

CSC Technical Report CSC/1-99/001

NOAA Cruise APR98SAB: South Atlantic Bight Cruise

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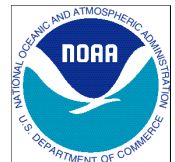
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January 1999

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Abstract

The algorithms for the calculation of chlorophyll *a* concentrations in the coastal waters of the U.S. need to be verified for the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on board the SeaStar spacecraft. This requires precise optical measurements below the sea surface in coastal waters from which remote sensing reflectance, downwelling irradiance and upwelling radiance can be calculated.

A total of 30 stations in the South-Atlantic Bight between Beaufort, North Carolina and Jacksonville, Florida were occupied between April 3, 1998 and April 27, 1998. *In-situ* measurements of temperature, spectral downwelling irradiance, and spectral upwelling radiance were made along with above-surface spectral downwelling irradiance. Samples were collected for measurement of surface chlorophyll *a* concentration, phytoplankton pigments, and total suspended sediments. *In-situ* depth, temperature and salinity were also measured.

Chlorophyll *a* and TSS concentrations in waters of the South Atlantic Bight during this cruise in April were highly variable. Chlorophyll *a* concentrations tended to be higher near shore, and TSS showed no discernible geographic pattern, with high and low concentrations being measured at both nearshore and offshore stations.

The OC2 version 2 algorithm over-estimated the chlorophyll *a* concentration by a factor of 4 and as much as a factor of 50. CZCS pigment concentrations are estimated more successfully with ratios of measured to estimated pigment ranging from 1 to 5. The overestimates may be due, in large part, to high concentrations of colored dissolved organic matter (cdom). High diffuse attenuation coefficients at 380 and 412 nm were measured; these wavelengths are affected by cdom absorption. The OC2 algorithm needs refinement in order to estimate chlorophyll *a* in coastal waters of the South Atlantic Bight.

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Acknowledgments

We thank the Captain and the crew of the R/V *Cape Hatteras* for assistance provided. A NOAA Coastal Ocean Program grant to Dr. Patricia Tester and Dr. Richard Stumpf made this cruise possible.

I. Introduction

Monitoring the health of U.S. coastal waters is an important goal of the National Oceanic and Atmospheric Administration (NOAA). Satellite ocean color sensors are capable of providing regular synoptic water quality data for the U.S. coast. Algorithms are used to derive products such as chlorophyll biomass from satellite data to study short and long term changes in water quality; however, these algorithms need to be evaluated and validated. Towards this purpose, scientists from the National Ocean Service (NOS) undertook a twenty-five day cruise in the South Atlantic Bight (Beaufort, NC to Jacksonville, FL).

II. Objectives

The objectives of this cruise were to obtain sub-surface downwelling irradiance, upwelling radiance, chlorophyll pigment concentration and total suspended sediment concentration in coastal waters. The remote sensing reflectance measurements calculated from these samples were used to evaluate and validate the OC2 version 2 (O'Reilly et al. 1998) algorithm for the NASA/OrbImage Sea-viewing Wide Field-of-view Sensor (SeaWiFS).

III. Methods

A description of the sample collection methods and instruments is detailed in the following sections.

A. Sampling Location

Optical profile measurements were made at a total of 30 stations, from April 3, 1998 thru April 27, 1998 (Figure 1). Surface samples were acquired at these locations for determination of total suspended solids (TSS) concentration and for chlorophyll analysis by fluorometric and High-Pressure Liquid Chromatography (HPLC) techniques.

B. Sampling Platform

The R/V *Cape Hatteras*, belonging to the Duke/University of North Carolina Oceanographic Consortium, was used on this cruise. The R/V *Cape Hatteras* is a 41-meter (m), steel hull, twin diesel engine oceanographic research vessel. It operates both on the continental shelf and in the deep sea in the western North Atlantic, concentrating in the region between Nova Scotia and the Caribbean.

C. Sample Collection Methods Summary

A Biospherical Instruments, Inc. Profiling Reflectance Radiometer (PRR600s) was deployed off the starboard side of the vessel using a davit (Figure 2). The PRR600s measured *in-situ* spectral downwelling irradiance, spectral upwelling radiance, and temperature. Surface bucket samples were obtained for pigment analysis. *In-situ*

temperature, salinity, and density were also measured at some stations with a SeaBird Conductivity-Temperature-Depth (CTD) sensor.

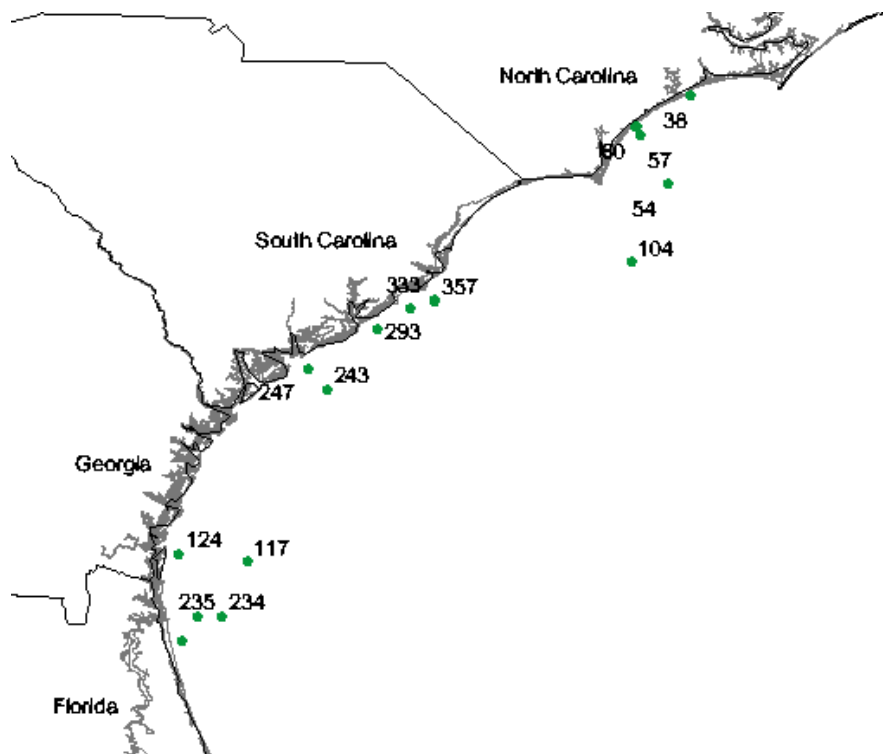


Figure 1. Location of stations

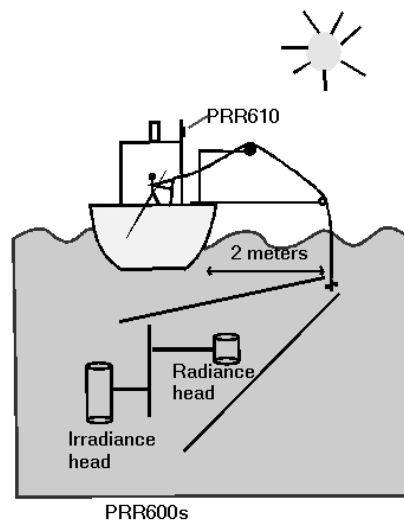


Figure 2. Deployment of the PRR600s

Table 1. Station Locations

Date	Station	Latitude	Longitude	Time (GMT)	ChlF VolFilt (L)	TSS VolFilt (L)
4/3/98	6	34.6522	-76.6583	-	0.1	1.0
4/4/98	25	34.6522	-76.6583	-	0.1	1.0
4/5/98	35	34.5403	-77.2544	14:09	0.1	-
4/5/98	38	34.5403	-77.2544	16:11	0.1	1.0
4/6/98	54	33.8478	-77.4336	14:24	0.5	1.5
4/6/98	55	33.8478	-77.4336	-	0.5	2.0
4/6/98	57	34.2256	-77.6444	18:16	0.5	2.0
4/6/98	60	34.2961	-77.6872	19:24	0.2	1.0
4/7/98	82	34.2853	-77.6803	17:17	0.3	2.0
4/8/98	96	33.6233	-76.3044	-	1.0	2.0
4/8/98	97	33.5639	-76.4914	16:08	1.0	2.0
4/10/98	104a	34.4903	-77.2233	-	0.2	1.0
4/11/98	104b	34.2933	-77.6825	16:15	0.2	1.0
4/12/98	104c	33.7100	-77.3875	17:11	0.5	2.0
4/13/98	104d	33.2306	-77.7178	17:06	0.5	2.0
4/14/98	117	30.8361	-80.7631	16:06	0.5	1.5
4/15/98	144a	30.9069	-81.3039	18:09	0.2	1.0
4/18/98	144b	30.2267	-81.2900	16:54	0.1	1.5
4/18/98	144c	30.0764	-81.2467	18:19	0.1	1.5
4/19/98	200	29.9303	-81.2628	-	0.1	1.5
4/20/98	221	30.4142	-80.0019	-	1.0	2.0
4/21/98	234	30.4181	-80.9633	14:42	0.5	2.0
4/21/98	235	30.4183	-81.1564	15:56	0.5	2.0
4/22/98	243	32.2206	-80.1325	15:45	0.25	1.5
4/23/98	269	32.3858	-80.2889	16:13	0.1	1.0
4/24/98	293	32.6947	-79.7297	14:58	0.1	1.0
4/25/98	314	31.8750	-79.0367	15:38	1.0	2.0
4/26/98	333	32.9297	-79.2861	16:36	0.25	1.0
4/27/98	357	32.9143	-79.2748	16:59	0.25	1.0
4/27/98	359	32.8640	-79.4731	18:49	0.25	1.0

D. Sampling Gear

The PRR600s (Serial No. 9643) is a spectroradiometer manufactured by Biospherical Instruments, Inc., which measures seven channels of downwelling irradiance, seven channels of upwelling radiance (Table 2), depth, tilt, roll, and temperature. A surface unit (PRR610 - Serial No. 9644) is used to measure seven matched channels of surface downwelling irradiance on deck. Channels 1 to 6 on all sensors and channel 7 on the radiance sensor are narrow band (10 nanometer [nm] full width at half-maximum)

centered at the indicated wavelengths, and channel 7 on the irradiance sensor is a broadband detector that measures Photosynthetically Available Radiation (PAR) between 400 and 700 nm (Table 2).

The irradiance and radiance sensors of the PRR600s are separate units, mounted such that the collectors are on the same horizontal plane. The instrument mount was attached to a tension release on a kevlar reinforced electrical cable. The PRR610 surface unit was strapped onto a radio antenna on the starboard side of the vessel, close to the davit used to lower the PRR600s (Figure 2).

Table 2. Center Wavelengths for the PRR System

Channel No.	PRR600s Downwelling Light Sensor	PRR600s Upwelling Light Sensor	PRR610
1	380 nm	380 nm	380 nm
2	412 nm	412 nm	412 nm
3	443 nm	443 nm	443 nm
4	490 nm	490 nm	490 nm
5	510 nm	510 nm	510 nm
6	555 nm	555 nm	555 nm
7	PAR	683 nm	PAR

E. Bottle Samples

The chlorophyll biomass was determined using a Turner Designs fluorometer (Parsons *et al.* 1984). The TSS concentration was measured as described by Parsons *et al.* (1984). Phytoplankton pigment concentrations were determined by HPLC as described in Tester *et al.* (1995). Discrete surface water samples were obtained for these analyses using a bucket, at the same time as the PRR cast.

F. Optical Data Processing

The PRR data was processed using the Bermuda Bio-Optics Project (BBOP) processing software (Siegel *et al.* 1995). A least common denominator (LCD) file was created from the binary data files, the cast card files, the calibration files, and cruise notes. The LCD file header contains the metadata for the cast and includes information on the parameters sampled, parameters derived, filters used, and the statistical results of the regression used to extrapolate to the sub-surface. An example header is presented in Appendix B. The pressure channel data was recalculated using an offset to adjust for the distance of the pressure sensor from the cosine collector. The tops and bottoms of the individual profiles were marked using an interactive Matlab[®] script and the corresponding record numbers were inserted into the LCD header section. Data less than the dark threshold was replaced by -9.9×10^{35} . The data was then quality controlled using flags for data with tilt and roll angles greater than 10°, and records in which the surface incident irradiance was not uniform. The temperature channel was despiked, in two passes with a difference threshold. A moving average was calculated for the temperature channel. The data were

separated into upcast and downcast profiles and then binned to 0.5-m bins. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface, and spectral attenuation coefficients were calculated for the optical channels over a five-point moving window.

IV. Results

Results of the study are detailed below.

A. Bottle Samples

TSS concentrations ranged from 3.495 to 22.01 mg/l (Table 3). Chlorophyll *a* concentrations as measured using HPLC ranged widely from 0.066 to 3.001 $\mu\text{g/l}$. Chlorophyll *a* concentrations tended to be higher in the nearshore areas, and TSS concentrations showed no consistent pattern with distance from shore.

Table 3. Pigment Analyses

Station	Latitude	Longitude	TSS mg/L	Total CHL $\mu\text{g/l}$	19'-But $\mu\text{g/l}$	Fuco $\mu\text{g/l}$	19'-Hex $\mu\text{g/l}$	Diadin $\mu\text{g/l}$	Zea $\mu\text{g/l}$	Chl <i>a</i> $\mu\text{g/l}$
6	34.6522	-76.6583	7.83	0.078	0	0.025	0.004	0.005	0.003	0.042
25	34.6522	-76.6583	12.25	2.314	0	1.044	0.033	0.180	0.040	0.523
35	34.5403	-77.2544		1.002	0	0.467	0	0.080	0	0.420
38	34.5403	-77.2544	14.11	1.035	0	0.439	0	0.094	0.225	0.298
54	33.8478	-77.4336	20.733	0.171	0.024	0.064	0.077	0.048	0	0.053
55	33.9970	-77.5198	5.115	0.218	0.015	0.052	0.033	0.031	0.022	0.140
57	34.2256	-77.6444	4.575	0.161	0	0.042	0.008	0.021	0	0.066
60	34.2961	-77.6872	22.01	0.518	0	0.245	0	0.067	0.017	0.236
82	34.2853	-77.6803	11.245	0.295	0	0.120	0	0.054	0	0.149
96	33.6233	-76.3044	9.44	0.375	0.025	0.068	0.065	0.041	0	0.208
97	33.5639	-76.4914	3.495	0.416	0.021	0.078	0.076	0.034	0.052	0.200
104a	34.4903	-77.2233	13.32	1.617	0	0.448	0	0.070	0	0.161
104b	34.2933	-77.6825	7.17	1.488	0	0.727	0	0.129	0	0.714
104c	33.7100	-77.3875	3.975	0.289	0.009	0.058	0.030	0.025	0	0.152
104d	33.2306	-77.7178	8.275	0.111	0	0.052	0.022	0.014	0	0.049
117	30.8361	-80.7631	15.927	0.810	0	0.289	0.039	0.057	0.036	0.190
144a	30.9069	-81.3039	10.85	1.278	0	0.696	0	0.155	0.031	0.169
144b	30.2267	-81.2900	17.047	1.898	0	0.736	0.030	0.166	0.023	0.192
144c	30.0764	-81.2467	5.78	0.926	0	0.400	0.021	0.094	0.035	0.319
200	29.9303	-81.2628	7.513	3.001	0	1.461	0.029	0.236	0.025	0.770
221	30.4142	-80.0019	8.18	0.088	0.006	0.042	0.010	0.010	0.038	0.054
234	30.4181	-80.9633	8.98	0.538	0	0.242	0.012	0.061	0.022	0.195
235	30.4183	-81.1564	12.01	0.742	0	0.305	0.019	0.085	0	0.135
243	32.2206	-80.1325	17.787	0.487	0	0.221	0	0.054	0.041	0.204
269	32.3858	-80.2889	12.4	1.471	0.018	0.520	0.036	0.139	0.062	0.390
293	32.6947	-79.7297	7.08	0.938	0	0.288	0	0.068	0.023	0.117
314	31.8750	-79.0367	4.995	0.066	0.003	0.015	0.010	0.007	0	0.032
333	32.9297	-79.2861	10.66	1.905	0	0.675	0.024	0.094	0	0.252
357	32.9143	-79.2748	15.26							
359	32.864	-79.4731	6.45							

B. Optical data

The optical data were collected in at various locations of the South Atlantic Bight. The profiles of downwelling irradiance, upwelling radiance, and PAR are shown in Appendix A (Figures A.1.a – A.29.a). Figures A.1.b – A.29.b show the tilt and roll of the PRR600 and when calculable, the spectral diffuse attenuation. Comments on the quality of the profile and the depth of measurement nearest to the surface are shown in Table 4. The above surface downwelling irradiance (E_s) should be constant during a profile if there was no change in the light field due to passing clouds etc. This was tested by calculating the coefficient of variation (standard deviation/mean) for E_s . Tilt or roll of greater than 10° do not allow for the robust measurement of downwelling irradiance or upwelling radiance.

Many of the stations off the coasts of South Carolina, Georgia, and Florida exhibited very high attenuation coefficients (exceeding 1 m^{-1}) for the blue wavelengths, particularly 380 and 412 nm. These wavelengths are affected by the absorption of colored dissolved organic matter (cdom) as well as chlorophyll *a* and would, if present, affect the pigment estimated from irradiance and radiance measurements. The stations off the coast of North Carolina did not exhibit these high attenuation coefficients in the blue wavelengths.

Table 4. Summary of Optical Profiles

Cast #	Depth of First Measurement (m)	Max. Coefficient of Variation Of E_s	Comments
P980405B1			Incomplete coverage at surface
P980405B2	1.38	1.8	Cast ok; increased tilt at bottom
P980405C1	3.23	0.6	Incomplete coverage at surface
P980405C2	0.68	0.4	Uniform, good cast
P980406A1	2.18	1.2	Shadow and cloud effects throughout
P980406A2	0.75	1.1	Shadow and cloud effects in E_d
P980406B1	1.78	3.2	Shadow over surface sensor, shadow effects
P980406B2	1.73	53.8	Shadow over surface sensor; ship shadow effects
P980406C1	0.79	1.1	Cast ok; some shadow effects; tilt 12 - 21
P980406C2	0.55	1.0	Cast ok; some shadow effects
P980406F1	1.37	8.6	Uniform, good cast
P980406F2	0.21	5.4	Surface extrapolation may be low
P980407A1	0.96	0.2	Ship shadow in top 2 m.
P980407A2	0.38	0.2	Ship shadow in top 5 m
P980411A1	1.23	0.4	Shadow over surface sensor
P980411A2	1.81	0.5	Shadow over surface sensor
P980412A1	2.07	0.9	Shadow effects with noisy cast
P980412A2	0.60	0.5	Noisy cast with some high angles
P980413A1	1.67	1.4	Noisy cast with unreliable surface extrapolation.
P980413A2	0.97	1.1	Shadow over surface sensor
P980414A1	2.67	1.0	Incomplete coverage near surface; tilt 16-33
P980414A2	0.93	0.8	Cast ok
P980415A1	0.80	15.6	High variability in E_s low sun angle
P980415A2	0.53	8.9	Slight ship shadow effects near surface

P980418A1	1.25	0.5	Noisy cast
P980418A2	1.10	0.6	Invalid Ed(412) near surface
P980418B1	1.89	0.9	Cast ok
P980418B2	0.44	0.5	Cast ok
P980421A1	1.70	2.1	Cast ok; high Ed(380) near surface
P980421A2	0.52	2.7	Uniform, good cast
P980421B1	1.65	1.1	Ship shadow effects near surface
P980421B2	0.30	1.2	Noisy Lu near surface
P980422A1	1.89	1.0	Cast ok; slight shipshadow effects
P980422A2	0.96	1.0	Cast ok
P980422B1	0.62	0.9	Uniform, good cast
P980422B2	1.20	1.5	Cast ok; some high angles
P980423A1	1.41	31.8	Shadows some high angles
P980423A2	0.37	0.5	High angles
P980424A1	0.83	0.8	Cast ok
P980424A2	0.30	0.4	Cast ok; low Lu(380)
P980426B1	1.33	0.9	Uniform, good cast
P980426B2	0.43	0.5	Cast ok; high tilt
P980427A1	0.67	0.3	Uniform, good cast
P980427A2	0.76	0.4	Uniform, good cast
P980427B1	1.29	0.4	Cast ok; tilt increasing at bottom
P980427B2	0.36	0.3	Uniform, good cast; tilt increasing at bottom

C. Algorithm Evaluation

The downwelling irradiance and upwelling radiance were extrapolated to the null depth just below the surface (E_0^-) by the BBOP software. The downwelling irradiance was propagated through the water-air interface using a transmission loss of 4% (SeaBAM Tech memo). The upwelling radiance was propagated through water-air interface using a factor of 0.544 (SeaBAM Tech memo). The above water (E_0^+) downwelling irradiance and upwelling radiance are shown in Table 5 ($E_d+(\lambda)$ and $L_u+(\lambda)$ respectively). The above water downwelling irradiance measured by the reference sensor mounted on the ship are also shown ($E_s(\lambda)$). The SeaWiFS OC2 algorithm (O'Reilly et al. 1998) was used to calculate the satellite estimates of chlorophyll *a* and Coastal Zone Color Scanner (CZCS) pigment concentration. Values for E_s were used in the algorithm unless the coefficient of variation for E_s exceeded 10%, then E_d^+ was used. The ratios of satellite-derived to measured quantities for chlorophyll *a* and CZCS pigment are shown in Table 5.

Table 5 Algorithm Evaluation

Station	35	38	54	57	60	97	104	124	144
Date	4/5/98	4/5/98	4/6/98	4/6/98	4/6/98	4/11/98	4/13/98	4/15/98	4/18/98
Time GMT	14:09	16:11	14:41	18:16	19:24	16:08	17:06	18:09	16:54
TSS mg/L	-999.99	14.11	20.73	4.575	22.01	7.17	8.26	10.85	17.05
ChlF ug/l	2.44	-999.99	0.52	0.38	1.22	0.12	0.48	2.91	2.76
Chla HPLC		0.36	0.05	0.066	0.24	0.71	0.05	0.17	0.19
PRR File	p980405b2	p980405c2	p980406a2	p980406c1	p980406f1	p980411a1	p980413a2	p980415a1	p980418a1
Ed0-380	35.326	50.581	48.764	83.637	57.429	74.780	36.727	112.760	109.350
Ed0-412	49.859	87.433	72.040	96.999	89.301	103.040	89.209	98.940	127.649
Ed0-443	62.286	112.206	78.447	139.205	101.649	126.660	114.926	69.033	116.538
Ed0-490	71.968	132.956	88.371	144.311	116.804	163.507	152.161	73.535	97.908
Ed0-510	74.983	130.606	93.233	126.072	124.721	199.574	198.387	76.665	82.262
Ed0-555	72.357	130.786	99.110	122.998	119.780	199.007	245.976	82.979	68.821
Lu0-380	0.151	0.379	0.135	0.183	0.308	0.341	0.113	0.022	0.129
Lu0-412	0.430	0.906	0.247	0.361	0.782	0.788	0.220	0.379	0.342
Lu0-443	0.695	1.496	0.345	0.596	1.312	1.279	0.389	0.422	0.475
Lu0-490	1.204	2.626	0.494	0.967	2.126	2.163	0.567	0.916	0.716
Lu0-510	1.335	2.888	0.479	0.971	2.177	2.364	0.657	1.102	0.813
Lu0-555	1.419	3.144	0.344	0.814	2.141	2.561	0.541	1.498	0.955
Lu0-683	0.292	0.657	0.040	0.088	0.346	0.526	0.088	0.692	0.308
Es0+380	38.141	74.550	55.902	70.950	58.578	72.590	78.527	68.451	77.611
Es0+412	61.161	117.623	89.770	113.086	92.936	115.735	124.191	108.749	123.671
Es0+443	72.344	140.506	108.187	134.093	111.446	136.694	146.684	129.304	147.084
Es0+490	78.452	153.040	117.565	143.972	120.401	147.766	157.521	140.596	159.940
Es0+510	78.397	152.001	116.404	143.930	118.557	148.884	158.164	142.611	162.442
Es0+555	76.616	148.510	113.359	141.309	113.915	146.756	155.134	141.178	160.688
Lwn380	0.202	0.260	0.123	0.131	0.268	0.240	0.073	0.009	0.085
Lwn412	0.649	0.710	0.254	0.294	0.776	0.628	0.163	0.339	0.255
Lwn443	0.982	1.089	0.326	0.454	1.204	0.957	0.272	0.601	0.330
Lwn490	1.605	1.794	0.439	0.702	1.847	1.531	0.377	1.250	0.468
Lwn510	1.733	1.933	0.418	0.686	1.868	1.615	0.423	1.403	0.509
Lwn555	1.855	2.119	0.304	0.577	1.881	1.747	0.349	1.735	0.595
ChlaOC2v2	2.9725	3.1357	0.9018	1.327	2.191	2.884	1.751	4.702	3.764
CZCSPigOC2	5.2141	5.6257	1.1939	1.843	3.439	4.998	2.580	10.313	7.344
MeasChla	-999.000	0.360	0.053	0.066	0.236	0.714	0.049	0.170	0.192
sat/meas	-999.000	8.7104	17.0147	20.103	9.284	4.040	35.744	27.742	19.604
MeasPig	2.435	-999.000	0.515	0.382	1.218	2.729	0.482	2.910	2.760
sat/meas	1.2207	-999.000	1.7510	3.473	1.799	1.057	3.634	1.616	2.661

Station	144	234	235	247	293	333	357	359
Date	4/18/98	4/21/98	4/21/98	4/22/98	4/24/98	4/26/98	4/27/98	4/27/98
Time GMT	18:19	14:42	15:56	17:29	14:58	16:36	16:59	18:49
TSS mg/L	5.78	8.98	12.01	9.092	7.08	10.66	15.26	6.450
ChlF ug/l	1.64	1.03	1.27	1.867	1.33	2.91	1.96	1.515
Chla HPLC	0.32	0.20	0.14	0.361	0.12	0.25		-999
PRR File	p980418b1	p980421a1	p980421b1	p980422b1	p980424a2	p980426b1	p980427a1	p980427b1
Ed0-380	51.019	181.752	87.078	61.636	23.564	60.497	103.693	62.495
Ed0-412	94.363	125.432	77.677	96.541	57.894	125.654	117.195	102.600
Ed0-443	141.398	121.198	77.890	113.716	70.322	141.351	121.045	120.903
Ed0-490	176.193	126.968	80.020	131.127	102.247	150.101	126.214	129.635
Ed0-510	201.182	129.232	87.976	146.817	102.764	146.041	136.177	127.303
Ed0-555	197.786	130.643	89.214	144.101	99.958	144.605	129.853	125.432
Lu0-380	0.039	0.026	0.029	0.056	0.003	0.051	0.148	0.051
Lu0-412	0.240	0.143	0.185	0.409	0.114	0.185	0.350	0.280
Lu0-443	0.411	0.184	0.259	0.713	0.307	0.352	0.554	0.473
Lu0-490	0.768	0.250	0.357	1.419	0.891	0.688	0.986	0.817
Lu0-510	0.913	0.273	0.405	1.729	1.067	0.825	1.127	0.933
Lu0-555	1.031	0.284	0.467	2.256	1.364	1.022	1.299	1.079
Lu0-683	0.200	0.087	0.134	0.748	0.343	0.264	0.351	0.264
Es0+380	69.999	57.788	72.531	79.201	61.026	75.966	75.407	69.403
Es0+412	110.477	95.123	116.407	125.238	97.650	121.183	120.243	112.057
Es0+443	131.472	113.424	137.858	147.975	117.114	143.796	142.860	133.741
Es0+490	141.218	123.235	148.513	158.768	126.692	155.418	154.503	145.797
Es0+510	141.425	125.207	150.019	159.550	125.904	157.215	156.178	148.338
Es0+555	138.296	124.331	148.202	156.650	122.860	155.062	154.285	147.139
Lwn380	0.029	0.023	0.020	0.036	0.003	0.034	0.100	0.037
Lwn412	0.201	0.138	0.147	0.301	0.108	0.141	0.268	0.230
Lwn443	0.320	0.166	0.193	0.493	0.268	0.250	0.397	0.362
Lwn490	0.569	0.212	0.251	0.935	0.736	0.463	0.667	0.586
Lwn510	0.657	0.222	0.275	1.102	0.862	0.534	0.734	0.640
Lwn555	0.746	0.228	0.316	1.442	1.111	0.660	0.843	0.734
ChlaOC2v2	6.420	2.496	3.657	6.190	5.858	5.041	3.705	3.624
CZCSPigOC2	4.080	4.093	7.036	16.049	14.659	11.505	7.173	6.942
MeasChla	0.319	0.195	0.135	0.361	0.117	0.252	-999.000	-999.000
sat/meas	12.790	12.798	27.089	17.145	50.070	20.002	-999.000	-999.000
MeasPig	1.643	1.029	1.267	1.867	1.328	2.910	1.958	1.515
sat/meas	5.045	3.977	2.886	3.315	4.411	1.732	1.892	2.392

V. Summary

Chlorophyll *a* and TSS concentrations in waters of the South Atlantic Bight during this cruise in April were highly variable. Chlorophyll *a* concentrations tended to be higher near shore, and TSS showed no discernible geographic pattern, with high and low concentrations being measured at both nearshore and offshore stations.

The OC2 version 2 algorithm over-estimated the chlorophyll *a* concentration by a factor of 4 and as much as a factor of 50. CZCS pigment concentration is estimated more successfully with ratios of measured to estimated pigment ranging from 1 to 5. The overestimates may be due, in large part, to high concentrations of colored dissolved organic matter (cdom). High diffuse attenuation coefficients at 380 and 412 nm were measured; these wavelengths are affected by cdom absorption. The OC2 algorithm needs refinement in order to estimate chlorophyll *a* in coastal waters of the South Atlantic Bight.

VI. References

O'Reilly, J. E., S. Maritorena, B. G. Mitchell, D. A. Siegel, K. L. Carder, S. A. Garver, M. Kahru, and C. McClain. (1998). Ocean color chlorophyll algorithms for SeaWiFS. *J. Geophys. Res.* **103**(C11): 24937-24953.

Parsons, T. R., Y. Maita and C. M. Lalli (1984). *A Manual For Chemical And Biological Methods For Seawater Analysis*, Pergamon Press.

Siegel, D. A., M. C. O'Brien, J. C. Sorensen, D. A. Konnoff and E. Fields (1995). BBOP Data Processing and Sampling Procedures. **Vol: 19**, Institute for Computational Earth System Science, UC Santa Barbara, Santa Barbara, CA, 23 pp.

Smith, R. C., K. S. Baker and P. Dustan (1981). Fluorometric Techniques for the Measurement of Oceanic Chlorophyll in the Support of Remote Sensing. *SIO Ref. 81-17*, Visibility Laboratory, Scripps Institution of Oceanography, La Jolla, CA 92093, 14 pp.

Tester, P.A., M.E. Geesey, C. Guo. H.W. Paerl and D.F. Millie (1995) Evaluating phytoplankton dynamics in the Newport River estuary (North Carolina, USA) by HPLC-derived pigment profiles. *Mar. Ecol. Prog. Ser.* **124**:237-245.

VII. Metadata

Identification Information:

Citation:

Citation Information:

Originator: Ajit Subramaniam, REMSA, NOAA Coastal Services Center

Originator: David Eslinger, NOAA Coastal Services Center

Originator: Patricia A. Tester, NOAA Center for Coastal Fisheries Habitat Research

Originator: Elin Haugen, NOAA Center for Coastal Fisheries Habitat Research

Originator: Richard P. Stumpf, NOAA National Center for Coastal Ocean Science
Originator: John C. Brock, USGS Center for Coastal Geology
Originator: Mary E. Culver, TPMC, NOAA Coastal Services Center
Originator: Ruth W. Kiambo, SeaGrant, NOAA Coastal Services Center
Publication Date: January 1999
Title: NOAA CSC/CRS Cruise APR98SAB: South Atlantic Bight Cruise
Geospatial Data Presentation Form: profile
Series Information:
Series Name: CSC Technical Report
Issue Identification: CSC/1-99/001
Publication Information:
Publication Place: Charleston, South Carolina
Publisher: NOAA Coastal Services Center
Online Linkage: <http://www.csc.noaa.gov/crs/cruises/apr98sab/index.html>

Description:

Abstract: See page iii.

Purpose: See Objective on page 1.

Time Period of Content:

Time Period Information:

Range of Dates/Times:

Beginning Date: 19980403

Ending Date: 19980427

Currentness Reference: Publication Date

Status:

Progress: Complete

Maintenance and Update Frequency: Unknown

Spatial Domain:

Bounding Coordinates:

West Bounding Coordinate: -81.3039

East Bounding Coordinate: -76.3044

North Bounding Coordinate: 34.6522

South Bounding Coordinate: 29.9303

Keywords:

Theme:

Theme Keyword Thesaurus: None

Theme Keyword: oceanography

Theme Keyword: bio-optical

Theme Keyword: turbidity

Theme Keyword: water clarity

Theme Keyword: algal blooms

Theme Keyword: coastal water optics

Theme Keyword: case II algorithms

Theme Keyword: light attenuation

Theme Keyword: in-situ optical profiling

Theme Keyword: ocean color satellites

Theme Keyword: coastal ocean algorithm development

Theme Keyword: downwelling irradiance

Theme Keyword: upwelling radiance

Theme Keyword: temperature

Theme Keyword: chlorophyll

Theme Keyword: spectral attenuation

Place:

Place Keyword Thesaurus: None

Place Keyword: North Carolina

Place Keyword: South Carolina

Place Keyword: Georgia

Place Keyword: Florida

Place Keyword: South Atlantic Bight

Place Keyword: United States

Temporal:

Temporal Keyword Thesaurus: None

Temporal Keyword: Spring

Temporal Keyword: April, 1998

Access Constraints: None

Use Constraints: This data was acquired for scientific research and is applicable for algorithm validation purposes. Knowledge of in-water optics is expected of users for interpretation of the data. Users of this data are required to provide appropriate attribution in the form of co-authorship for any publications that use this data, unless formal permission to do otherwise is granted by NOAA/CSC.

Point of Contact:

Contact Information:

Contact Organization Primary:

Contact Organization: NOAA Coastal Services Center

Contact Address:

Address Type: mailing and physical address

Address: 2234 S. Hobson Avenue

City: Charleston

State or Province: South Carolina

Postal Code: 29405-2413

Country: USA

Contact Voice Telephone: (843) 740-1200

Contact Facsimile Telephone: (843) 740-1224

Contact Electronic Mail Address: csc@csc.noaa.gov

Hours of Service: 8AM-5PM, M-F

Data Set Credit: Master and crew of R/V *Cape Hatteras*. Sample processing was conducted by Elin Haugen at the NOAA Center for Coastal Fisheries Habitat Research in Beaufort, NC. A NOAA Coastal Ocean Program grant to Dr. Patricia Tester and Dr. Richard Stumpf made this cruise possible.

Data Quality Information:

Attribute Accuracy:

Attribute Accuracy Report: Refer to the Process Step section for specific calibration information. The primary instrumentation on the cruise are sent to the respective manufacturers for calibration at least once per year. Calibration certificates for the relevant instrumentation are available in the full written report. Secondary instrumentation was calibrated only upon purchase. Laboratory calibrations of the Turner Designs fluorometer and the HPLC are conducted as needed using known concentrations of purified photosynthetic pigment extracts (measured using a spectrophotometer) purchased commercially or isolated from algal cultures.

Logical Consistency Report: The PRR data was processed using the Bermuda Bio-Optics Project (BBOP) processing software. A least common denominator (LCD) file was created from the binary data files, the cast card files, the calibration files, and cruise notes. The LCD file header contains the metadata for the cast and includes information on the parameters sampled, parameters derived, filters used, and the statistical results of the regression used to extrapolate light to the sub-surface. An example header is presented in Appendix C. The pressure channel data was recalculated using an offset to adjust for the distance of the pressure sensor from the cosine collector. The tops and bottoms of the individual profiles were marked using an interactive Matlab[®] script and the corresponding record numbers were inserted into the LCD header section. Data less than the dark threshold was replaced by -9.9×10^{35} . Then the data was quality controlled using flags for data with tilt and roll angles greater than 10° (flag value greater than 0 in the “aq-1Tilt-1Roll” field), and records where the surface incident irradiance was not uniform (flag value greater than 0 in the “kq-1ed412” field). The temperature, transmissometer, and fluorometer data were despiked, in two passes, with a difference threshold. A moving average was calculated for these channels. The data were separated into upcast and downcast profiles and then binned to 0.5-m bins. Spectral attenuation coefficients were calculated for the optical channels over a five point moving window. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface using data from the top 3 meters. The statistics for calculation of subsurface irradiance and radiance are shown in Appendix B.

Completeness Report: Refer to the separate sections of Logical Consistency, Methodology, and Process Steps for descriptions of completeness of the data.

Lineage:

Methodology:

Methodology Type: Shipboard Deployments and data collection

Methodology Identifier:

Methodology Keyword Thesaurus: None
Methodology Keyword: bio-optical data
Methodology Keyword: depth profiles
Methodology Keyword: spectral downwelling irradiance measurement
Methodology Keyword: spectral upwelling radiance
Methodology Keyword: temperature measurement
Methodology Keyword: bottle sampling
Methodology Keyword: CTD profiles
Methodology Keyword: water sampling
Methodology Keyword: Niskin bottles

Methodology Description: The Profiling Reflectance Radiometer (PRR) cage was deployed off the stern of the boat, to measure *in-situ* spectral downwelling irradiance, spectral upwelling radiance, temperature, chlorophyll fluorescence, light scattering, quantum scalar irradiance, and beam attenuation. Following the PRR cast *in-situ* temperature, salinity, and density were measured with a Conductivity-Temperature-Depth (CTD) instrument. Water samples for chlorophyll biomass, HPLC-determined photosynthetic pigments, and total suspended solids were obtained from a separate cast.

Methodology Type: Lab calibration of fluorometer and analysis of chlorophyll extracts.

Methodology Identifier:

Methodology Keyword Thesaurus: None

Methodology Keyword: chlorophyll

Methodology Keyword: fluorescence

Methodology Keyword: fluorometer

Methodology Keyword: extraction

Methodology Description: The concentration of purified chlorophyll *a*, dissolved in 90% acetone (10% water), was measured using a spectrophotometer and used to calibrate the Turner Designs Model 10-AU fluorometer. Aboard ship, a measured volume of seawater was filtered onto a Whatman GF/F filter and stored in liquid nitrogen until lab analysis. In the lab the filter was ground and extracted in 10 ml of 90% acetone and left in a freezer (-20 C) overnight. After centrifugation, the chlorophyll concentration in the supernatant was measured using the fluorometer.

Methodology Citation:

Citation Information:

Originator: T.R. Parsons

Originator: Y. Maita

Originator: C.M. Lalli

Publication Date: 1984

Title: A manual for Chemical and Biological Methods for Seawater Analysis

Publication Information:

Publication Place: New York, New York, USA

Publisher: Pergamon Press

Methodology Type: HPLC calibration and analysis of phytoplankton pigments.

Methodology Identifier:

Methodology Keyword Thesaurus: None

Methodology Keyword: photosynthetic pigments

Methodology Keyword: high performance liquid chromatography

Methodology Keyword: chlorophylls

Methodology Keyword: carotenoids

Methodology Keyword: chemotaxonomy

Methodology Description: The concentration of purified photosynthetic pigments were measured using a spectrophotometer. In a series of runs, known amounts (generally 1 to 100 ng) were injected into the HPLC to establish the retention time and define a calibration curve for each pigment. Aboard ship, a measured volume of seawater was filtered onto a Whatman GF/F filter that was stored in liquid nitrogen. In the lab the filter was ground and extracted with 1.0 ml of 90% acetone, placed in the freezer overnight to

extract. After centrifugation, 0.2 ml was injected into the HPLC to quantify the pigments present.

Methodology Citation:

Citation Information:

Originator: S.W. Wright

Originator: S.W. Jeffrey

Originator: R.F.C. Mantoura

Originator: C.A. Llewellyn

Originator: T. Bjornland

Originator: D. Repeta

Originator: N. Welschmeyer

Publication Date: 1991

Title: Improved HPLC method for the analysis of chlorophylls and carotenoids from marine phytoplankton.

Series Information:

Series Name: Marine Ecology Progress Series

Issue Identification: Volume 77: 183-196.

Methodology Type: Measurement of total suspended solids

Methodology Identifier:

Methodology Keyword Thesaurus: None

Methodology Keyword: total suspended solids

Methodology Keyword: suspended particulate matter

Methodology Description: A measured volume of seawater was filtered through a dried and pre-weighed Whatman GF/F filter. The filter was subsequently dried at 60C and re-weighed.

Methodology Citation:

Citation Information:

Originator: T.R. Parsons

Originator: Y. Maita

Originator: C.M. Lalli

Publication Date: 1984

Title: A manual for Chemical and Biological Methods for Seawater Analysis

Publication Information:

Publication Place: New York, New York, USA

Publisher: Pergamon Press

Process Step:

Process Description: Calibration of the Biospherical PRV-600s PRR Spectroradiometer.

Process Date: 19980108

Process Contact:

Contact Information:

Contact Organization Primary:

Contact Organization: Biospherical Instruments, Inc.

Contact Address:

Address Type: mailing and physical address

Address: 5340 Riley Street

City: San Diego
State or Province: California
Postal Code: 92110-2621
Country: USA
Contact Voice Telephone: (619) 686-1888

Process Step:

Process Description: Calibration of the Biospherical PRV610 PRR Spectroradiometer.

Process Date: 19980108

Process Contact:

Contact Information:

Contact Organization Primary:

Contact Organization: Biospherical Instruments, Inc.

Contact Address:

Address Type: mailing and physical address

Address: 5340 Riley Street

City: San Diego

State or Province: California

Postal Code: 92110-2621

Country: USA

Contact Voice Telephone: (619) 686-1888

Process Step:

Process Description: Calibration of Satlantic SAS II MVD 7-channel Radiance Sensor system.

Process Date: 19980122

Process Contact:

Contact Information:

Contact Organization Primary:

Contact Organization: Satlantic, Inc.

Contact Address:

Address Type: mailing and physical address

Address: 3295 Barrington Street

City: Halifax

State or Province: Nova Scotia

Postal Code: B3K 5X8

Country: Canada

Contact Voice Telephone: (902) 492-4780

Spatial Data Organization Information:

Indirect Spatial Reference: South Atlantic Bight, North Carolina, South Carolina, Georgia, Florida, USA.

Distribution Information:

Distributor:

Contact Information:

Contact Organization Primary:

Contact Organization: NOAA Coastal Services Center

Contact Address:

Address Type: mailing and physical address

Address: 2234 S. Hobson Avenue

City: Charleston

State or Province: South Carolina

Postal Code: 29405-2413

Country: USA

Contact Voice Telephone: (843) 740-1200

Contact Facsimile Telephone: (843) 740-1224

Contact Electronic Mail Address: csc@csc.noaa.gov

Hours of Service: 8AM-5PM, M-F

Resource Description: APR98SAB Cruise Report

Distribution Liability: None

Custom Order Process: The data can be accessed on-line at
<http://www.csc.noaa.gov/crs/cruises/>.

Metadata Reference Information:

Metadata Date: 19981026

Metadata Review Date: 19981026

Metadata Contact:

Contact Information:

Contact Organization Primary:

Contact Organization: NOAA, Coastal Services Center

Contact Position: Metadata Specialist

Contact Address:

Address Type: mailing and physical address

Address: 2234 Hobson Avenue

City: Charleston

State or Province: South Carolina

Postal Code: 29405-2413

Country: USA

Contact Voice Telephone: (843) 740-1200

Contact Facsimile Telephone: (843) 740-1224

Contact Electronic Mail Address: csc@csc.noaa.gov

Hours of Service: 8AM-5PM, M-F

Metadata Standard Name: Content Standard for National Biological Information
Infrastructure Metadata.

Metadata Standard Version: December 1995

VIII. Appendix A - Water Column Profile Data Figures

IX. Appendix B - Example Profile Header information

The following information is found as a header on all BBOP processed files.

```
<cruise_info>
filename p980405b
date 04-05-1998
day_of_year 95
file_created 09:09:03
cruise
position 77 15.262 34 32.387
longitude 77 15.262
latitude 34 32.387
sky_state clouds
operator_name hw
sun_position 2
cruise_id ch16-97
session_started 09:09:09
session_stopped 09:10:17
depth_offset 0.32
most_recent_dark_file
deck_comparison_file
cal_date_uw9643 010798
cal_date_sfc9644 010798
affiliations NOAA_Coastal_Services_Center
investigators John_Brock, Pat_Tester
contact csc@csc.noaa.gov
calibration_files unit0_010798.cfl/unit1_010798.cfl/unit2_010798.cfl
downcast_ended 09:09:20.121 16
upcast_ended 09:10:05.890 89
collection_software_version prrprof_002086c
number_units 1
collection_cal_file 96439644.cfl;prr-600 #9643/9644 calibration file 2/10/97 cac
lcd_calib_file 0 /csc/nac1/crs/cruisedata/calib_prr/unit0_010798.cfl
1 /csc/nac1/crs/cruisedata/calib_prr/unit1_010798.cfl
2 /csc/nac1/crs/cruisedata/calib_prr/unit2_010798.cfl
lcdfile_created Jul 24 1998 11:11:41
<sampled_parameters>
```

X. Appendix C - Calibration Certificates

The following pages contain the calibration history of the PRR600 instrument.