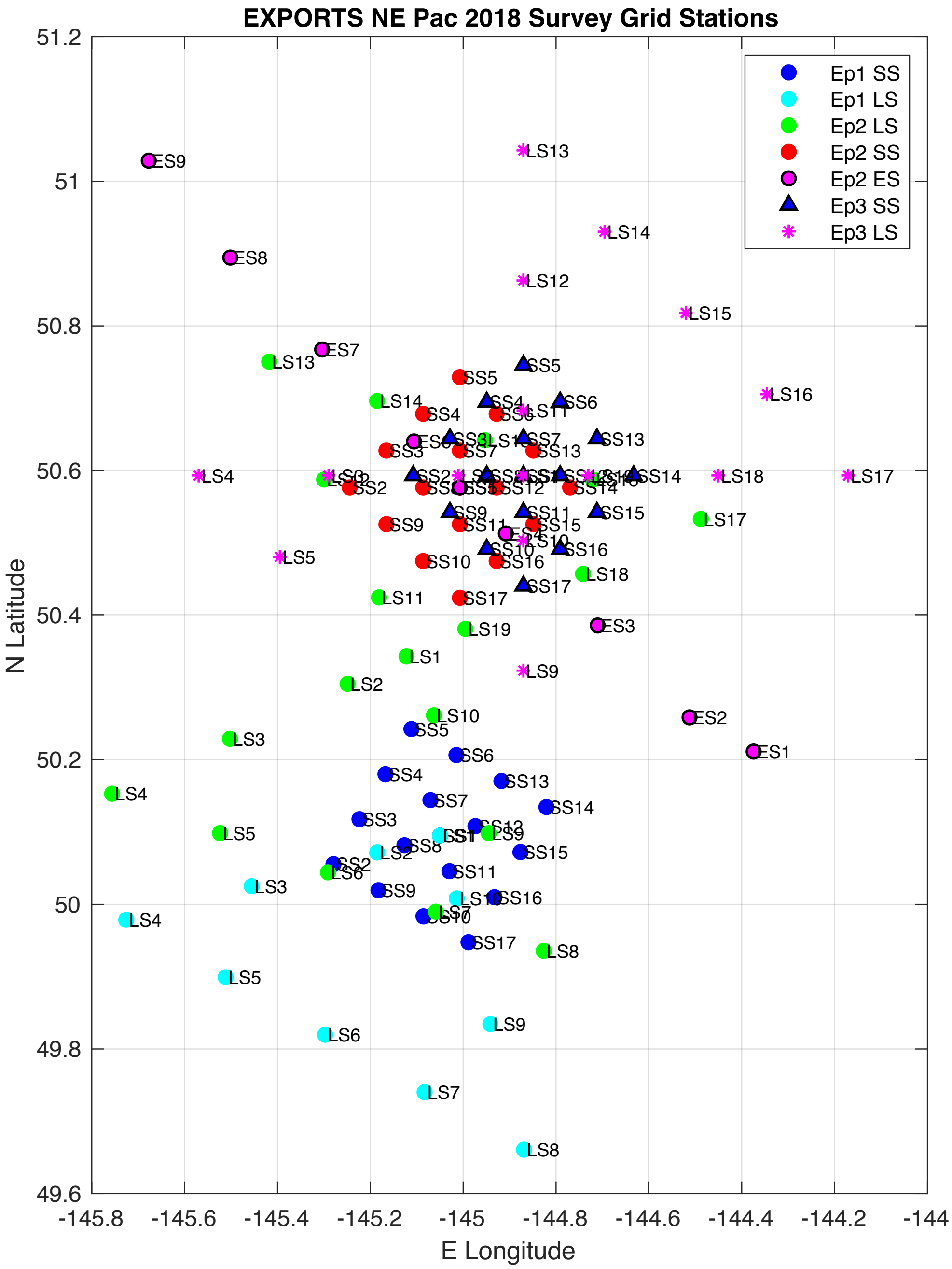


Figure 1: Station locations occupied by R/V Sally Ride during the EXPORTS 2018 Northeast Pacific expedition. Symbols are color coded by epoch (1, 2, 3) and survey grid (SS: small scale, LS: large scale, ES: extended survey).

Summaries of Individual Projects:

Hydro Survey Team

Norm Nelson Sasha Kramer, Kelsey Bisson, Dave Siegel

Goals / Objectives: The main purpose of the EXPORTS Hydro Team is to provide basic hydrographic context for the field project, by conducting ctd casts and rosette sampling on the survey sample grids. Activities revolve around three main objectives:

1) CTD and ancillary sensor operation and NRT preliminary data processing;
2) Sample collection for basic hydrographic variables;
3) Sample collection for selected PI-specific variables.

Results:

CTD casts

We conducted 144 CTD casts using an SIO 24-place Rosette, of which 107 included bottle sampling. The chief scientists (NBN and MJP) operated the console on most casts, with a few casts operated by J. Pretty (UAF) or C. Lopez (UMiami). The SIO Sea-Bird 911 system was configured with two SBE temperature and salinity sensors, one SBE 43 oxygen sensor, and one Digiquartz pressure sensor. Connected to the 911 were a Biospherical QSE scalar PAR sensor and a WET Labs C-Star 650 nm beam transmissometer (SIO supplied), and a WET Labs FLBBRTD combination chlorophyll fluorometer and b(700nm) sensor (UMaine/MJP). Stand-alone instruments mounted to the Rosette frame included a Satlantic ISUS (MBARI), a Hydro Optic UVP5 (UAF), a Sequoia LISST-Deep (UAF), and a Nortek Glider ADCP (UW APL). The Glider ADCP was not configured for current profiling; instead it was mounted to the UVP5 frame so one transducer could illuminate (insonify) the sample volume of the UVP5 to test for zooplankton acoustic scattering signatures. The UMaine/MJP provided C-Star transmissometer failed on the first cast (water intrusion), which was surprising because it had just come from a WET Labs calibration.

Most casts in Epoch 1 were to 500 m and in Epoch 2 most casts were to 750 m even though the deepest water sampled depth was typically 500 or 330 m. Calibration casts included 1000 m and 2000 m maximum depths, and one ~3000 m cast was carried out per epoch. For the >1000 m casts the PAR and ADCP sensors were removed.

We used standard SBE SeaSoft software to carry out preliminary CTD processing, which included window filtering, loop editing, correction for alignment (delays provided by SIO) and cell thermal mass correction, and computation of selected derived products (potential temperature, sigma-theta, density, oxygen saturation). We binned the data two ways: 2Hz time bins, and 2db depth bins, and bottle files were compiled that computed each sampled parameter at bottle trip time. Processed data were made available on the share drive, as were the raw data.

The SIO transmissometer had no recent calibration, so the SIO Res Techs carried out a number of on-deck blocked / unblocked measurements to try and track calibration drift. We also noticed a linear depth-dependent trend in transmissometer data below 750 m and strong hysteresis on deep casts below 750 m, where the signal did not return from the deep-ocean value until near the surface. Preliminary data processed by the SBE software are incorrect, as the SBE software inconsistently applied calibration coefficients and we couldn't figure out how to make it obey our wishes. NBN is working on corrections to the data and estimating the correct calibration, working from the raw (Voltage 4) transmissometer data. This is promising; we can remove the depth and time trends from the deep-ocean (>1000m) voltage data and compute consistent and somewhat plausible c_p profiles from the corrected data. Absolute values of c_p are too high when compared to AC-9 c_p data from similar wavelengths. Some casts early on in the cruise did not produce reasonable data for unclear reasons. These casts coincided with our first bad weather episode, but this may have been coincidental.

All other sensors performed nominally, and appeared to remain stable throughout the cruise. We will continue to delve into this ashore. Final products from CTD data will await commentary from the broader research group. We have in mind to produce unfiltered high-frequency products for the optical sensors as well as the binned products. Other comments regarding filter parameters and quality control will be appreciated.

We suffered ca. 10 Niskin mis-trips resulting in sample loss, and several more lanyard/spring failures on deck while cocking bottles. The Res Techs were generally proactive in anticipating the need for Niskin maintenance. Age of the bottles seems to be an issue, as even the new lanyards seemed to fail at an unusually high rate.

Sample Collection

The Hydro team collected samples on approximately 100 casts (Table 1). As noted above some casts were instrument-only, and some casts did not involve Hydro samples (details are in other summaries, below). Hydro would like to acknowledge the assistance of the science team helping with sampling, in particular C. Lopez (UMiami, Hansell/Carlson group), who collected a significant number of the nutrient samples along with the DOC samples. PI parameters were collected by field teams by the respective research groups, except for the URI transcriptome samples and some of the FCM samples that we collected.

Table 1		
Hydro Parameter	**# Collected**	**Planned Disposition**
Dissolved Nutrients (NO3, NO2, PO4, SiO4)	631	Analysis at UCSB MSI Analytical Lab
POC/PON	504	Analysis at UCSB MSI Analytical Lab
BSi	219	Analysis at UCSB Brzezinski Lab
PIC	198	Analysis at GSFC
HPLC	370	Analysis at GSFC
Chl (Fluorometric)	373	Analysis at UCSB / Nelson lab
Particulate absorption	373	Analysis at sea (Bowdoin/WHOI)
Dissolved absorption / fluorescence EEM (CDOM)	376	Analysis at UCSB / Nelson lab
PI Parameter	**# Collected**	**Planned Disposition**
Transcriptome grazing markers (URI)	72	Analysis at URI
DOC/N (UMiami/UCSB)	tba	Analysis at UMiami
FCM (Bowdoin/WHOI)	40	Analysis at WHOI
pH (MBARI)	tba	Analysis at sea
DIC (MBARI)	tba	Analysis at MBARI
O2 (Duke/WHOI)	tba	Analysis at sea
O2/Ar discrete (Duke/UNC)	tba	Analysis at Duke
16S/18S genomics (Duke/UNC)	25	Analysis at UNC

Assessment:

CTD operations went well, with the Chief Scientists doing most of the CTD console operations. As stated above CTD data seemed to be excellent with the exception of the transmissometer data, which are being worked on.

Initial plans for sample number were pretty much in conformance with what was collected, except for nutrients, where additional samples were collected to try and match up with DOC and Th samples collected on non-optics stations/casts. PI expectations for co-located samples were not fully explored/settled before the cruise, and this presented a problem that required a lot of futzing with the schedules (to try and get POC [particulate organic carbon] sampling to match up with Th for example). The big problem here is the time needed to prepare and filter particle samples, and the personnel time available to do this. Sufficient equipment was available to do the preparation, but the round-the-clock nature of the survey meant that our team wasn't always available to do the work. Contributions from other research group members, while valuable, were subject to the same constraints so it wasn't possible to entrain people to do sample prep on a regular basis. This wasn't a problem for nutrients, where the sampling and preparation were done at the draw (inline gravity filtration) and could be done by anyone (in particular C. Lopez). For filtering we were also reluctant to introduce operator variability to the sampling.

In summary we were able to meet all the stated Project goals for hydrographic sampling. Some PI measurements were not accommodated with a full set of co-located parameters.

Dissolved Organic Matter

Chelsi Lopez, Dennis Hansell

The goals for DOM sampling were to collect discrete water samples from the Rosette for both DOC (dissolved organic carbon) at all depths and TOC (total organic carbon) below 100 meters at all stations and depths sampled by the thorium group. This was accomplished, all well as samples for the majority of the AUV calibration casts, all deep 3000 meter casts, and a few extra large-scale stations. This amounted to 23 boxes filled of samples, equating to 2,300 vials, that will be analyzed at University of Miami.

Large Particle Profiles on the CTD

Jessica Pretty, Andrew McDonnell

The UVP and LISST instruments were both mounted on the CTD Rosette for all 144 CTD casts of the 2018 North Pacific EXPORTS cruise aboard the R/V Sally Ride. The overarching goal of deploying both instruments was to capture and describe the PSD (particle size distribution) across a large range: 2.0 µm to approximately 3 cm. The UVP captured data during CTD downcasts during 138 of 144 casts; the unsuccessful casts did not have a clear cause as to why the instrument did not work as programmed. The UVP captured and stored vignettes of particles larger than 500 µm for 136 casts that will allow for sorting and visual identification during future analysis. The LISST successfully captured data on all 144 casts, but 2 casts do not have usable data as the background scattering window was left on during these casts, which prevented proper sampling.

Below are figures showing the total particle abundance (#/L) during large (Fig. 2) and small (Fig. 3) scale transects in Epoch 1, viewed across latitude.

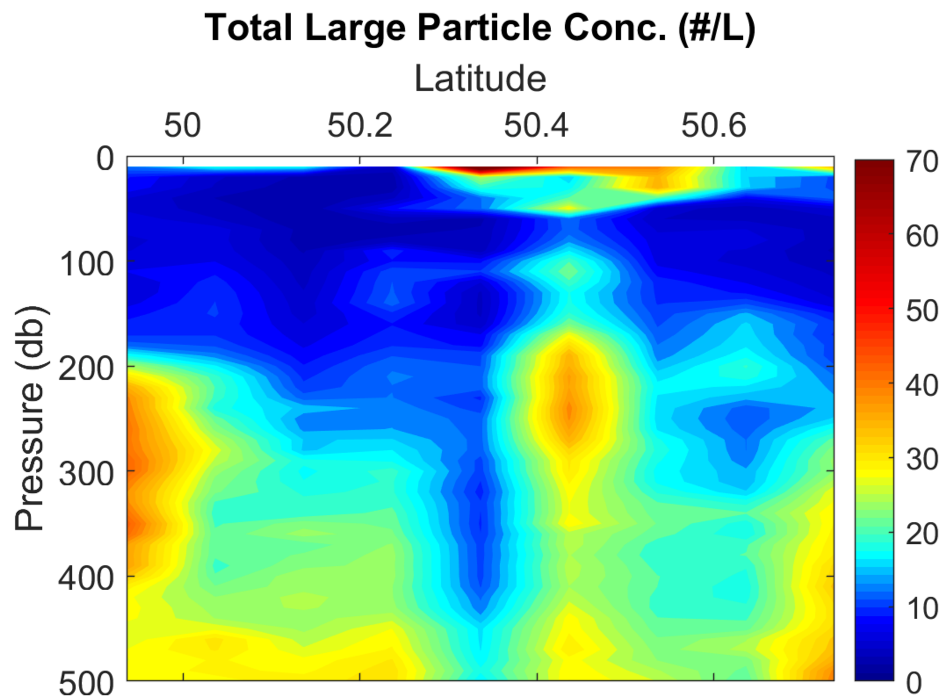


Figure 2. A latitudinal gradient view of particle abundances (#/L) at all small scale stations in Epoch .

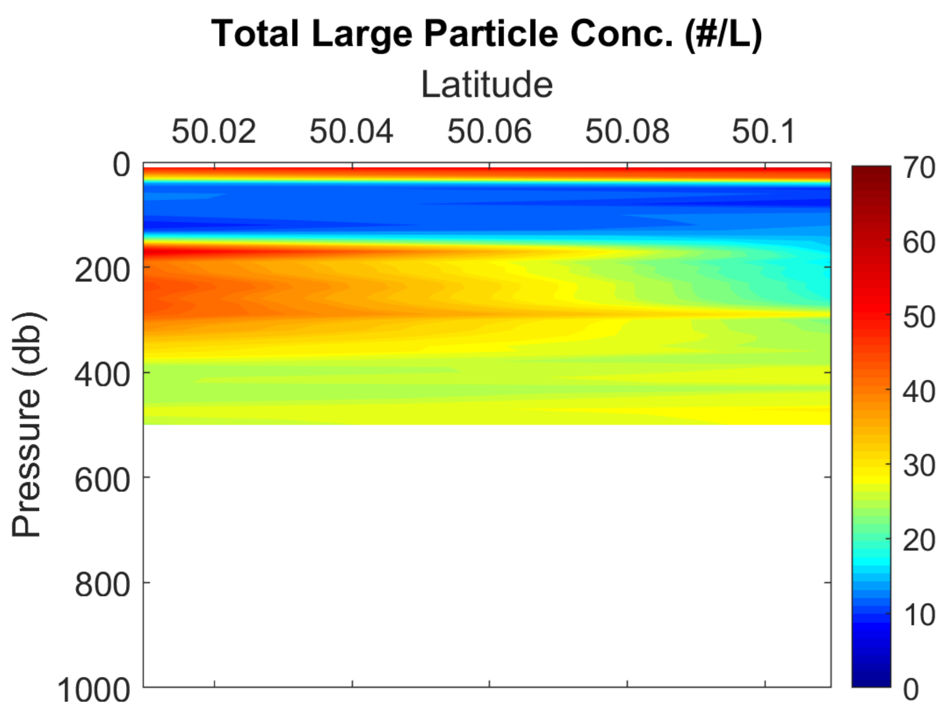


Figure 3. A latitudinal gradient view of particle abundance (#/L) in epoch 1 at large scale stations.

Café Thorium

Claudia Benitez-Nelson, Steve Pike, Muntsa Roca Marti, Sam Clevenger, Blaire Umhau, Abigale Wyatt and Ken Buesseler

The focus of our EXPORTS component was to examine the spatial and temporal heterogeneity of particle formation, export, and remineralization using Uranium-238:Thorium-234 (^{234}Th half-life, $t_{1/2}$ = 24.1 d) disequilibrium. Samples were collected at every station during the small scale surveys of Epochs 1 and 3, the large scale survey of Epoch 2, and at selected stations throughout the other large scale and small scale grids. More than 1300 samples were collected, encompassing 60 distinct water column profiles from 0 – 500 m (Figures 4 and 5). Three water column profiles were collected for Lead-210:Polonium-210 disequilibrium, a tracer pair similar to ^{238}U:^{234}Th, but with a longer time period of integration (^{210}Po $t_{1/2}$ = 138 days) and for barium, which can be used as a remineralization indicator. Samples also included particle collection using *in situ* pumps (12 casts of 6 to 9 depths), where particles of varying size classes (0.3 mm to > 51 mm) were collected matching the depths of the sediment trap deployments occurring on the *R/V Roger Revelle*. In addition to particulate ^{234}Th, and selected samples for particulate ^{210}Po and ^{210}Pb activities, pump samples will be analyzed for a suite of elements (e.g., inorganic and organic carbon, biogenic silica, trace metals, etc.), as well as for microbial diversity, pigments, and the ^{15}N signature of amino acids in collaboration with other PIs. Two neutrally buoyant sediment trap moorings were recovered and processed on behalf of the *R/V Roger Revelle* during Epoch 3.

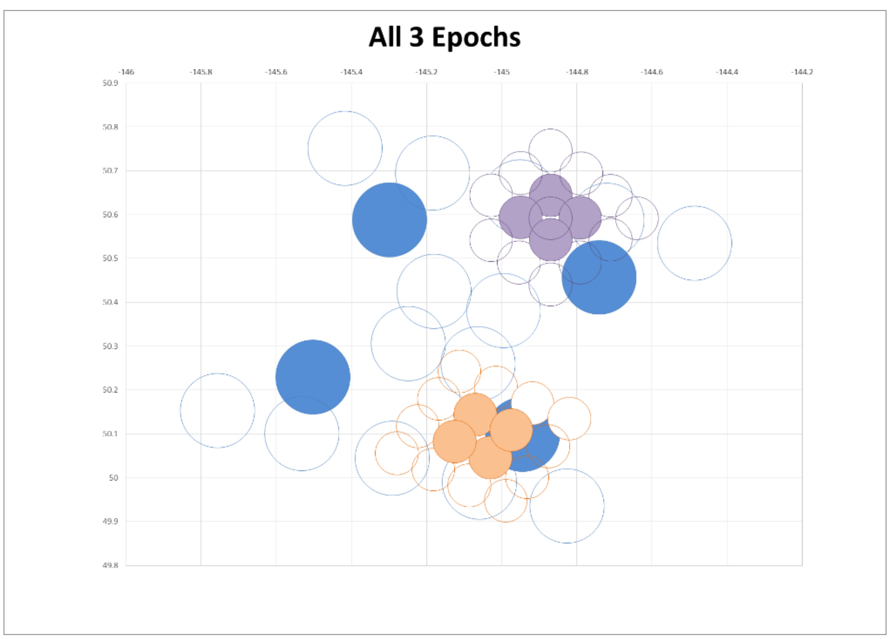


Figure 4: Station locations of ^{234}Th sampling. Orange = Epoch 1, Blue = Epoch 2, and Purple = Epoch 3. Filled circles denote in situ *pump sampling.*

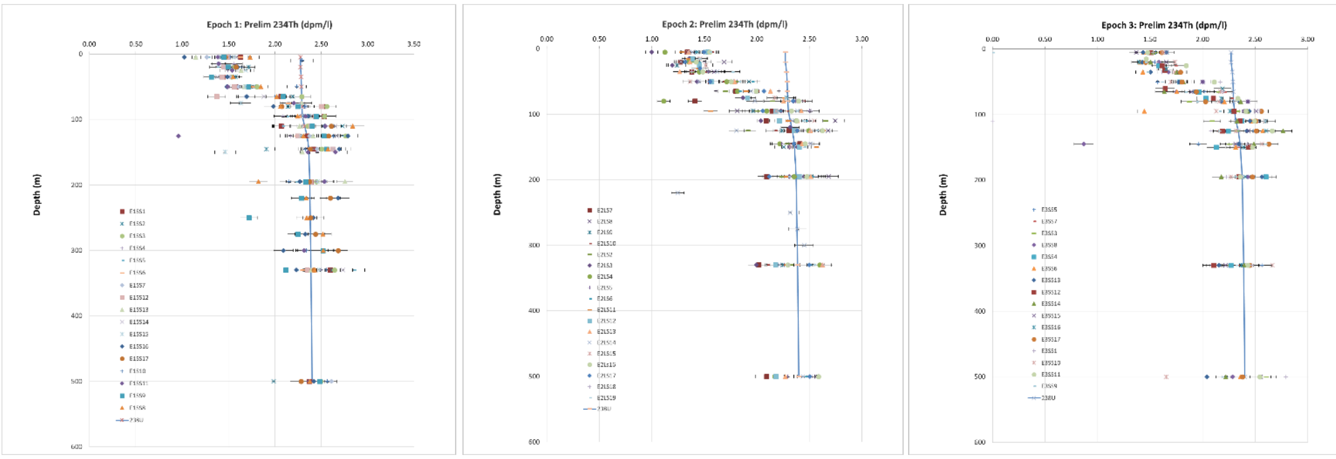


Figure 5. ^{234}Th:^{238}U disequilibrium profiles for stations collected during each Epoch. Where ^{234}Th activities (dpm/L) < ^{238}U activities (dpm/L), particle formation and export is occurring and where ^{234}Th activities > ^{238}U activities, particle remineralization is occurring.

Preliminary results show relatively homogenous and consistent ^{238}U:^{234}Th disequilibria, i.e., higher ^{234}Th fluxes increasing to depths of 50 – 100 m and remaining relatively constant or decreasing deeper in the water column (Figure 6). Elemental fluxes, such as carbon, will likely follow the same trend, but with fluxes decreasing more sharply with increasing depth to lower element/^{234}Th ratios with increasing depth in the water column.

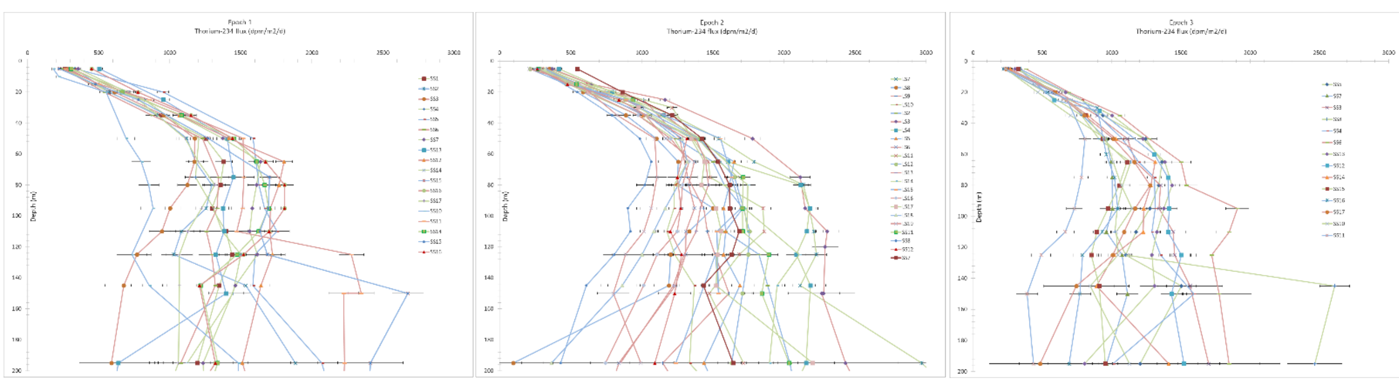


Figure 6. Cumulative ^{234}Th fluxes for each station, plotted in order of collection and separated by Epoch.

There are no obvious larger scale spatial or temporal trends, however smaller trends may appear with closer data analysis and after data are finalized with background counts and recoveries. Preliminary ^{234}Th fluxes measured at ~ 100 m are significant, on the order of 1000 to 1500 dpm m^{-2} d^{-1}, and are consistent with previous, albeit limited studies in this region.

This data set is unique in the number of spatial and temporal samples ever collected for ^{234}Th analyses. We view this cruise as an unqualified success (only three profiles were not collected due to weather) and look forward to considering the physical and biological data in interpreting subtleties in our data set.

Inorganic Carbon System and Nitrate Measurements

Jacki Long, Andrea Fassbender

The objectives that we proposed to achieve during the field experiment were to:

1) measure chemical tracers of biological activity and carbon export near Ocean Station Papa, both vertically and horizontally, and
2) deploy two BioArgo floats (ID numbers 948 and 949) in conjunction with nearby CTD casts for later float sensor calibration/validation.

To characterize vertical gradients in the carbonate system, 557 discrete water samples were collected for pH and 114 for DIC/TA from various depths (5 m to 3,000 m) during 44 CTD casts. These samples were analyzed for pH spectrophotometrically [*Clayton and Byrne*, 1993] using a semi-automated system developed by Dr. Yui Takeshita at MBARI following the methodology of Carter et al. (2013). Nitrate (NO31-) concentrations in the water column were measured autonomously using an in situ ultraviolet spectrophotometer (ISUS; *Johnson and Coletti*, 2002) enclosed in a titanium housing that was mounted to the CTD rosette.

The ISUS was launched during 110 casts and took measurements at a rate of 1 Hz, providing ~1 m vertical resolution. Near-surface measurements of pH (Fig. 7) and $NO3^{1-}$ (Fig. 8) were made continuously on water supplied by a forward, in-line pump while the ship was underway using a prototype sensor system from the Takeshita Lab at MBARI. This system employs an ISUS nitrate sensor and a Deep-Sea-Durafet (DSD) pH sensor [*Johnson et al.*, 2016] oriented in series within a custom flowcell. An SBE45 thermosalinograph was located directly downstream (< 10 cm) of the flowcell for underway temperature and salinity measurements near the sensors. Nitrate measurements were taken every 4 minutes, and pH measurements were taken every 15 seconds. Underway sampling was not possible during days with high-seas due to air intake that halted the forward pump at the bow.

The two BioArgo floats were deployed successfully and calibration casts were conducted over the following two weeks, from which samples were collected for shipboard pH analysis as well as later DIC and TA analysis at MBARI. On August 27, the transmitted engineering log from float 948 indicated a high-pressure valve leak, likely due to debris in the oil bladder obstructing the seal, which could lead to failure of the buoyancy engine over time. Retrieval of the float was therefore required and was successfully conducted on September 2. We anticipate that float 948 will be redeployed during the a cruise lead by Dr. Eric D'Asaro in December 2018.

References:

Carter, B. R., J. A. Radich, H. L. Doyle, and A. G. Dickson (2013), An automated system for spectrophotometric seawater pH measurements, *Limnol. Oceanogr. Methods*, *11*(1), 16-27, doi:10.4319/lom.2013.11.16.

Clayton, T. D., and R. H. Byrne (1993), Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale calibration of m-cresol purple and at-sea results, *Deep Sea Res. Part I Oceanogr. Res. Pap.*, *40*(10), 2115–2129.

Johnson, K. S., and L. J. Coletti (2002), In situ ultraviolet spectrophotometry for high resolution and long-term monitoring of nitrate, bromide and bisulfide in the ocean, *Deep Sea Res. Part I Oceanogr. Res. Pap.*, *49*(7), 1291–1305, doi:10.1016/S0967-0637(02)00020-1.

Johnson, K. S., H. W. Jannasch, L. J. Coletti, V. A. Elrod, T. R. Martz, Y. Takeshita, R. J. Carlson, and J. G. Connery (2016), Deep-Sea DuraFET: A Pressure Tolerant pH Sensor Designed for Global Sensor Networks, *Anal. Chem.*, *88*(6), 3249–3256, doi:10.1021/acs.analchem.5b04653.

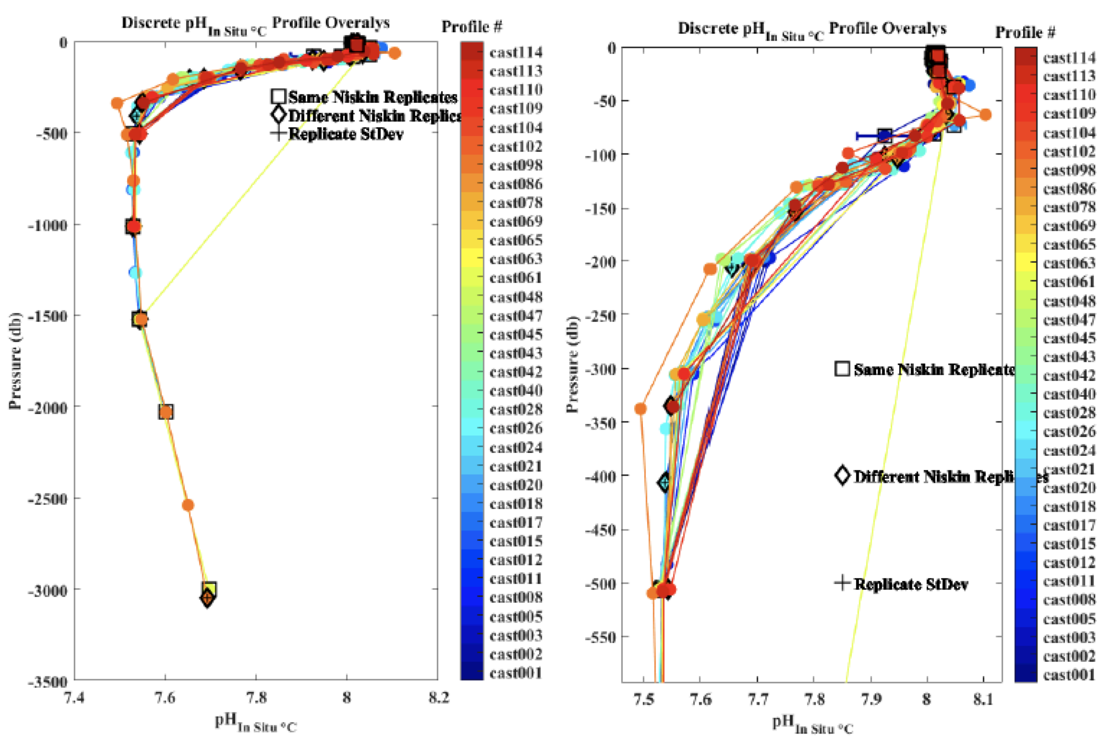


Figure 7. Preliminary discrete pH data show good agreement with the nearby float pH observations. Replicate samples indicate acceptable performance of the spectrophotometer with some larger deviations that will require closer analysis during quality control.

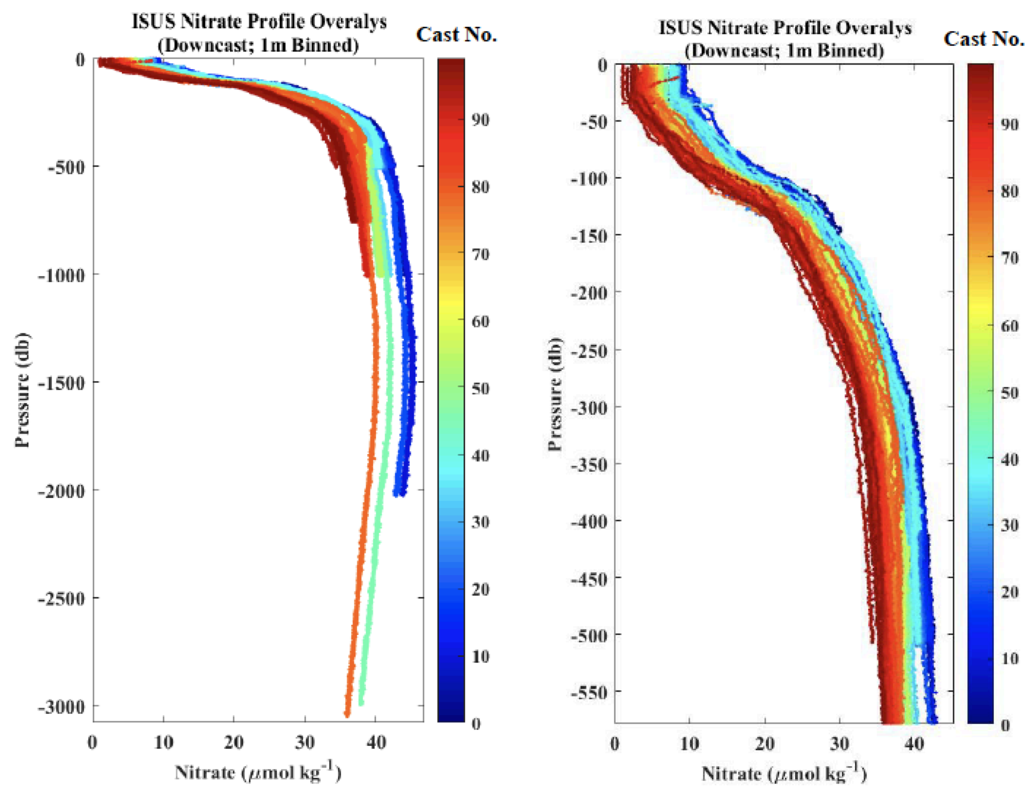


Figure 8. There is a constant drift in the vertical NO31- profiles that will be corrected during post-processing. Preliminary data review suggests a combination of contamination on the optics and strengthening of the light source output, which will be verified during quality control.

Inherent and Apparent Optical Properties and Above-water Radiometry

Scott A. Freeman

The EXPORTS 2018 campaign presented a valuable opportunity to collect in-water and above-water optical measurements concurrently with phytoplankton pigments and other biogeochemical parameters to support NASA's satellite ocean color validation activities at GSFC.

In-Water Optical Measurements (AOPs, IOPs)

The NASA Field Support Group's cage to measure inherent optical properties (IOPs) was equipped with two attenuation and absorption spectrometers (ac-s, ac-9; WET Labs, Inc.). These were equipped with a 0.2 µm pre-filter in succession to allow the in-situ measurement of spectral dissolved absorption (a_g (λ)) by each. The IOP package also included two scattering meters (bb-9, VSF-9; WET Labs, Inc.), and a CTD (Sea-Bird, Inc SBE 49), and a 3-channel fluorometer (FL-3, WET Labs, Inc), which measured chlorophyll, CDOM, and phycoerythrin fluorescence. The ac-s and ac-9 meters measure absorption and attenuation (and total scattering by difference) at 90 and 9 wavelengths, respectively, between 400 and 740 nm, while the bb-9 measures backscatter at 9 wavelengths and 117°. The VSF-9 measures scattering at 9 angles from 60° to 170° at 532 nm. The package performed profiles to 200m at 46 stations (92 profiles) during the campaign.

Apparent optical properties (AOPs), both downwelling irradiance (E_d) and upwelling radiance (L_u), were measured using a Biospherical Instruments C-OPS system. Surface direct and diffuse solar irradiance (E_S and E_{sky}, respectively) were measured with a matching reference radiometer equipped with a shadow band. All parameters were measured at 19 wavelengths between 305 and 900 nm. Profiles were conducted within 2 hours of local solar noon when weather conditions permitted, down to the 1% of surface light level (generally 60-70 meters). In all, profiles at 19 stations were accomplished.

Above-water AOP measurements

Mounted at the bow, a HyperSAS (Satlantic, Inc) system was used to measure surface irradiance (E_s), radiance emanating from water surface (L_t) and sky radiance (L_i). These measurements are combined to calculate water-leaving radiance. In order to prevent sun-glint, the surface and sky measurements are required to be at 90 to 120 degrees from the solar azimuth. This was to be accomplished using an automated solar tracker, but it failed within 24 hours, and was replaced with a turntable, with frequent changes to react to changes in solar azimuth and ship's heading. During bad weather, the entire system was taken down to minimize damage due to seas breaking on the bow. Including the transit to station, data were collected on 28 full or partial days.

Hyperspectral E_s was collected independently on each day from sunrise to sunset using a Satlantic radiometer. These data will be converted to photosynthetically-active radiation (*PAR*).

Particle Scattering

Xiaodong Zhang, Deric Gray, Yuangheng (Eric) Xiong, Genevieve Potvin

The objective that we proposed to achieve during the field experiment is to obtain the size and density distributions of particles over a wide size range from 20 nm to 20 mm. The fundamental principle is that all particles interact with light and the interaction manifested in the angular distribution of scattered light contains all the information about particles. By measuring the volume scattering functions using a suite of instruments, we can construct the full particle size distribution but extending and validating the PSDs derived by individual instrument.

In this cruise, water samples were collected at various depths and analyzed using a suite of 6 instruments applying 5 different techniques to piece together particle size distributions spanning an unprecedented size range over 6 orders of magnitude from 20 nm to 20 mm. A ViewSizer resolves submicron particles by tracking Brownian motions; a Coulter Counter measures electric resistance change to size particles from 2 – 60 µm; a UVP takes pictures and analyzes images to show larger particles of sizes 60 µm – 25000 µm; two LISST instrument measure diffraction of particles of sizes 1 – 100 µm; two scattering instrument measure angular scattering from 0.5 to 179 degrees and retrieve particles of 0.02 – 200 µm. The overlaps of sizes derived from these instruments and techniques provide a consistency check as well as validations. During the entire cruise, we analyzed over 3 tons of water collected from 315 bottles at 50 CTD casts, at a rate about 7-8 depths per cast. In addition, we also measured VSFs of water from 3000 m depth in three deep cast, which in itself was the first in the history of VSF measurement.

The two images (Fig. 9) show the derived particle size distributions (PSD) at a depth of 5 meter during CTD cast 004 and at 25 m during CTD cast 007.

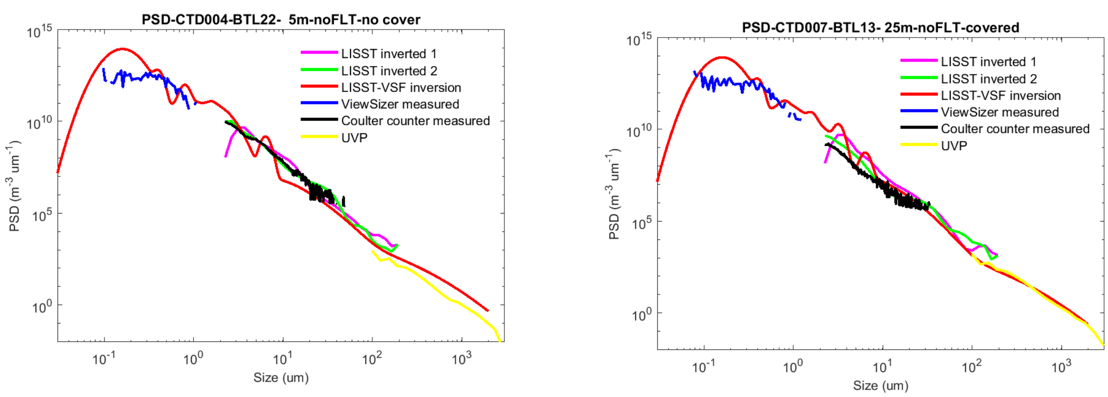


Figure 9. Derived particle size distributions (PSD

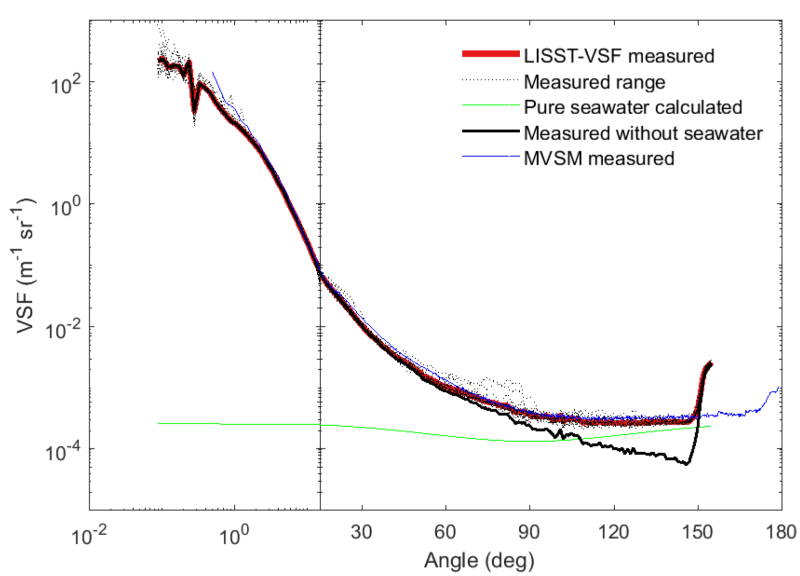


Figure 10. Volume scattering function

During the cruise, we could not analyze the MVSM data into particle size distributions. However, we did compare the VSF measurements by MVSM and LISST-VSF; the two instruments agree very well with each other (Fig. 10).

In summary, we were able to achieve what we planned with these preliminary findings: (1) the instruments have performed as expected and showed inter-instrument consistency; (2) we're able to derive self-consistent PSDs over the size range of 20 nm to 20 mm by using different instruments; (3) scattering at depths > 1000 m may be subject to pressure effect of scattering by pure seawater.

During the cruise, it occurred three times that our MVSM sensor had issues that need to be serviced, but according to Deric, this has been the best performance of the MVSM in the past 14 years. Several days after the official start of CTD casts, our LISST-VSF had an issue with its outer rings (measuring the scattering at angles from 13 to 15 degrees). Unfortunately, this issue could not be fixed onboard. We tried to mitigate this issue by interpolation and we will further evaluate using the independent LISST measurements at these angles later.

Role of Diatoms in the Carbon Budget

Collin Roesler, Heidi Sosik, Taylor Crawford

The objectives of this project are to investigate the role of diatoms in the carbon budget of the North Pacific. In particular we are interested in the role of nanoplankton-sized diatoms as the convention is to assume that diatoms and their proxies (e.g., fucoxanthin) fit into the microplankton size class. Thus we are focused on underway microscopy with the Imaging Flow CytoBot (IFCB), underway size fractioned optical proxies (absorption, beam attenuation, multichannel fluorescence and backscattering), with associated discrete samples (size fractioned) for spectrophotometric absorption, flow cytometry, HPLC and POC. We also collected discrete samples from the Niskin Rosette for spectrophotometric absorption and POC (relieving the Hydro team of these duties), targeted discrete IFCB and flow cytometry. Finally these are associated with 30-45 minute time series of incident spectral irradiance and upwelling subsurface radiance at each noon-time station. The inventory of these activities follows.

IFCB and flow cytometry (FCM) - As of this writing, the IFCB collected 8,333 5-ml samples for image analysis, primarily continuous underway samples from the seawater line connected to the diaphragm pump and 109 from discrete Niskin Samples. Flow cytometry samples were also collected from these 109 Niskin samples plus another 23 from the flow through system. They are preserved with glutaraldehyde and will be sent to WHOI for analysis. All IFCB samples have been processed for blobs, features, and classification. They were loaded into a shipboard dashboard so that the cruise participants had access to the imagery with less than a day lag. As of this writing, 53 of the IFCB samples have been fully manually annotated.

Inline Optics - The underway optical system was initially configured into the diaphragm flowing seawater system. It was turned on 2018/08/10 at 15:26 UTC. By 17:37 all instruments were online. After issues arose with bacterial growth on the ship-supplied hosing (which underwent 3 cleanings with bleach), the inline system was switched to the forward impeller-pump seawater system on 2018/08/27 at 19:25 UTC. The system was not turned off until 2018/09/12. Daily cleaning and MilliQ calibrations were performed on the whole system. A total of 755 hourly acs files and ECO (four-channel backscattering, 4-channel chlorophyll fluorescence, CDOM fluorescence) plus TSG (temperature and salinity) files were collected. They each consist of 1 Hz resolution observations. These two file types have been processed into daily files of 5 minute medians and geo-located by merging with the ship navigation files (which were available in raw form and had to be processed to 5-minute median values).

Water sample processing – A total of 345 discrete water samples from the Niskin rosette were collected and filtered for spectrophotometric particulate absorption and POC (as help to the Hydro team). An additional 75 size-fractioned samples were collected from the inline system and filtered for particulate absorption, POC, and HPLC.

Spectrophotometric absorption – A total of 420 filtered samples (Niskin and underway) were measured for particulate absorption in a Cary 3 uv-vis spectrophotometer configured with the center-mounted integrating sphere. The samples were scanned from 300 nm to 800nm at 100 nm/minute. A blank filter baseline was subtracted and multiple blank filters measured each day at the beginning and end of the sample runs. Each filter was extracted in 100% methanol to remove soluble pigments and was scanned a second time to measure the contribution by non-algal particulate matter. Approximately 75% of the optical density files have been processed to final absorption values. Phytoplankton absorption spectra were calculated by difference. In addition to these samples, we took advantage of collecting punches of the Thorium groups pump sample filters (associated HPLC punches were also collected). A total of 62 pump filter samples were measured for particulate and non-algal particle absorption. Once we receive final filter volumes these will be processed for absorption coefficients.

Surface Radiometry – A Satlantic Hyper- Tethered Spectral Radiometer Buoy (HTSRB) was deployed at approximately local noon each day in concert with the C-ops profiles when conditions allowed. A total of 20 deployments were performed. All files have been processed, calibration coefficients applied, dark- corrected, sample medians computed and remote sensing reflectance determined.

Net Community Productivity and Oxygen

Weiyi Tang, Alex Niebergall

Goals for data collection:

- Continuous underway O_2/Ar measurements using the Equilibrator Inlet Mass Spectrometer (EIMS).
- Continuous F_v/F_m measurements using the Fluorescence Induction and Relaxation Fluorometer System (FIRe).
- Discrete samples 4x per epoch from the underway system and the 5m CTD for O_2/Ar analysis to correct the EIMS measurements for respiration in the underway line.
- Discrete samples 4x per epoch from the 5m CTD for N_2O analysis.
- Duplicate 4L samples every day from the 5m CTD, filtered and frozen for 16S and 18S DNA sequencing.
- Winkler titrations to measure oxygen concentrations to calibrate various sensors and as needed by the chief scientists.

The EIMS was started the morning of August 10, 2018 and ran for most of the cruise with minimal issues. The FIRe was started on August 10, 2018 and collected data continuously for the entire cruise, except during routine maintenance. The largest gaps in net community production (NCP) data from the EIMS and F_v/F_m data from the FIRe were 4-6 hours twice on the cruise, while the underway lines were bleached. Both instruments will continue to collect data as we approach the coast, until the diaphragm pump is shut off. 26 discrete O_2/Ar samples were collected on station (13 sets of underway measurements paired with 5m CTD measurements). 24 discrete samples were taken on station for N_2O analysis in the lab. 54 water samples were taken for 16S and 18S DNA sequencing. Of these 54 samples one was from the test station, two were blanks ran with Milli-Q, three were from the underway line, and 48 were samples taken from the 5m CTD while on station. 376 samples were collected and Winkler titrations were performed to calibrate oxygen concentrations for the Lagrangian float, Wire Walker, Seaglider, Bio-Argo Floats, and the underway system.

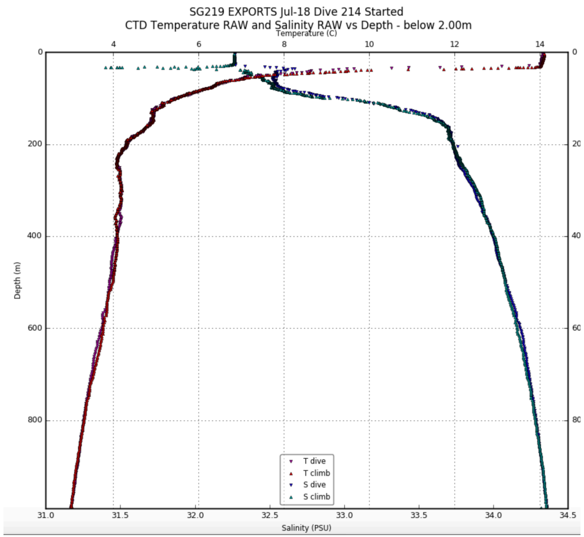
Overall, our data collection goals were met. There will be a lot of effort put into post-processing when we return to Duke. A large portion of this post-processing will be focused on calculating the NCP measurements from both ships and pairing that with microbial community composition data from the 16S and 18S DNA sequencing of samples collected on both ships.

AUV Calibrations

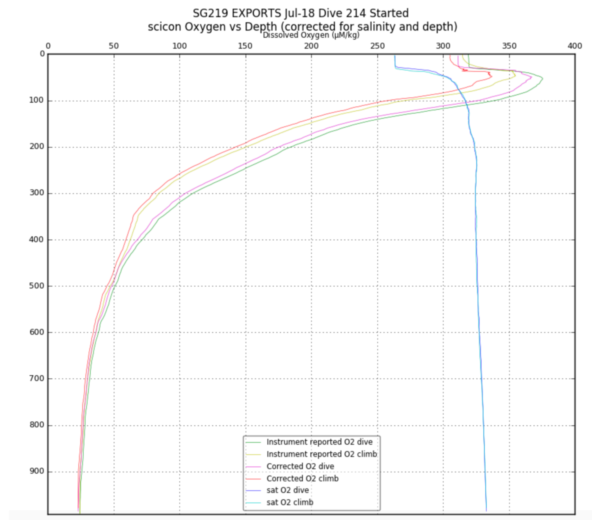
Mary Jane Perry

The AUV component of EXPORTS is a multi-month autonomous observation at the EXPORTS site by a Lagrangian float, a Seaglider and a Bio-Argo float. It was designed to measure upper and deep ocean phytoplankton and particles, sinking particles, changes in oxygen and nitrate, physical export, and migrating zooplankton. These observations were designed to complement ship-based programs by spanning a wider range of ecosystem states and providing a diverse dataset for EXPORTS modeling.

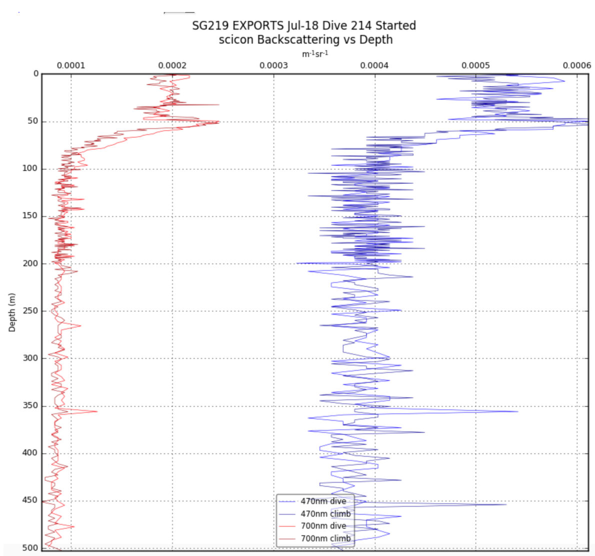
A Seaglider was deployed on the previous OOI cruise, operated throughout SR1812, and will continue sampling into December when it will be retrieved. The glider profiled to 1000 m, measuring temperature, salinity, oxygen, chlorophyll fluorescence, optical backscatter, 4 channels of downwelling irradiance, and acoustic backscatter for small zooplankton. By the end of the EXPORTS cruise, the glider accomplished over 215 dives (Fig. 11). The preliminary data show that the mixed layer depth was variable, ranging from less than 25 m to slightly greater than 35 m; in general mixed layers were extremely well mixed. Chlorophyll fluorescence showed strong daytime quenching (solar quenching of fluorescence). A Lagrangian float was deployed as the first operation of the cruise. It was ballasted for the base of the mixed layer and carried sensors for temperature, salinity, oxygen nitrate, chlorophyll fluorescence, optical backscatter, and beam transmission. The later was oriented vertically, to operate as an optical sediment trap. The float surfaced daily around 5 pm local time during the cruise and for the calibtration casts. The Lagrangian float will continue operating until retrieval in December but will surface at night, to provide the best air calibration of the oxygen optode. Two BioArgo floats were deployed, although one needed to be recovered halfway through the cruise due to leaking of hydraulic fluid leak in buoyancy bladder. The second BioArgo float will continue operating for several years, measuring temperature, salinity, oxygen, nitrate, pH, chlorophyll fluorescence, optical backscattering, and PAR. All the platforms were calibrated with at least one CTD cast; calibration cast totals are: five Lagrangian float, four Seaglider, two per BioArgo float, and three Wire Walker. We accomplished all, and slightly more, of tasks proposed before the cruise.



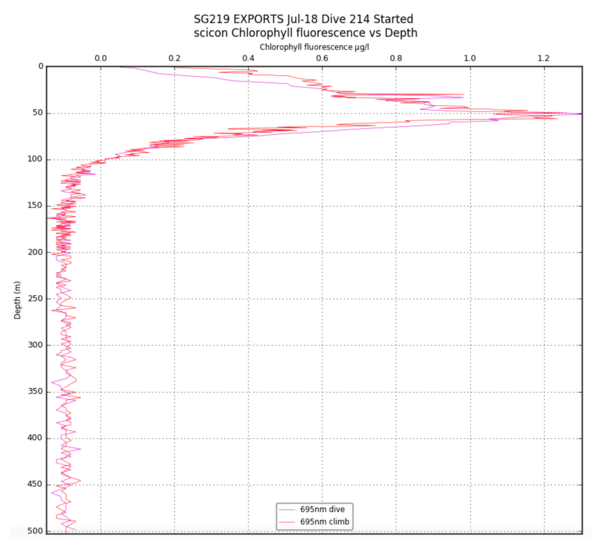
Seaglider dive 214: preliminary data for temperature and salinity



Seaglider dive 214: preliminary data for dissolved oxygen



Seaglider dive 214: preliminary data for optical backscatter at 700 nm (red) and 470 nm (blue)



Seaglider dive 214: preliminary data for chlorophyll fluorescence. Note low values at the surface due to daytime solar quenching of fluorescence.

Figure 11. Preliminary example plots for Seaglider dive 214, 9 September 2018.

UNOLS Cruise Personnel Manifest

Ship* R/V Sally Ride
Cruise ID* SR1812
Cruise Title* EXPORTS Survey Ship

Start Date:* 9-Aug-18 **End Date:*** 13-Aug-18
Start Port:* Seattle WA **End Port:*** Seattle WA

Cruise Party Information

Last Name*	First Name*	Institution*	Role*	Gender*
Benitez-Nelson	Claudia	University of South Carolina	Scientist	Female
Bisson	Kelsey	UC Santa Barabara	Student, Graduate	Female
Clevenger	Samantha	WHOI	Student, Graduate	Female
Crockford	Taylor	WHOI	Technician, science provided	Female
Freeman	Scott	NASA Goddard	Scientist	Male
Gray	Derek	NRL	Scientist	Male
Kramer	Sasha	UC Santa Barabara	Student, Graduate	Female
Long	Jacqueline	MBARI	Technician, science provided	Female
Lopez	Chelsi	Univeristy of Miami	Student, Graduate	Female
Nelson	Norm	UC Santa Barabara	Scientist, Co-Chief	Male
Niebergal	Alexandria	Duke Univerity	Student, Graduate	Female
Perry	Mary Jane	University of Maine	Scientist, Co-Chief	Female
Pike	Steven	WHOI	Technician, science provided	Male
Pretty	Jess	University of Alaska	Student, Graduate	Female
Roca Marti	Montserrat	WHOI	Scientist, Post-Doc	Female
Roesler	Collin	Bowdoin College	Scientist	Female
Umhau	Blaire	University of South Carolina	Student, Graduate	Female
Tang	Weiyi	Duke Univerity	Student, Graduate	Male
Wyatt	Abigale	Princeton University	Student, Graduate	Female
Xiong	Yuanheng	University North Dakota	Student, Graduate	Male
Zhang	Xiaodong	University North Dakota	Scientist	Male