ANACONDAS CRUISE REPORT

U.S. Dept. of State CRUISE No.:	**2009-103**
SHIP NAME:	RV Knorr (KN-197-8)
OPERATING INSTITUTE OR AGENCY:	Woods Hole Oceanographic Institution
PROJECT TITLE:	ANACONDAS / ROCA
CRUISE DATES (INCLUSIVE):	May 22 – June 24, 2010

CHIEF SCIENTIST:	
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CLEARANCE COUNTRIES:	Barbados, France (French Guiana) *Note that we requested permissions from Guyana, Suriname, Trinidad and Tobago, and Brazil, but either did not receive them in time or did not use them. One of our Argos floats drifted into Suriname waters near the end of the expedition and we did receive permissions from Suriname on the day we recovered the float.
FOREIGN PARTICIPANTS:	Marcelo Fernandes (Brazilian scientist), Luis Felipe Silva Santos (Brazilian Naval officer)

DESCRIPTION OF SCIENTIFIC PROGRAM:

This research project studied the effects of the Amazon River plume on the carbon and nitrogen cycling of the western tropical North Atlantic Ocean. Phytoplankton blooms triggered by the river plume are thought to be responsible for significant carbon dioxide drawdown from the atmosphere. Our team came together to try to understand the factors affecting the phytoplankton bloom and also the fate of its production, including the amount of carbon dioxide taken up by the plume. **Fieldwork in the western tropical North Atlantic onboard the *RV Knorr*** took place along the salinity gradient of the river plume (16 ppt to 36 ppt) at a series of stations within and adjacent to the plume (see **Figures 1 and 2**). Onboard the *RV Knorr*, our primary sampling tools were:

CTD/rosette (microbiology and geochemistry measurements)
MOCNESS net tows for zooplankton
Multicorer for seafloor sediment cores
Floating **sediment traps** for collecting sinking detritus
A suite of optical instruments (**FRRF**, **Optics Cage**, and **spectroradiometer**) measured the quality of light
Surface pumps, **buckets**, and smaller **nets** were used to collect additional water and plankton samples
An underwater camera was used for educational purposes.

See **Table 1** for the times and locations of each station, with the number of deployments of each of these tools.

The ship's underway system was used to measure surface water properties such as temperature, salinity, fluorescence, and oxygen and carbon dioxide concentration during transit periods. Between stations, discrete water samples were collected from the underway system for additional nutrient and plankton analyses.
See **Table 2** for the times and locations of underway samples.

An untethered, depth-profiling (0-1000 m) ARGOS float was deployed on May 25 (10.3°N, 54.4°W) and recovered on June 14 (8.9°N, 55.9°W). It measured optical properties of the seawater.

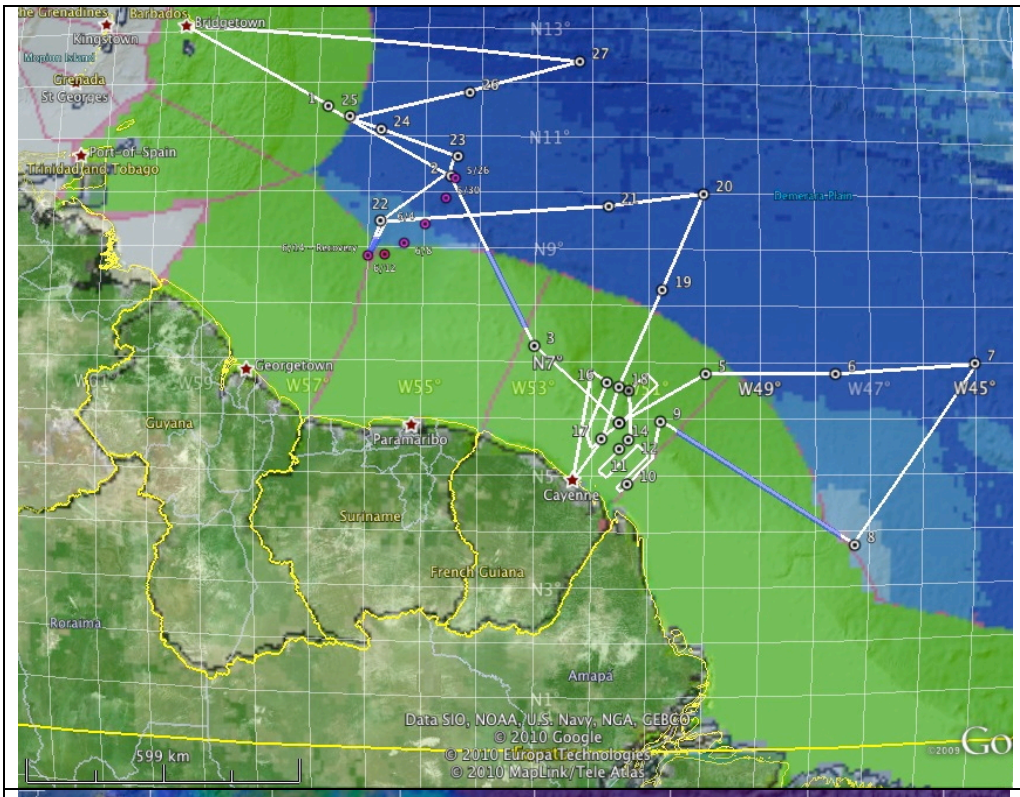


Figure 1. *Ship's track (white line; Bridgetown, Barbados to Cayenne, French Guiana, to Bridgetown, Barbados) with enumerated stations designated with white and black dots. The purple dots are the positions of the Argos drifter every four days between May 26 and June 14. The green areas illustrate the EEZ's of each coastal state. Underway sampling did not occur during transits through Brazil, Suriname, or Guyana EEZs (white line changes to light blue).*

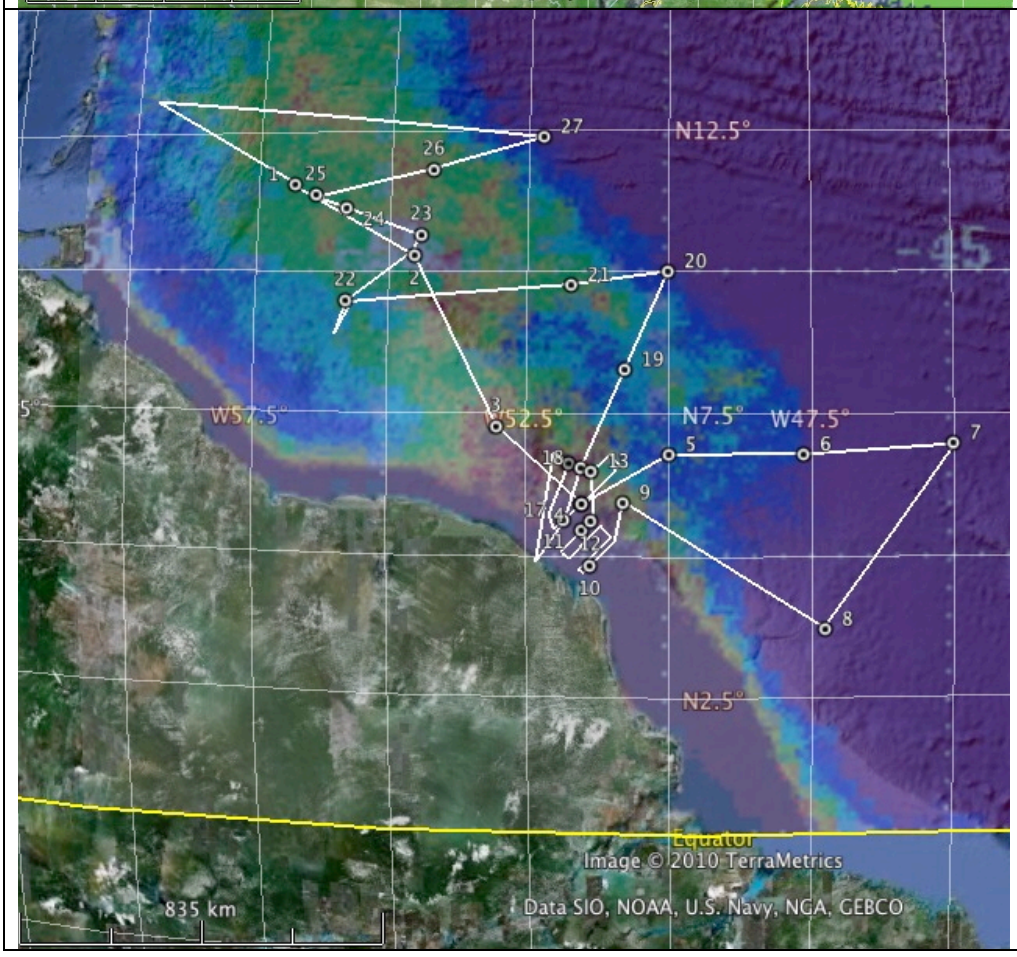


Figure 2. *Station map superimposed on climatological position of the plume for June (red and orange are lowest salinity, increasing to green and blue, with purple colors in the open ocean), according to 10 years of satellite data (courtesy A. Subramaniam).*

Table 1. *Station times, locations, and number of samples collected by each method. Stations shaded in blue are within Barbados EEZ. Stations shaded green are within French Guiana EEZ.*

Sta. #	Date GMT	Time GMT	Lat °N	Long °W	CTD	MOC	Multi corer	Sed Traps	FRRF	OPT	Spec	Surf Pump	Net Tow	Bucket	CAM
01	5/23/10	0530	11.56	56.80	3	0	2	0	2	0	0	6	6	1	1
02	5/24/10	1430	10.29	54.51	8	2	0	0	3	2	0	7	4	1	0
03	5/26/10	1130	7.29	53.00	3	1	0	0	1	1	0	3	1	1	1
04	5/27/10	1130	5.95	51.49	4	1	0	0	1	1	0	3	1	1	0
05	5/28/10	0700	6.81	49.98	4	1	2	0	1	1	1	3	2	1	1
06	5/29/10	1200	6.82	47.64	4	2	1	0	1	2	1	1	1	1	0
07	5/30/10	2330	7.00	45.00	8	1	1	0	2	1	1	6	3	1	0
08	6/1/10	1000	4.35	46.85	4	0	0	0	1	1	2	1	4	2	0
09	6/2/10	1630	5.96	50.78	11	5	3	3	7	3	1	3	2	2	0
10	6/5/10	0930	4.87	51.35	4	0	0	0	2	1	1	4	5	1	0
11	6/6/10	1030	5.49	51.50	4	0	2	0	3	0	0	3	5	2	0
12	6/6/10	1930	5.65	51.34	1	0	0	0	0	0	0	0	0	1	0
13	6/7/10	0100	6.51	51.34	1	0	0	3	0	0	0	0	0	0	0
14	6/7/10	1000	5.95	51.50	4	1	0	0	2	1	1	1	0	1	0
16	6/8/10	0800	6.66	51.72	4	1	0	0	3	1	1	1	2	3	0
17	6/9/10	2200	5.67	51.81	1	0	1	0	1	0	0	0	0	0	0
18	6/10/10	0400	6.58	51.51	1	0	0	0	0	0	0	0	0	0	0
19	6/10/10	1500	8.29	50.76	5	2	2	0	2	2	2	1	4	1	0
20	6/12/10	0100	9.95	50.02	4	1	2	0	2	1	1	3	4	1	0
21	6/13/10	0230	9.77	51.70	4	1	1	0	3	1	1	3	5	1	0
22	6/14/10	1700	9.49	55.77	1	0	0	0	0	0	0	0	0	0	0
23	6/15/10	0230	10.44	54.48	8	2	2	2	4	1	1	2	6	2	0
24	6/17/10	1800	11.19	56.05	1	0	0	0	1	0	0	0	0	1	0
25	6/17/10	2100	11.31	56.37	14	2	1	2	7	3	2	4	7	3	0
26	6/20/10	1030	11.80	54.21	0	0	1	0	1	0	0	0	0	0	0
27	6/21/10	1630	12.40	52.22	11	2	1	2	5	1	0	4	4	2	0

Table 2. Times and locations of underway samples. Stations shaded in blue are within Barbados EEZ. Stations shaded green are within French Guiana EEZ.

Event #	Date GMT	Time GMT	Latitude °N	Longitude °W
9.20	6/3/10	1230	6.014	50.849
9.21	6/3/10	1330	6.018	50.864
9.22	6/3/10	1430	6.098	50.917
9.23	6/3/10	1540	6.166	50.954
9.25	6/3/10	1630	6.152	50.933
9.26	6/3/10	1740	6.118	50.903
9.27	6/3/10	1830	6.098	50.880
9.28	6/3/10	1930	6.046	50.872
9.32	6/3/10	2030	6.059	50.883
9.33	6/3/10	2150	6.004	50.755
9.34	6/3/10	2230	5.999	50.751
10.19	6/5/10	2200	5.079	51.265
10.20	6/5/10	2300	5.198	51.159
10.21	6/6/10	0000	5.323	51.046
10.22	6/6/10	0100	5.462	51.073
10.23	6/6/10	0200	5.547	51.195
10.24	6/6/10	0300	5.422	51.314
10.25	6/6/10	0400	5.298	51.433
10.26	6/6/10	0500	5.182	51.555
10.27	6/6/10	0600	5.054	51.669
10.28	6/6/10	0700	5.035	51.801
10.29	6/6/10	0800	5.173	51.804

10.30	6/6/10	0900	5.300	51.676
10.31	6/6/10	1000	5.451	51.525
13.05	6/7/10	0200	6.514	51.335
13.06	6/7/10	0300	6.666	51.299
13.07	6/7/10	0400	6.781	51.188
13.08	6/7/10	0500	6.713	51.047
13.09	6/7/10	0600	6.565	51.126
13.10	6/7/10	0700	6.371	51.238
13.11	6/7/10	0800	6.220	51.333
13.12	6/7/10	0900	6.068	51.417
13.13	6/7/10	1000	5.950	51.495
15.01	6/7/10	2200	5.737	51.745
15.02	6/7/10	2300	5.625	51.842
15.03	6/8/10	0000	5.526	52.010
15.04	6/8/10	0100	5.683	52.121
15.05	6/8/10	0200	5.860	52.058
15.06	6/8/10	0300	6.017	51.991
15.07	6/8/10	0400	6.201	51.924
15.08	6/8/10	0500	6.379	51.853
15.09	6/8/10	0600	6.536	51.769
15.10	6/8/10	0700	6.646	51.713
16.16	6/8/10	2400	7.064	52.185
16.17	6/9/10	0100	6.875	52.185
16.18	6/9/10	0200	6.670	52.198
16.19	6/9/10	0300	6.503	52.183
16.20	6/9/10	0400	6.342	52.182
16.21	6/9/10	0500	6.152	52.153
16.22	6/9/10	0600	5.984	52.149
16.23	6/9/10	0700	5.787	52.149
16.24	6/9/10	0800	5.609	52.188
16.25	6/9/10	0900	5.405	52.174
16.26	6/9/10	1000	5.262	52.159
16.27	6/9/10	1100	5.096	52.137
16.28	6/9/10	1900	5.107	52.109
16.29	6/9/10	2000	5.310	52.014
16.30	6/9/10	2100	5.488	51.932
17.04	6/10/10	0100	5.994	51.705
17.05	6/10/10	0200	6.200	51.637
17.06	6/10/10	0300	6.398	51.567
17.07	6/10/10	0300	6.404	51.564
18.02	6/10/10	0600	6.763	51.434
18.03	6/10/10	0700	6.952	51.347
18.04	6/10/10	0800	7.139	51.259
18.05	6/10/10	0900	7.298	51.184
18.06	6/10/10	1000	7.474	51.107
18.07	6/10/10	1100	7.643	51.040
18.08	6/10/10	1200	7.809	50.966
18.09	6/10/10	1300	7.993	50.884
18.10	6/10/10	1400	8.125	50.828
19.02	6/10/10	1500	8.280	50.755
19.23	6/11/10	1600	8.446	50.692
19.24	6/11/10	1700	8.633	50.621
19.25	6/11/10	1800	8.854	50.530
19.26	6/11/10	1900	9.016	50.463
19.27	6/11/10	2000	9.197	50.378
19.28	6/11/10	2100	9.380	50.298
19.29	6/11/10	2200	9.564	50.209
19.30	6/11/10	2300	9.757	50.109
19.31	6/11/10	2400	9.940	50.025
20.19	6/12/10	1800	10.005	49.973
20.20	6/12/10	1900	9.967	50.173
20.21	6/12/10	2000	9.938	50.367
20.22	6/12/10	2100	9.908	50.572
20.23	6/12/10	2200	9.879	50.780
20.24	6/13/10	0000	9.820	51.198
20.25	6/13/10	0100	9.799	51.402
20.26	6/13/10	0200	9.777	51.612
21.21	6/13/10	1700	9.739	51.907
21.22	6/13/10	1800	9.713	52.103
21.23	6/13/10	1900	9.691	52.305
21.24	6/13/10	2000	9.676	52.528
21.25	6/13/10	2100	9.664	52.741
21.26	6/13/10	2200	9.656	52.950
21.27	6/13/10	2300	9.648	53.172
21.28	6/14/10	0000	9.638	53.385
21.29	6/14/10	0100	9.614	53.637
21.30	6/14/10	0200	9.597	53.816
21.31	6/14/10	0300	9.576	54.046
21.32	6/14/10	0400	9.561	54.269
21.33	6/14/10	0500	9.547	54.492
21.34	6/14/10	0600	9.528	54.709
21.35	6/14/10	0700	9.501	54.963
21.36	6/14/10	0800	9.472	55.147
21.37	6/14/10	0900	9.454	55.366
22.02	6/14/10	1909	9.565	55.677
22.03	6/14/10	2000	9.659	55.539
22.04	6/14/10	2100	9.768	55.371
22.05	6/14/10	2200	9.886	55.216
22.06	6/14/10	2300	10.008	55.059
22.07	6/15/10	0000	10.133	54.885
22.08	6/15/10	0100	10.256	54.713
22.09	6/15/10	0200	10.382	54.542

23.07	6/15/10	0600	10.484	54.459
23.08	6/15/10	0700	10.578	54.655
23.09	6/15/10	0800	10.671	54.855
23.10	6/15/10	0900	10.763	55.058
23.11	6/15/10	1000	10.784	55.233
23.12	6/15/10	1100	10.947	55.409
23.13	6/15/10	1200	11.042	55.603
23.14	6/15/10	1300	11.140	55.802
23.15	6/15/10	1400	11.225	55.991
23.16	6/15/10	1500	11.308	56.189
23.17	6/15/10	1600	11.411	56.391
23.18	6/15/10	1700	11.495	56.585
23.19	6/15/10	1800	11.565	56.742
23.20	6/15/10	1900	11.567	56.812
23.21	6/15/10	2000	11.502	56.662
23.22	6/15/10	2100	11.427	56.466
23.23	6/15/10	2200	11.370	56.313
23.24	6/15/10	2300	11.279	56.101
23.25	6/16/10	0000	11.216	55.956
23.26	6/16/10	0100	11.142	55.775
23.27	6/16/10	0200	11.066	55.587
23.28	6/16/10	0300	10.974	55.426
23.29	6/16/10	0400	10.930	55.234
23.30	6/16/10	0500	10.852	55.055
23.31	6/16/10	0600	10.815	54.879
23.32	6/16/10	0700	10.715	54.692
23.33	6/16/10	0800	10.651	54.516
23.60	6/17/10	1130	10.854	54.715
23.61	6/17/10	1230	10.894	54.908
23.62	6/17/10	1330	10.947	55.121
23.63	6/17/10	1430	11.006	55.337
23.64	6/17/10	1530	11.067	55.548
23.65	6/17/10	1630	11.127	55.751
23.66	6/17/10	1730	11.183	55.999
25.48	6/19/10	2100	11.334	56.526
25.49	6/19/10	2200	11.384	56.338
25.50	6/19/10	2300	11.428	56.150
25.51	6/20/10	0000	11.465	55.968
25.52	6/20/10	0100	11.498	55.801
25.53	6/20/10	0200	11.535	55.592
25.54	6/20/10	0300	11.565	55.418
25.55	6/20/10	0400	11.581	55.314

25.56	6/20/10	0500	11.617	55.152
25.57	6/20/10	0600	11.656	54.982
25.58	6/20/10	0700	11.689	54.825
25.59	6/20/10	0800	11.716	54.658
25.60	6/20/10	0900	11.740	54.492
25.61	6/20/10	1000	11.773	54.325
25.62	6/20/10	1100	11.801	54.207
26.03	6/20/10	1700	11.855	54.004
26.04	6/20/10	1800	11.873	53.878
26.05	6/20/10	1900	11.897	53.710
26.06	6/20/10	2000	11.934	53.574
26.07	6/20/10	2100	11.959	53.412
26.08	6/20/10	2200	11.982	53.257
26.09	6/20/10	2300	12.020	53.081
26.10	6/21/10	0000	12.049	52.910
26.11	6/21/10	0100	12.066	52.745
26.12	6/21/10	0200	12.077	52.579
26.13	6/21/10	0300	12.165	52.441
27.33	6/22/10	1900	12.459	52.335
27.34	6/22/10	2000	12.465	52.493
27.35	6/22/10	2100	12.470	52.739
27.36	6/22/10	2200	12.479	52.849
27.37	6/22/10	2300	12.499	53.156
27.38	6/23/10	0000	12.516	53.359
27.39	6/23/10	0100	12.532	53.557
27.40	6/23/10	0200	12.549	53.757
27.41	6/23/10	0300	12.563	53.949
27.42	6/23/10	0400	12.580	54.158
27.43	6/23/10	0500	12.596	54.373
27.44	6/23/10	0600	12.630	54.574
27.45	6/23/10	0700	12.633	54.779
27.46	6/23/10	0800	12.649	54.990
27.47	6/23/10	0900	12.668	55.230
27.48	6/23/10	1000	12.681	55.453
27.49	6/23/10	1100	12.687	55.685
27.50	6/23/10	1200	12.692	55.872
27.51	6/23/10	1300	12.715	56.078
27.52	6/23/10	1400	12.729	56.271
27.53	6/23/10	1500	12.745	56.479
27.54	6/23/10	1600	12.752	56.681
27.55	6/23/10	1700	12.763	56.907
27.56	6/23/10	1800	12.772	57.086

Individual cruise reports from Principle Investigators:

PI Victoria J. Coles (UMCES/HPL)
Physical Oceanography

Activities:

During the KN197-08 cruise, I was in charge of the **CTD operations**. We deployed the CTD/Rosette package on 117 casts at 27 stations. The instrument functioned well, with some problems initially with the #1 sensor units that were largely corrected when the pump system was taken apart and carefully flushed by SSSG Anton Zafereo. The oxygen sensor was deployed only on the #1 pump, so there are some stations (about 5) where there are no good oxygen data.

The rosette functioned well, although there remain some persistent leakage issues with Niskin bottle 6 despite the efforts of the SSSG's to improve the lanyard system, and to smooth the surface at the cap closure. This Niskin may require replacement.

For **CTD calibration**, bottle salt and oxygen samples were taken at every fourth cast, or at least one per station. These were analyzed on the WHOI Autosal, and on the Bigelow Oxygen titration system respectively. Oxygen data have not yet been fully analyzed, however the salinity data suggest a constant offset of .01 from the CTD sensor. Salinity replicates were at the .003 level. The bottle chlorophyll-a concentration samples will also be used to calibrate the CTD fluorometer, but these are not yet available.

The **underway system** operated consistently and well, with no issues. The underway data appear consistent with the CTD to first order.

The **ADCP profilers** also operated well, needing only one restart during the 30+ day cruise. They were turned on and off as we entered and left exclusive economic zones of countries for which we had no clearance for science activities. These data are being post-cruise processed by Jules Hummon (University of Hawaii).

Science Findings:

The physical data showed a very stable fresh **Amazon plume** extending to more than 12°N, which was not in place on the initial southward transit. This plume maintained surface salinities of less than 19, and was consistently 10-20m thick. This exceeded our expectations for the spatial coherence of the very low salinity water. We also found evidence of fossil or remnant river plumes that were overlain by the newer fresh tongue. These fossil plumes appeared to have biological communities that were maintained whether the layer was at the surface or underneath a newer fresher plume layer.

Light levels below the plume were very low due to the presence of high colored dissolved organic matter (**CDOM)** levels, and the results from P vs I experiments will be of great interest to evaluate how these communities adapt to the low light conditions.

The ADCP data showed very high surface velocities in the **North Brazil Current** (NBC) region, as well as in eddy structures surrounding the NBC. We do not yet know to what extent the plume layer sits on top of the NBC current structure vs interacts with it, however there was considerable evidence of vertical shear in the ADCP current data suggesting that the Ekman layer was confined to the fresh plume layer where it was present.

We also saw considerable evidence for **double diffusive mixing** in the salinity profiles, or stairstep vertical structures in both temperature and salinity fields. This will have to be investigated further to understand what processes are driving this layering. Often the oxygen data show commensurate layering structures suggesting that bacterial communities may find refuge in the increased stability associated with these density variations. Sampling to investigate this hypothesis occurred, but we do not yet have the results.

PI Joaquim I. Goes (Bigelow Laboratory for Ocean Sciences)
Ocean Optics and Phytoplankton

Team members: Helga do Rosario Gomes and Courtney Beaulieu

Our observations were two pronged and included measurements from 1) the *R/V Knorr's* underway flow through seawater system and from 2) discrete depths at several hydrographic stations along a cruise track. Station selection was guided by daily satellite ocean color observations of the Amazon River plume and its extent as discernible from the fields of chlorophyll and attenuation being made available on board by NASA.

An **Automated Laser induction Fluorometer** (ALF) developed at Lamont Doherty Earth Observatory, was serially fitted to the ship's underway seawater flow through system, along with several other instruments (fluorometer, salinometer, SST, pCO2 and O2 etc). The ALF provides spectral deconvolution (SDC) analysis of blue (405 nm) and green (532 nm) laser excited, emission spectra for assessment of bulk chlorophyll a, phycoerythrin, and chromophoric dissolved organic matter (CDOM). Emission spectra by the green laser can be used for discriminating three types of phycoerythrin. The emission peak at 565 nm for instance, allows for the characterization of open-ocean, blue water cyanobacteria with high phycourobilin/phycoerythrobilin (PUB/PEB) ratios. The emission peak (λmax = 578 nm) allows for the detection of low-PUB/PEB containing cyanobacteria that usually thrive in turbid waters with elevated CDOM. The third phycoerythrin emission peak at 545 can be attributed to cryptophytes that are often abundant in the coastal, bay and estuarine environments. With a few breaks for reconditioning, the ALF was operated throughout the cruise period providing near-real time distribution patterns of CDOM, total phytoplankton and the three different types of cyanobacterial populations. In addition the ALF, provided real-time estimates of variable fluorescence (F_v/F_{max}) that will allow for assessment of the photo-physiological status of the populations inhabiting the Amazon River Plume. A screen capture of the data collected by the ALF when operated in underway mode from Station 27 (a blue water station) towards Barbados across the northern section of the Amazon River Plume is illustrated in Fig. 1 (below).

Size fractionated pigment concentrations. Observations for total phytoplankton pigment and of the major functional types (i.e DDAs, *Trichodesmium*, Diatoms, etc) within and outside of the Amazon River plume were undertaken by filtering seawater samples through filters that helped discriminate chlorophyll concentrations within three different size classes (<200mm, <20mm and < 3mm). In addition to measurements of chlorophyll concentrations, a separate set of size-fractionated samples were collected to obtain the absorption spectra of different size fraction and for HPLC measurements of phytoplankton pigment composition. These measurements when used in conjunction with CTD data and with microscopic counts of phytoplankton by the Carpenter group, nutrient concentrations by the Montoya group, spectrophotometric CDOM by the Goes group and total dissolved inorganic carbon (DIC) measurements, will be utilized to investigate the distribution of various phytoplankton

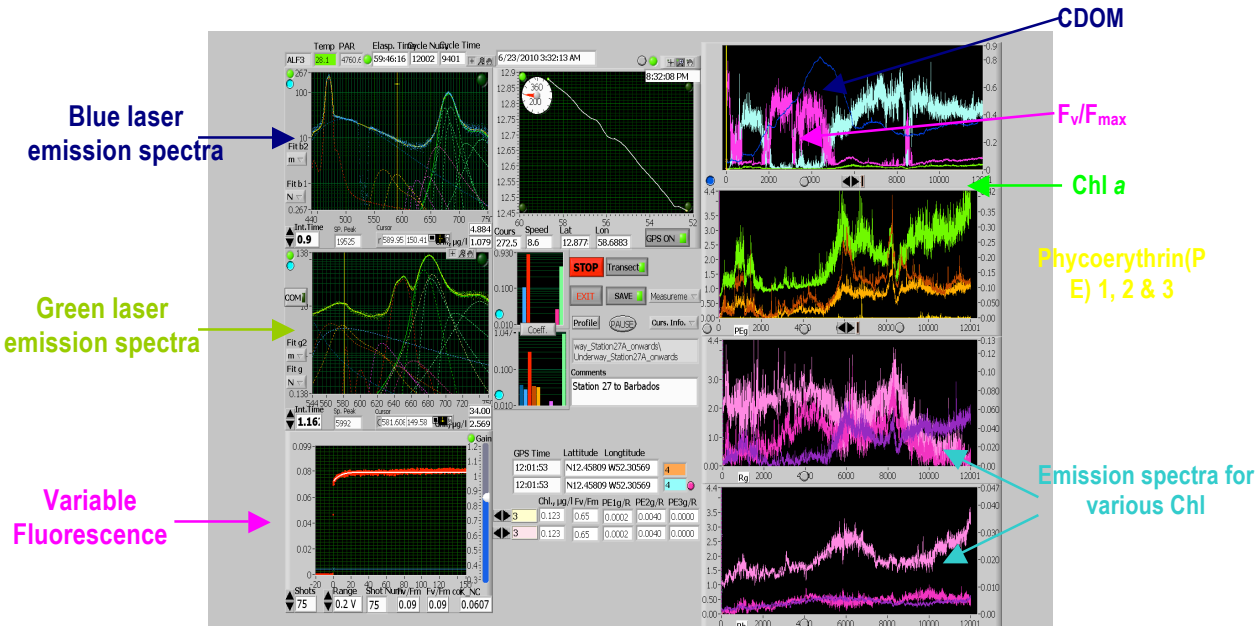


Fig. 1. Screenshot showing measurements provided by the ALF in underway mode along a transect from Sta. 27 towards Barbados

populations in relation to their environment. In particular we are interested in establishing whether each subset of the phytoplankton populations within the Amazon River Plume has a specific ecological niche.

Our goal is to process these rich datasets derived from the ALF and seawater size-fractionated analysis of phytoplankton biomass, HPLC pigments, and phytoplankton absorption spectra and phytoplankton microscopic counts in relation to various hydro-chemical and optical properties (Satlantic Micro spectroradiometer underwater PAR and spectral light fields, Wet Lab's ac-S and ac-9 measurements of attenuation, absorption and scattering.

Our group also aims to develop robust empirical and semi-analytic algorithms for ocean color products for the Amazon River Plume that would allow us to discern chlorophyll rich waters from CDOM and suspended matter rich waters from satellite ocean color data. Our plan is to utilize these data sets to construct regional algorithms for mapping CDOM, DDAs, *Trichodesmium,* and diatom communities from satellite ocean color data. If successful these algorithms will be applied to NASA's large >10 year data base of ocean color data from SeaWiFS and MODIS (Aqua) satellites, with the idea of establishing seasonal, annual to interannual variability in the Amazon River Plume phytoplankton communities. By utilizing this data in conjunction with other satellite data products such as SST, photosynthetically available radiation (PAR) sea surface winds (NSCAT and QUIKSCAT) and mesoscale eddy activity etc., we hope to address the longer climate-sensitivity questions associated with this project.

Primary production and light response. To estimate rates of productivity associated with different phytoplankton functional types from the Amazon river plume, we conducted several laboratory experiments with bulk phytoplankton, sorted *Trichodesmium* sp., and DDAs using a "photosynthethron" to measure phytoplankton photosynthetic rate against a light gradient (P vs I curves). These data will be used along with remotely sensed ocean color of plume phytoplankton populations for estimating their productivity rates from space. We also measured oxygen changes in deck incubated light and dark water samples to estimate photosynthetic and respiration rates associated with different populations in the Amazon River Plume waters.

Over the course of the cruise, we also monitored the photo-physiological status of the different communities encountered at various locations along the cruise track using an in-water, profiling Kimoto, Fast Repetition Rate Fluorometer (FRRF). Variable fluorescence (F_v/F_{max}), measured by the FRRF provides a measure of the maximum photosynthetic quantum yields and also an indication of the overall health of the phytoplankton populations with respect to their environment. An example of the data provided over the course of the day at Process Study Station 23 is shown below (Figure 2).

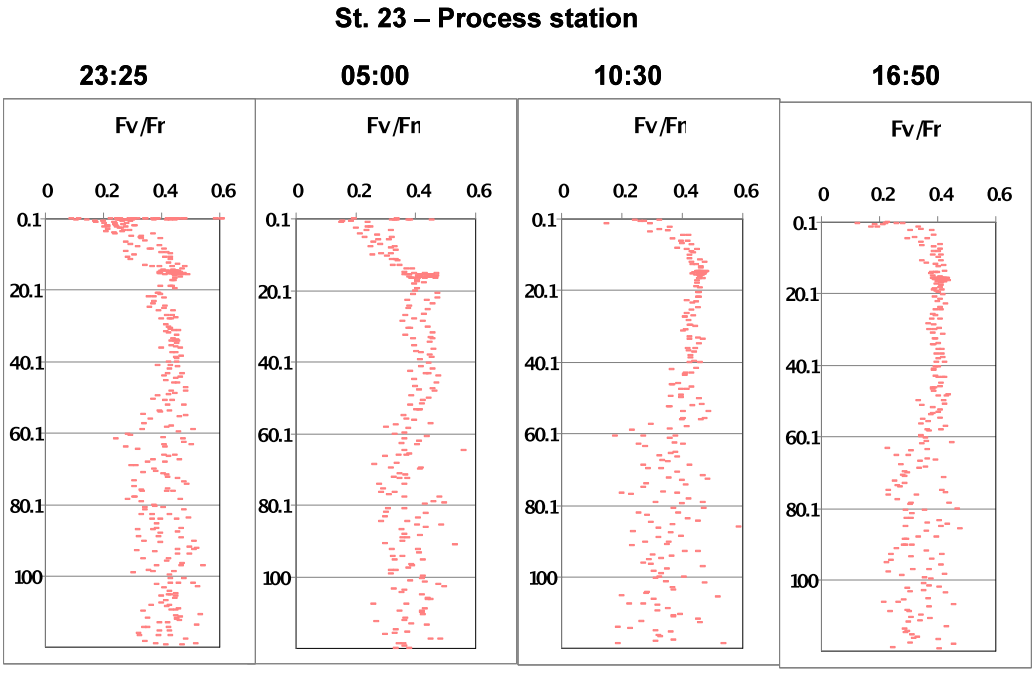


Fig. 2. Changes in the profiles of variable fluorescence (F_v/F_{max}) of phytoplankton populations over the course of the day at Process study station 23. Note the transition to a healthier population in the upper 20m by the evening of day 2 of the observations.

At the process study stations, PAR and Chlorophyll distributions obtained by the Kimoto FRRF, helped provide the first indications of the existence of an extremely low-light adapted population of phytoplankton that was capable of vertical migrating upwards by about ~30m during the day and in the opposite direction by the end of the day. Radio-tracer studies by the Yager group suggest that these populations may be capable of fixing CO_2 in the dark.

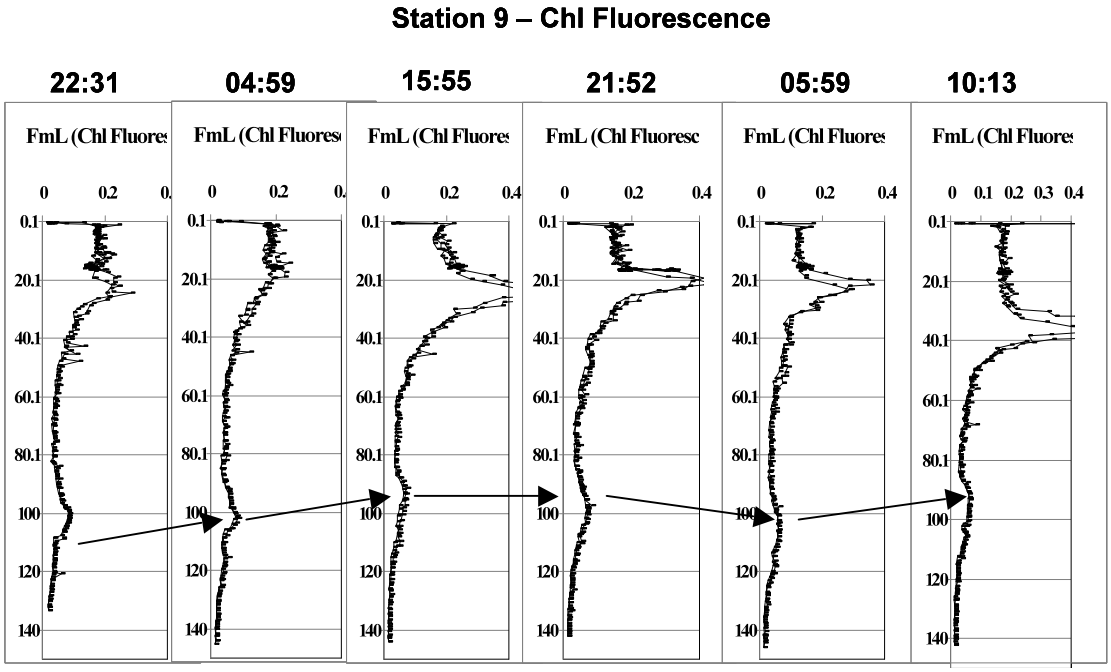
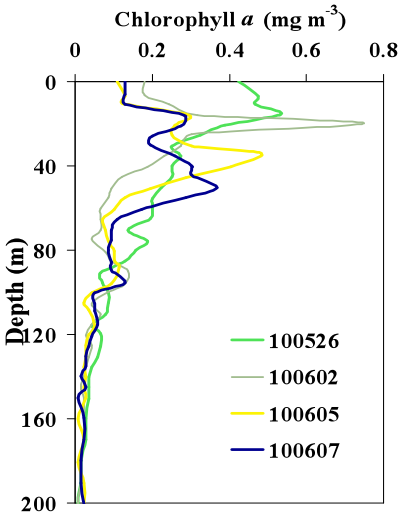


Fig. 3. Changes in chlorophyll profiles over the course of the day at Station 9 showing the migration of phytoplankton populations from the deeper layers.

To investigate the evolution of the Amazon River Plume's DDA community and its contribution to particle fluxes we deployed an **Autonomous Profiling Explorer** (APEX) float -equipped with Seabird Electronics CTD and Oxygen Sensors, a Wet Labs, FLBB (fluorescence and backscattering sensor) at Station 2 where an actively growing DDA population was located. The float was programmed to drift to depths to 200m once a day and then to dive to 1000m before ascending to the surface at midnight once a day. The float provided data for a period of 13 days that revealed the growth and sinking of the DDA bloom (see Fig. 4, right). This data will allow us to compare vertical fluxes of C in relation to hydrographic and O_2 concentrations within the bloom.



PI: Edward J. Carpenter (San Francisco State University)
Algal biomass and community structure + Dissolved Organic Carbon

Other team members onboard: Ina Benner, Brandon Russell

Activities:

Our group measured dissolved organic carbon (DOC) in seawater and typically measured concentrations at 8 to 12 depths in CTD Rosette casts at each station. These samples are still being analyzed. We also measured phytoplankton Chlorophyll a concentrations on 8 depths in CTD bottle casts at each station. These samples have all been analyzed.

Additionally, phytoplankton species composition was determined in surface water samples at each station using epifluorescence microscopy to identify free living and symbiotic diazotrophic cyanobacteria. Coccoid cyanobacterial concentrations (Synechococcus) were determined at 8 depths in CTD Rosette station casts. Light microscopy was used to identify phytoplankton species composition from the ship's underway seawater system on an hourly basis. All of the phytoplankton species composition counts have been done and the data are presently being analyzed.

Dr. Benner also performed some CO2-addition experiments with phytoplankton samples from the plume.

PI Debbie Steinberg (Virginia Inst. Marine Sciences)
Zooplankton Ecology

Other team members onboard: Joe Cope, Brandon Conroy, Miram Gleiber

Activities:

The aim of the zooplankton ecology group for this cruise was to investigate the role of zooplankton grazing in POC flux, with a focus on the importance of diazotrophs as food and as a source of the exported POC. Our first objective was to characterize the **mesozooplankton community structure** in and out of the plume waters. We conducted 26 MOCNESS tows (Multiple Opening/Closing Net and Environmental Sensing System), a cruise record for the Steinberg lab! We performed depth-stratified, day and night hauls in the top 150 m, and at selected stations in the top 500 m. We have a suite of samples from these tows, including those for determination of size-fractionated biomass, isotopic signatures, taxonomic composition, and grazing by gut fluorescence.

The second objective was to determine **grazing and fecal pellet production rates**. Mesozooplankton grazing will be calculated from gut fluorescence samples mentioned above. We performed 5 dilution experiments to determine microzooplankton grazing rates, with a comparison in vs. out of the plume waters. We also collected samples of individual species to analyze for evidence of feeding on diazotrophs. We will use microscopy to examine gut contents and fecal pellets of these important taxa, and analyze frozen specimens for cyanobacteria pigments and for molecular analysis (the latter in collaboration with R. Foster who has developed probes for N-fixing endosymbionts). We performed 4 fecal pellet production experiments on live animals of different size classes to use in conjunction with the grazing data to determine relative contribution of mesozooplankton to C and N flux.

The last objective was to examine **sediment trap material** and compare between sites fecal pellet number, size and shape (indicative of major taxa), and color (indicative of food source) to determine the relative contribution of zooplankton to flux, and to look for evidence of export of N-fixers (e.g., *Trichodesmium*). We examined on board all the trap material from all 5 sediment trap deployments and did some preliminary counting of particle types in the traps, and have preserved samples to take home for quantitative analysis of pellets.

Preliminary Findings:

There were obvious differences in mesozooplankton community structure in vs. out of plume waters. Our surface (0-25m) "plume" water samples contained high numbers of *Lucifer* sp. shrimp, cladocera, and a very diverse larval crustacean community. Further analysis should allow us to determine if the source of the larvae (river/estuary-originated, or larvae from deep benthos entrained in the plume waters). We saw pronounced diel vertical migration at both plume and blue water sites, so active transport by zooplankton is likely to be important (and a mechanism of export of DDAs). Other analyses of the biomass and preserved samples (e.g., isotopic signatures delineating consumption of N-fixers) will be conducted at home or in collaboration with other PIs.

We have not conducted the gut fluorescence analyses yet, and have analyzed only the first several dilution experiments. We got mixed results with the initial dilution experiments, with some negative phytoplankton growth rates. We suspect that there may have been a mixture of nutrient limitation and photoinhibition in the experiment, so adjusted our protocol for the rest of the experiments (yet to be analyzed). The fecal pellet production experiments will be analyzed back at our home laboratory.

The sediment traps contained a variety of fecal pellets, originating from both copepods and euphausiids, and some as yet unidentified. At stations 25 (plume station with DDAs and *Trichodesmium*) and 27 (open ocean/blue water) we found *Trichodesmium* in the traps, evidence of export of fixed N.

PI- Will Berelson (University of Southern California)
Vertical and Benthic Flux

Team members: Laurie Chong, John Fleming, Nick Rollins, Ellen Roosen

Sediment Coring. Our primary goal was to determine the spatial patterns and diagenetic processes and rates occurring within deep sea sediments underlying the Amazon Plume. We will also analyze the sediments to establish a history of sedimentation in the region. The diagenesis of organic carbon and biogenic silica is our major focus, but we have sampled and intend to analyze nitrate, Fe and Mn distributions as well as oxygen, TCO2, Ca, Si and ammonium.

Sediments were collected with a Multi-corer at 14 stations. We processed 71 cores in the following ways: Pore water collection on cm scale using rhizon extraction process, pore water collection on mm scale using whole core squeezing, profiling cores for oxygen using a thin optode, sectioning a core at cm scale for solid phase collection and for assessment of porosity profiles, archiving a whole core for later analysis of magnetic stratigraphy.

All sediment processing was conducted in a cold van (T=0-5 C) and cores were profiled and pore waters obtained within minutes of the multicore arriving on deck. Often two cores were profiled for oxygen. Dissolved Si and ammonium were measured on board ship. Other pore water will be stored for delivery to USC.

Sediment Trapping—A key element of the program is to ascertain export flux, and to this end, we ran a floating trap operation. We deployed 3 traps at one station and two at four stations (after losing one trap to a collision with a fishing ship). The traps were tethered to surface floats and hung at 150 m. Traps collected for 30-48 hours and material was obtained in splits representing 280 cm2 of collection area.

Splits were merged into groups representing each trap and 'swimmers' were picked out of each merged sample (by Debbie Steinberg, co-PI). Trap material was then processed by filtering onto GFF and acetate filters for subsequent analyses of organic carbon, nitrogen, inorganic carbon and bSi. We will also obtain C and N isotope values for this material. Splits of trap material were also provided to co-PI's: Patricia Madeirios, Tish Yager, Joachim Goes and Rachel Foster/Ed Carpenter.

Oxygen/Argon—As a further measure of Corg export, we collected water samples at 8 stations for analysis of O2/Ar ratios and of D17O. We also collected underway oxygen data with an optode sampling the uncontaminated sea water line. O2/Ar samples (3-4 per station) were collected from Niskin bottles into pre-evacuated glass flasks. Analysis will occur by mass spectrometry at USC and with colleagues at UCLA. Underway oxygen data will be used with underway CO2 and wind speed data to estimate oxygen fluxes throughout the region.

Preliminary Results

Oxygen penetration depth within a sediment column is a metric for the amount and lability of organic carbon flux to the sea floor. We have created a map of oxygen penetration depth which defines sediments underlying the plume as receiving much more Corg than sediments a short distance off axis. However, the sediment plume is shifted to the east of the climatological water column plume. One site (Sta. 25) which lies near the center of the climatological water column plume and which had a rich community of DDA's was a site where sediment oxygen penetration was the deepest. These results suggest that little Corg from this community is reaching the sea floor.

The pattern of **dissolved Si flux**, as ascertained by the pore water Si gradient near the sediment water interface shows a sharp gradient both N-S and E-W with very high rates of bSi flux to the sea floor closest to the Amazon. The gradient in bSi deposition (and remineralization) is not as dramatic as the gradient in Corg deposition (also showing increases toward the Amazon). This suggests that bSi may be the carrier of Corg closer to the river but other biogenic Si, less effective at carrying Corg, is also being deposited throughout the region.

Sediment trap material was visually inspected by Debbie Steinberg and Rachel Foster and trap filters were markedly different in terms of mass of material collected and its composition. Trap filters confirmed our assessment of Site 25, that much less Corg export appears to occur under this DDA-dominated site.

PI: Patricia L. Yager (University of Georgia)
Carbonate system, net community production, and microbial heterotrophy

Team members: Karie Sines, Christine Ewers, Delores Garay (teacher)

Our primary objective was to determine the impact of the Amazon plume on air-sea carbon dioxide exchange and to determine the influence of heterotrophic microorganisms on that flux. We made measurements on both underway samples and discrete samples from the CTD.

Activities

Carbonate System. 1) We measured **underway pCO2** in line with the rest of the underway sampling using a shower-head equilibrator connected to a LICOR infrared detector. This system ran continuously throughout the expedition, except when we were in transit through non-permitted EEZs (Suriname and Brazil), and for ten minutes every hour while the system was calibrated to NOAA CMDL standard gases. Precision is about 1 ppm. The system collects data every minute and the equilibrator has an efolding time of about 10 minutes. 2) We also collected discrete seawater samples from Niskin rosette bottles for measuring **total dissolved inorganic carbon and alkalinity**. We collected depth profiles of 12-14 bottles between 0 and 2000 m, with highest resolution in the near-surface. These samples will be taken home to UGA and run for both total DIC and total alkalinity (TALK). Our DIC system has a conductivity cell and so we will also get an additional measure of salinity.

Microbial heterotrophy. We collected discrete samples from the CTD for a suite of microbial biomass and activity measurements. These include: **bacterial abundance** and biomass, **bacterial production** (measured by 3H-leucine incorporation into protein), size-fractionated (whole water and <3 um) **microbial respiration** (by changes in DIC over time) and **dark fixation** (14C-bicarb incorporation during dark incubations). We also estimated the potential rates of microbial conversion from particulate to dissolved organic matter with **extracellular enzyme activity** for several substrates (leucine-aminopeptidase, beta-glucosidase, chitobiase, and alkaline phosphatase, and then measured the microbial **incorporation and respiration** of these organic substrates (amino acids, glucose, glucosamine, acetate).

Preliminary results

Underway pCO2 data exhibited values significantly below atmospheric equilibrium across the entire plume area. Supersaturation was only observed when we were outside the influence of the river plume (S > 35.5). It was thought that we might see supersaturation in some of the lower salinity waters of the plume where heterotrophy might dominate autotrophy in the organic-rich waters of the river, but we did not observe this.

Despite the apparent dominance of autotrophy over heterotrophy indicated by the low CO2 values of the plume, we did observe significant rates of microbial heterotrophy there. This result suggests that autotrophic processes are enhanced to an extraordinary degree by the plume and that the large-scale atmospheric drawdown of CO2 is not due to inhibition of heterotrophic microbes.

Overall, we found greater microbial activity in the plume than in the waters just below it. We also tended to find higher microbial activity in the lower salinity regions of the plume. **Bacterial production** rates were highest in the plume, decreasing below the plume and with depth. They were also highest in the lower salinity areas of the plume. **Bacterial respiration** was also high in the plume, again with the highest rates observed in the lowest salinity range. Exoenzyme activity was highest in the plume water - with significant decreases in rates just below the plume. **Peptidase** activity correlated well with salinity (r = -0.7) - with highest rates at lower salinities, peptidase and **glucosidase** activity correlated well with algal biomass (r = 0.77 and 0.89, respectively), and **alkaline phosphatase** (typcally an indicator of phosphate limitation) spiked at Stations 2 and 25, where DDA populations were most abundant. **Chitobiase** activities were generally low and uniform throughout, with some spikes in low salinity plume waters. Except for alkaline phosphatase activity, most measures of bacterial activity did not peak in the region of DDA bloom, where net community production has been seen to be the greatest.

Sediment trap material from 200 m indicated very high rates of bacterial production and hydrolysis compared to the water column. Rates can be scaled once we have data for organic carbon and nitrogen content, but it would seem that particulate organic matter is being incorporated in the microbial biomass as it sinks.

PI: Doug Capone (University of Southern California)
Nitrogen fixation and nutrient uptake

Other team members onboard: Matt Tiahlo, Laila Barada, Troy Gunderson,

No cruise summary received.

Measurements made from CTD/Niskin Rosette casts and from sediment traps:

DOP - Dissolved organic phosphorous
SRP - Soluble reactive phosphorous

$^{15}N_2$ uptake / ^{13}C uptake
$^{15}NO_3$, $^{15}NH_4$, $^{33}PO_4$ uptake
Acetylene reduction
DOP uptake
PO4 uptake

No results onboard.

PI: Joe Montoya (Georgia Tech)
Nitrogen fixation and fate

Other team members onboard: Rachel Horak, Julie Grosse, Jason Landrum

No cruise summary received.

Measurements made from CTD/Niskin Rosette casts and from sediment traps:

Ammonia
Nutrients (autoanalyzer)
POC, PON, POP(?) - water column, sediment trap
Particulate ^{15}N abundance - water column and plankton (?)
DI^{15}N

No results onboard. All 15N samples need to be returned to Georgia for analysis.

ROCA - Team

PI: Patricia Medeiros (University of Georgia)
Organic matter characterization

Activities

A total of 24 POC and DOM samples were collected during the ANACONDAS cruise along the plume, both at the surface and beneath the low-salinity waters. Collections (ocean and river) and organic matter analyses are also being conducted in collaboration with Nick Ward, a Ph.D. student at the University of Washington (UW).

POC samples were extracted and concentrated to posterior derivatization for the analysis of molecular multi-biomarkers. Biomarkers identification and quantification will be performed at UGA Marine Sciences using a recently acquired GC-MS.

DOM samples were extracted, and the extracts were prepared for ultra-high resolution mass spectrometry analysis (ESI FT-ICR MS). This analysis will be conducted at the Max Planck Institute (Germany) in March/April 2011 by the PI in collaboration with Dr. Thorsten Dittmar. Lignin analyses in both particulate and dissolved fractions from plume and river cruises are being performed by Nick Ward at UW.

No results onboard.

ROCA - Team

Brian Zelinski (University of South Florida)

(PIs: John Paul, Mary Ann Moran, Byron Crump)

Ship activities: My main objective on this cruise was filtering water to preserve the DNA and RNA for the 'omics portion of the ROCA project funded by the Gordon and Betty Moore Foundation. In addition, I collected water samples at each station for Flow Cytometer viral counts.

Table 1: Nucleic acid samples were collected from the surface (except where indicated) at the following sites (DNA from all stations listed, RNA from stations in bold).

Station	CTD	Event	Lon	Lat	Date GMT 2010	Time.GMT	Avg.Temp (C)	Avg.Salinity (PSU)
1	**2**	**1.08**	**56.80**	**11.56**	**23-May**	**12:48**	**28.762**	**31.981**
2 (day)	**8**	**2.12**	**54.51**	**10.29**	**25-May**	**1:44**	**28.756**	**32.014**
2 (night)	**10**	**2.17**	**54.51**	**10.29**	**25-May**	**10:14**	**28.613**	**31.801**
3	**12**	**3.03**	**53.00**	**7.29**	**26-May**	**12:31**	**28.732**	**30.231**
4	**15**	**4.04**	**51.49**	**5.95**	**27-May**	**12:54**	**28.795**	**22.399**
5	**19**	**5.06**	**49.98**	**6.81**	**28-May**	**12:40**	**28.684**	**35.181**
6	24	6.07	47.63	6.82	29-May	14:47	28.649	35.576
7	**30**	**7.14**	**45.02**	**7.00**	**31-May**	**10:56**	**28.108**	**35.872**
8	37	8.08	46.85	4.35	1-Jun	14:13	28.719	35.595
9	**42**	**9.18**	**50.84**	**6.00**	**3-Jun**	**12:04**	**29.415**	**33.212**
10	**50**	**10.04**	**51.35**	**4.87**	**5-Jun**	**10:29**	**29.352**	**20.766**
11	**55**	**11.05**	**51.50**	**5.49**	**6-Jun**	**12:49**	**29.599**	**21.987**
14	62	14.06	51.50	5.95	7-Jun	14:31	29.830	17.306
16	67	16.14	51.82	6.71	8-Jun	15:42	29.761	18.065
19	74	19.21	50.76	8.29	11-Jun	14:38	28.662	34.943
20	76	20.07	50.02	9.96	12-Jun	9:15	28.507	35.205
21	**82**	**21.14**	**51.70**	**9.77**	**13-Jun**	**11:39**	**28.716**	**33.736**
22	**83**	**22.01**	**55.77**	**9.49**	**14-Jun**	**18:22**	**29.244**	**32.800**
23	**87**	**23.04**	**54.40**	**10.62**	**16-Jun**	**11:35**	**29.149**	**26.472**
23 (subsurf)	**88**	**23.43**	**54.41**	**10.65**	**16-Jun**	**13:12**	**28.191**	**36.209**
25	**97**	**25.14**	**56.42**	**11.32**	**18-Jun**	**11:39**	**29.076**	**31.833**
25 (subsurf)	**103**	**25.34**	**56.64**	**11.29**	**19-Jun**	**11:40**	**29.190**	**32.481**
27	**109**	**27.09**	**52.22**	**12.40**	**21-Jun**	**11:38**	**28.381**	**36.043**

Table 2. RNA and DNA samples selected for transcriptomic and metagenomic analyses.

Station	CTD	Event	Lon	Lat	Date GMT 2010	Time.GMT	Avg.Temp (C)	Avg.Salinity (PSU)
2	10	2.17	54.51	10.29	25-May	10:14	28.613	31.801
3	12	3.03	53.00	7.29	26-May	12:31	28.732	30.231
10	50	10.04	51.35	4.87	5-Jun	10:29	29.352	20.766
23	87	23.04	54.40	10.62	16-Jun	11:35	29.149	26.472
25	97	25.14	56.42	11.32	18-Jun	11:39	29.076	31.833
27	109	27.09	52.22	12.40	21-Jun	11:38	28.381	36.043

Dr. Rachel A. Foster (University of California, Santa Cruz; guest participant)
Phytoplankton Symbioses

ACTIVITIES

Nucleic acid (DNA and RNA) samples were taken from depth profiles (6 depths) within the upper euphotic zone (upper 200m). Samples were 1-2.5 L bulk water samples collected from the CTD Rosette which were filtered onto a 0.2um pore size filter and were usually collected in the early morning (before local noon). These samples will be extracted and used in highly specific qPCR assays, which quantify the abundance (DNA) and activity (RNA) of cyanobacterial symbionts of diatoms. In addition, microscopy samples were collected in parallel to estimate the abundance and cell integrity of the symbiotic diatoms.

Short-term (less than 12 hrs) and long-term incubation (24 hrs) experiments with $^{15}N_2$ and ^{13}C-labelled bicarbonate were run to estimate cell-specific rates of nitrogen (N_2) and carbon (C) fixation on individual symbiotic diatom cells. In several experiments, bulk seawater (2.5 L) was collected from the CTD rosette from 4-6 depths, amended with stable isotopes, incubated in on deck incubators under simulated light conditions (100%, 50%, 25%, 10%, 1%), and archived for later laboratory analysis. Similar experiments were run, however, 500 mL bottles were amended with 15-labelled nitrate to investigate nitrate (and C) uptake on individual phytoplanktonic populations. In addition, when the symbiotic diatoms were observed at high densities, a eukaryotic photosynthetic inhibitor (cycloheximide) was amended to experimental bottles to investigate if carbon is potentially provided by the symbiont to the host. After incubation, all cells were collected and archived for a high-resolution nanometer scale secondary ion mass spectrometry (nanoSIMS) analyses. The depth series experiments were run in parallel and to compliment the uptake incubation experiments of Dr. JP Montoya.

COLLABORATIVE ACTIVITIES.

Microscopy samples were collected from the underway seawater system for quantifying the abundance of phytoplankton on an hourly basis between stations 23-27. Foster enumerated the symbiotic diatoms (*Hemiaulus, Rhizosolenia, Climacodium*) and a variety of free-living cyanobacterial populations (*Trichodesmium, Crocosphaera*). Qualitative observations were also recorded which describe the cell integrity for the symbioses and the phytoplanktonic community in general. The samples have been fixed onto slides and can be used for further analyses. On the second leg, Foster collected and archived depth profile microscopy samples of the larger (>8 um) and smaller (0.2 um) size fractions for Dr. EJ Carpenter.

Samples were provided by Dr. W. Berelson from the 3 sediment trap deployments on the second leg. Qualitative observations and images of two size fractions (>8.0 μm and 0.2 μm) were recorded from the sub-samples of the trap material.

Individual zooplankton cells were collected in collaboration with Dr. D. Steinberg for molecular analysis of the gut contents of the animals. We hope to identify by qPCR if the copepods were consuming diazotrophic populations (i.e. *Richelia*, *Trichodesmium*, *Crocosphaera*). In addition, Steinberg assisted Foster and Dr. J. Landrum (Montoya lab) in the design and implantation of several grazing experiments. In these latter experiments, a variety of copepod genera (*Miracia*, *Macrosetella*, and mixed community) were incubated with either *Trichodesmium* or cell concentrates of *Hemiaulus-Richelia* symbioses and stable isotopically labeled carbon and nitrogen (^{13}C-bicarbonate and $^{15}N_2$, respectively). After incubation, the cells were collected and preserved for nanoSIMS analysis, and in addition samples were taken from the filtrate of the experimental bottles for nutrient (dissolved inorganic nitrogen and phosphate) analyses. We hope to visualize the enrichment of C and N in the copepods, and in addition identify the influence of grazing (or presence of a grazer) on N_2 and C fixation of *Trichodesmium* and *Hemiaulus-Richelia.*