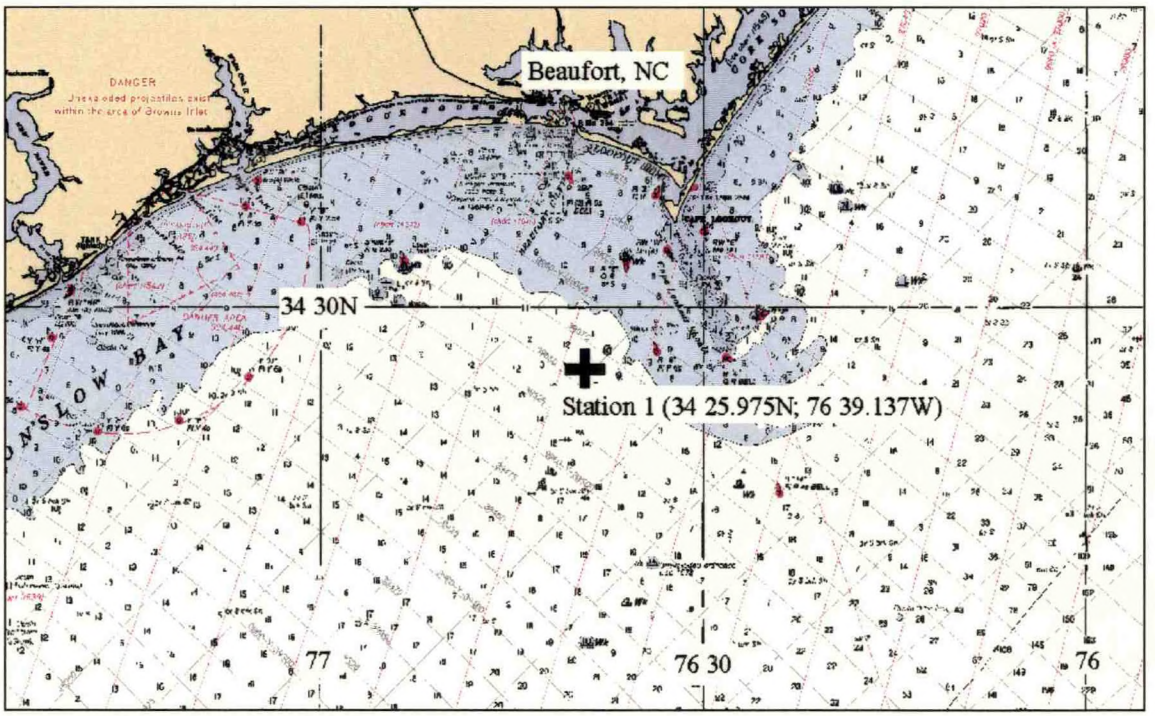
UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
COASTAL SERVICES CENTER
2234 Hobson Avenue, Charleston, SC 29405-2413

CSC Technical Report CSC/5-97/001 May 1997

NOAA CSC/CRS Cruise MAR97OCC
OCTS Calibration Cruise



Participants:

Coastal Services Center - Coastal Remote Sensing Program
National Marine Fisheries Service - Southeast Fisheries Science Center

CSC Technical Report CSC/5-97/001

NOAA CSC/CRS Cruise MAR97OCC: OCTS Calibration Cruise

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This is a NOAA Coastal Services Center Technical Report. The NOAA CSC Coastal Remote Sensing Program intends to publish forthcoming reports as official NOAA Technical Reports.

Abstract

The calibration of the Ocean Color and Temperature Sensor (OCTS) on board the Advanced Earth Observing Satellite (ADEOS) needs to be verified. This requires precise measurements of radiance just below the sea surface in reasonably clear waters from which water leaving radiance can be calculated. Scientists from the Coastal Remote Sensing Program at the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center and the Southeast Fisheries Science Center at NOAA/National Marine Fisheries Service undertook a cruise out of Beaufort, North Carolina. One station, located at 34° 25.98'N, 76° 39.14'W, was occupied at 11:05 a.m., March 13, 1997, contemporaneous with an ADEOS overpass. *In-situ* measurements of temperature, spectral downwelling irradiance, and spectral upwelling radiance to a depth of 15 meters were made along with above surface spectral downwelling irradiance. Surface chlorophyll concentration was also measured.

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Acknowledgments

We thank Captain Doug Willis and the crew of the *R/V Onslow Bay* for assistance provided. The chlorophyll sample analysis was performed by Elin Haugin, Southeast Fisheries Science Center, Beaufort, North Carolina. This cruise was made possible by a NOAA Coastal Ocean Program Grant to Dr. Tester.

Data Usage Constraints

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.

I. Introduction

The Ocean Color and Temperature Sensor (OCTS) on the Japanese Advanced Earth Observing Satellite (ADEOS) requires sea-truth data for post-launch characterization. Accurate measurements of water-leaving radiance in relatively clear waters are required to verify the calibration on this sensor after launch. To support this activity, the Coastal Remote Sensing (CRS) Program at the National Oceanic and Atmospheric Administration (NOAA)/Coastal Services Center (CSC) undertook a cruise out of Beaufort, North Carolina, on 13 March 1997.

II. Objectives

The objectives of this cruise were to obtain sub-surface upwelling radiance in relatively clear, deep waters. The water-leaving radiance calculated from these measurements can be compared to those derived from the OCTS sensor, in order to assess the sensor's calibration.

III. Methods

A. Sampling Location

One station (Station 1) was occupied on 13 March, 1997, to make optical profile measurements in the water column. Surface samples were also acquired at this location for chlorophyll analysis by fluorometric and High-Pressure Liquid Chromatography (HPLC) techniques. The station was located at 34° 25.975'N, 76°39.137'W, and is shown in Figure 1.

B. Sampling Platform

The *R/V Onslow Bay*, belonging to the NOAA/National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center, was used for this cruise. The *Onslow Bay* is a 15-meter (m) fisheries survey vessel.

C. Sample Collection Methods Summary

A PRR600s was deployed off the starboard side of the vessel, using a davit and a 4-m long pole with a pulley at the end (Figure 2). The instrument was lowered to a depth of 15 m and brought back to the surface between 11:00 a.m. and 11:15 a.m. The PRR600s measured *in-situ* spectral downwelling irradiance, spectral upwelling radiance, and temperature. Surface bucket samples were obtained for chlorophyll analysis.

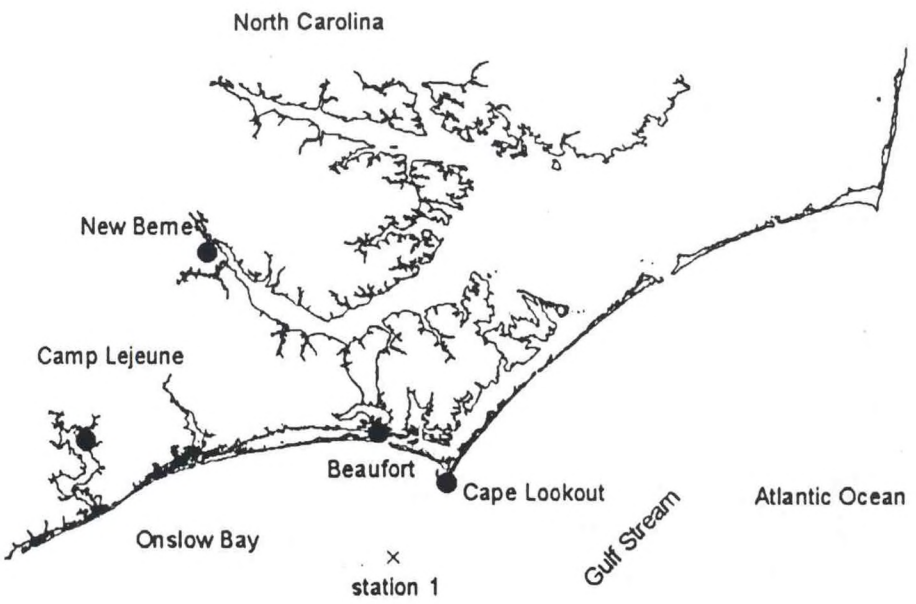

Figure 1. Location of Station 1, Occupied at 11:05 A.M. EST on 13 March 1997.

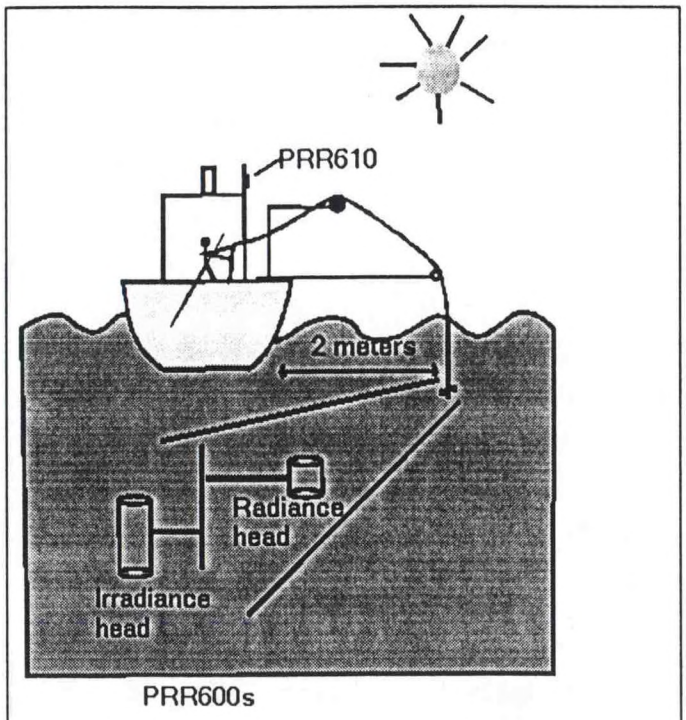

Figure 2. Deployment of the PRR600s

D. Sampling Gear

The PRR600s (Serial No. 9643) is a spectroradiometer manufactured by Biospherical Instruments, Inc., that measures seven channels of downwelling irradiance, seven channels of upwelling radiance (Table 1), 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 [FWHM]) centered at the indicated wavelengths, while channel 7 on the irradiance sensor is a broadband detector that measures Photosynthetically Available Radiation (PAR) between 400 and 700 nm (Table 1).

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 1. 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). Discrete surface water samples were obtained for chlorophyll analysis using a bucket, at the same time as the PRR cast. In the lab, 1 liter (l) of sea water was filtered through glass fiber GF/F filters which were then stored in 90 percent acetone in a freezer for about 24 hours. Then the filters were ground and the chlorophyll *a* and phaeopigment concentrations were determined using the formula given in Smith *et al.* 1981.

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 A. 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°, 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 5 point moving window.

IV. Results

Although initial weather forecasts had called for clear skies in the morning with Northeast winds at 15 knots, there were cloud banks to the east, presumably over the Gulf Stream. Also, winds were considerably stronger at 20 to 25 knots and wave heights were 3 to 4 feet (ft), with swells up to 8 ft. We did not occupy a Gulf Stream station as originally planned, because it was obviously under clouds. The water depth at station was 24 m and surface water temperature was 16.6° Celcius (C). The temperature profile showed that the water column was very well mixed from surface to 15 m (16.6°C from surface to 15 m).

A. Pigment Analyses

The average chlorophyll *a* concentration at the surface at Station 1 was 0.539 µg Chlorophyll *a* /liter (Chl *a*/l) (0.539, 0.552, 0.526).

B. Optical data

Because the boat rolled as much as it did, the instrument was quickly lowered to about 2 m below the surface during the downcast and no data was collected near the surface during the downcast (Figure 3). The water column was optically clear with measurable light at all wavelengths to 14 m. Data was obtained all the way to the surface during the upcast (Figure 4). The rough sea state also caused the instrument to jerk around a lot and much of the data is flagged for tilt and/or roll greater than 10°. The effect of the rough sea state could be seen as kinks in the optical profiles (Figures 3 and 4), as well as in the tilt and roll data (Figure 5). The rolling motion of the boat can also be seen in the changes in surface irradiance data (Figure 5). While there were no dense clouds overhead during the cast, the surface irradiance changed by an average of 18 percent during the downcast and upcast respectively. Overall, there was a 11 percent change in incident irradiance at the surface from the beginning of the downcast to the end of the upcast. The sub-surface irradiance and radiance were calculated using BBOP processing software and the results for the upcast and downcast are shown in Tables 5 and 6, respectively. The min and max depth refer to the minimum and maximum depths of data

sub-surface irradiance and radiance were calculated using BBOP processing software and the results for the upcast and downcast are shown in Tables 5 and 6, respectively. The min and max depth refer to the minimum and maximum depths of data used to calculate the sub-surface light, and n points is the number of data points used in the calculation. b0 is the intercept and b1 is the slope of the regression, min, max, and mean refer to the minimum, maximum, and mean of the data used in the regression.

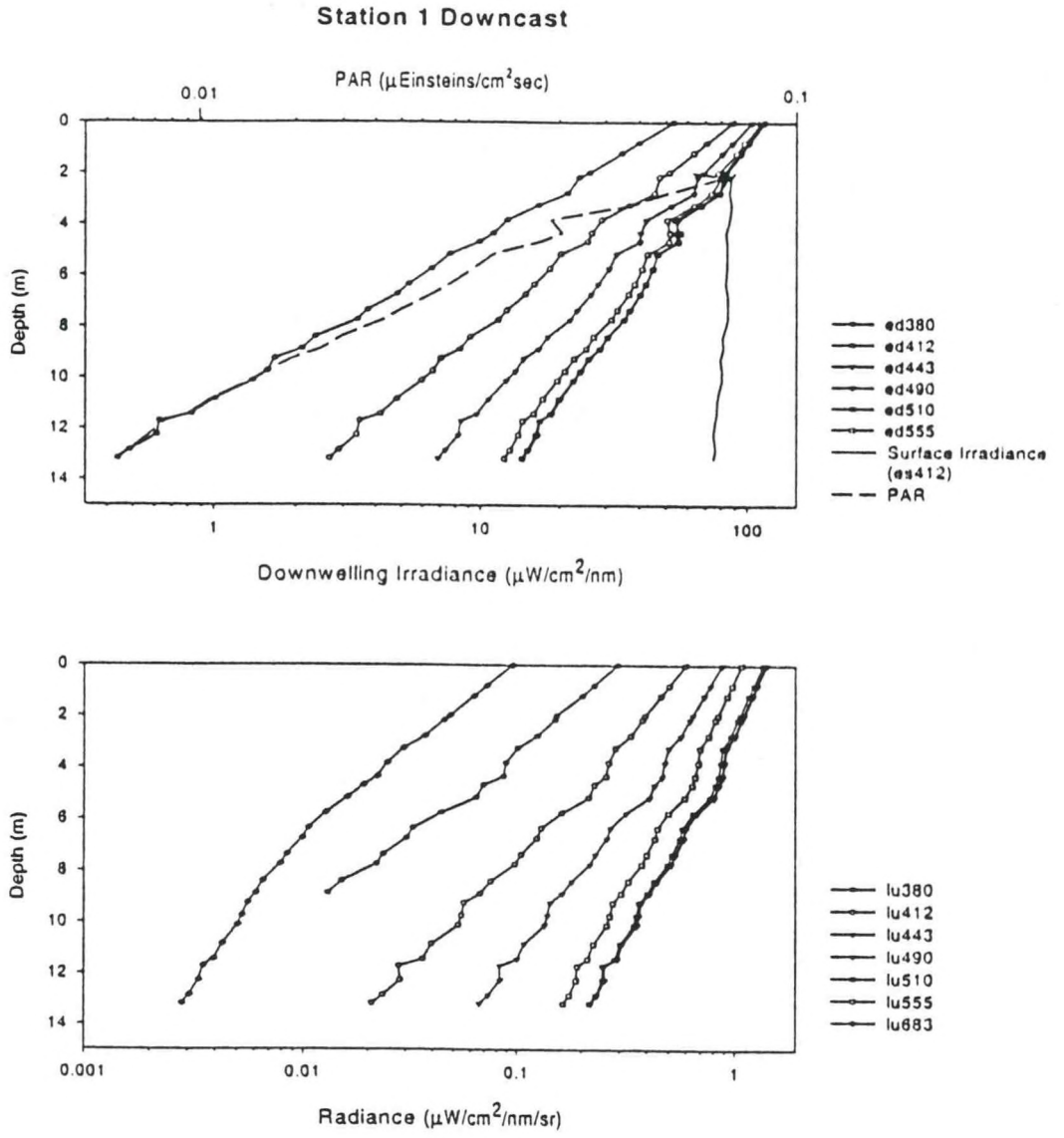

Figure 3. Optical Profiles at Station 1 - Downcast

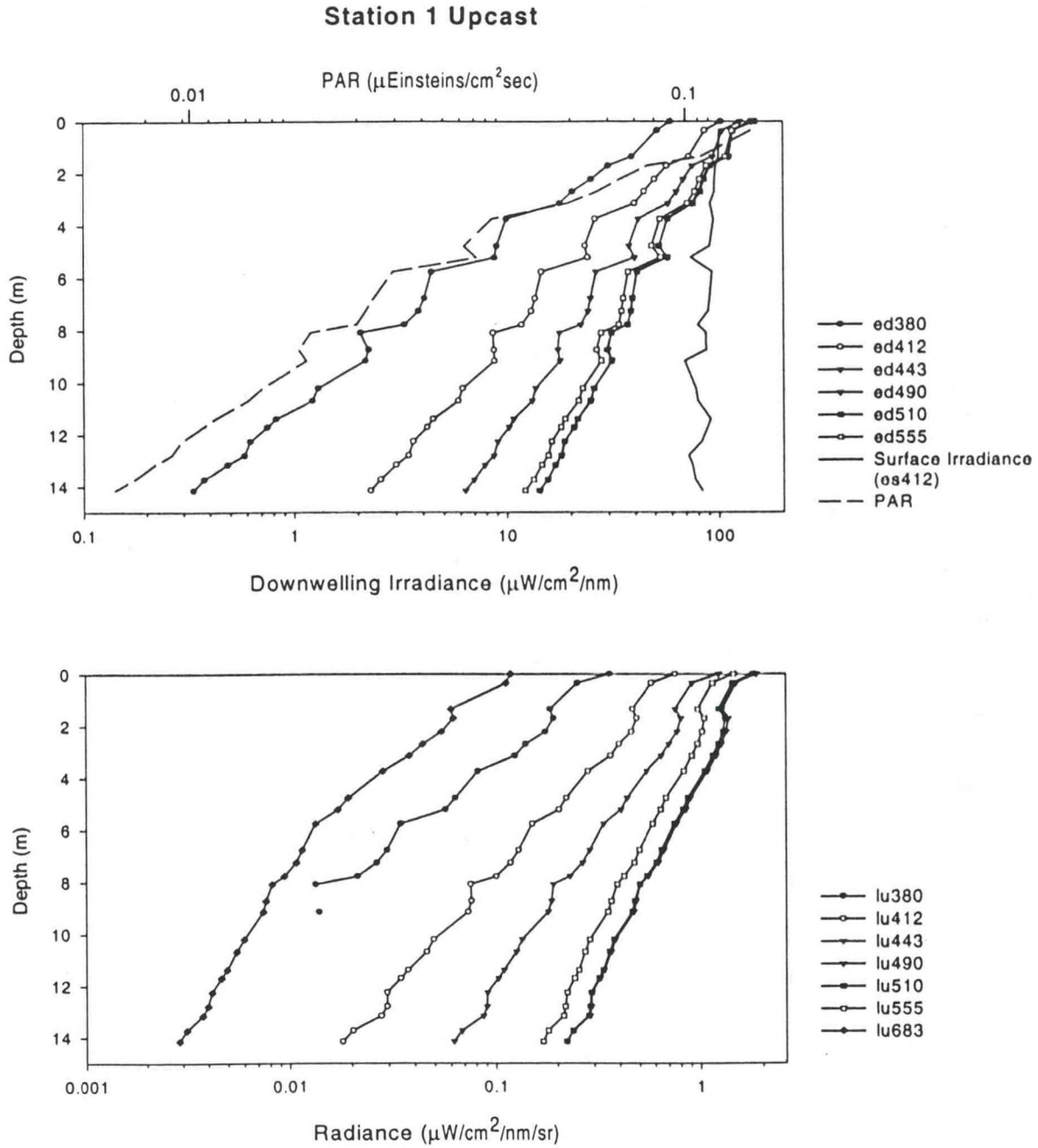

Figure 4. Optical Profiles at Station 1 - Upcast

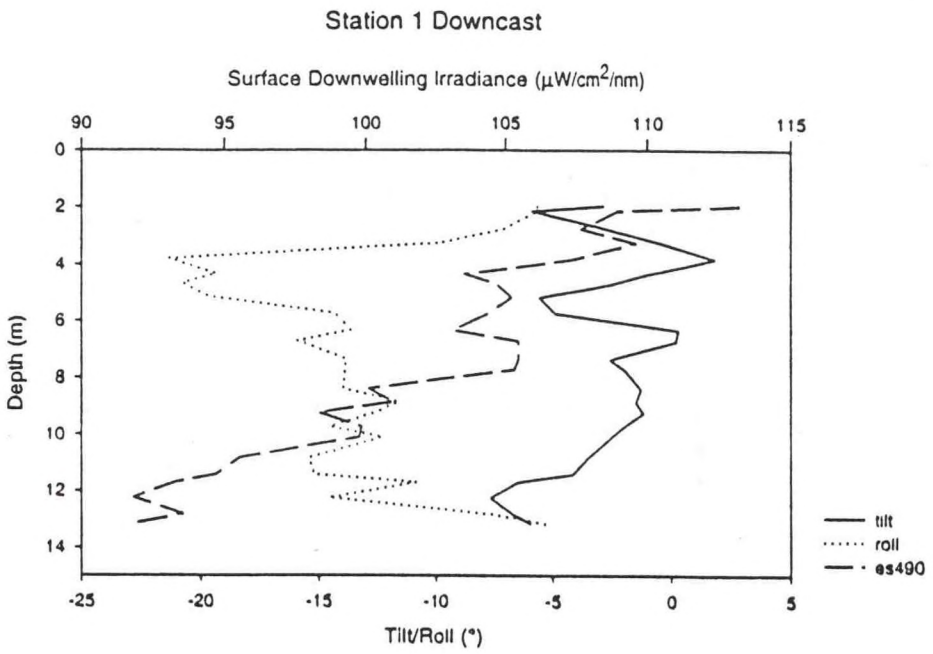

Figure 5. Profiles of Tilt, Roll and Downwelling Surface Irradiance - Downcast

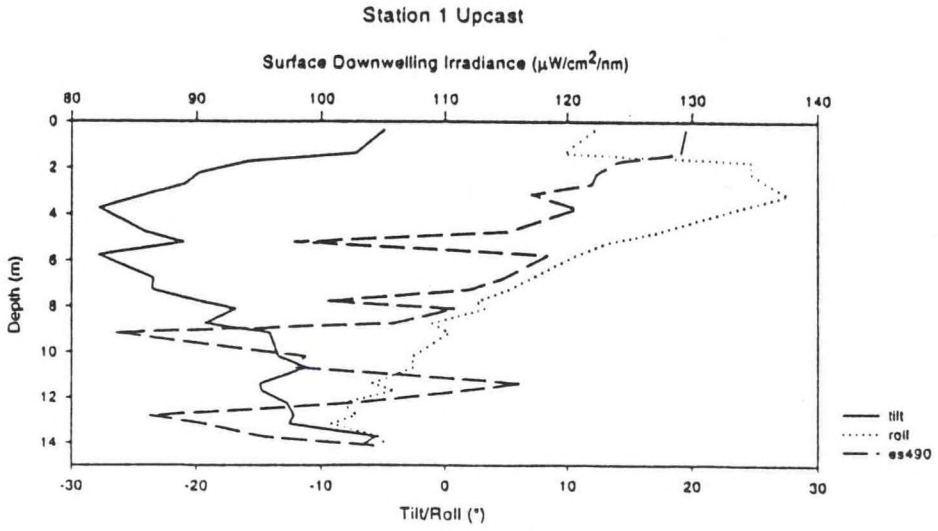

Figure 6. Profiles of Tilt, Roll and Downwelling Surface Irradiance - Upcast

Table 2. Sub-surface Light

channel	min depth	max depth	n points	b0	b1	min	max	mean	std dev	var	un-certainty	abdev
Down cast												
ed380	0.5	6	10	53.22	0.69	5.33	26.07	12.36	1.75	1.36	1.11	0.03
ed412	0.5	6	10	87.93	0.76	16.14	51.50	29.39	1.51	1.19	1.12	0.04
ed443	0.5	6	10	104.13	0.81	28.07	68.87	44.25	1.38	1.11	1.12	0.04
ed490	0.5	6	10	115.58	0.85	42.21	83.62	59.21	1.29	1.07	1.13	0.04
ed510	0.5	6	10	114.27	0.85	42.05	84.70	59.36	1.30	1.07	1.14	0.04
ed555	0.5	6	10	112.52	0.84	38.35	80.11	55.16	1.31	1.08	1.13	0.04
lu380	0.5	6	10	0.29	0.73	0.03	0.15	0.08	1.66	1.30	1.26	0.07
lu412	0.5	6	10	0.60	0.81	0.13	0.39	0.25	1.43	1.14	1.21	0.05
lu443	0.5	6	10	0.88	0.85	0.27	0.64	0.46	1.32	1.08	1.18	0.05
lu490	0.5	6	10	1.40	0.89	0.60	1.11	0.87	1.21	1.04	1.12	0.04
lu510	0.5	6	10	1.35	0.88	0.58	1.06	0.84	1.21	1.04	1.12	0.04
lu555	0.5	6	10	1.08	0.88	0.45	0.84	0.65	1.23	1.04	1.12	0.04
lu683	0.5	6	10	0.10	0.71	0.01	0.05	0.02	1.68	1.31	1.06	0.02
Upcast												
ed380	0.5	6	10	59.46	0.67	4.06	38.78	13.09	2.19	1.85	1.33	0.09
ed412	0.5	6	9	102.62	0.73	14.57	72.66	35.00	1.68	1.31	1.27	0.08
ed443	0.5	6	9	126.22	0.78	26.22	94.10	52.28	1.50	1.18	1.22	0.07
ed490	0.5	6	9	142.85	0.81	40.81	111.67	69.30	1.37	1.11	1.20	0.06
ed510	0.5	6	9	147.29	0.81	41.04	111.39	69.70	1.37	1.11	1.21	0.06
ed555	0.5	6	9	142.24	0.80	37.18	107.42	65.27	1.40	1.12	1.21	0.06
lu380	0.5	6	9	0.36	0.70	0.03	0.19	0.10	1.84	1.45	1.29	0.09
lu412	0.5	6	9	0.76	0.77	0.15	0.49	0.31	1.52	1.19	1.17	0.06
lu443	0.5	6	9	1.23	0.80	0.33	0.81	0.58	1.38	1.11	1.16	0.04
lu490	0.5	6	9	1.87	0.86	0.76	1.37	1.09	1.24	1.05	1.15	0.04
lu510	0.5	6	9	1.80	0.86	0.75	1.32	1.06	1.24	1.05	1.15	0.04
lu555	0.5	6	9	1.45	0.85	0.58	1.05	0.83	1.25	1.05	1.15	0.04
lu683	0.5	6	9	0.12	0.68	0.01	0.06	0.03	1.78	1.39	1.14	0.04

Normalized water leaving radiance, as defined by Gordon *et al.* 1988, was calculated as:

$$(L_w)_N = \left[\frac{(1 - \rho)(1 - \overline{\rho}) F_0 \left(\frac{L_u}{E_d} \right)}{m^2 (1 - r Q \frac{L_u}{E_d})} \right]$$

where:

- $(L_w)_N$ is the normalized water leaving radiance
- ρ is the Fresnel reflectance of the sea surface for normal incidence, here = 0.021
- $\overline{\rho}$ is the Fresnel reflection albedo of the sea surface for irradiance from the sun and sky, here = 0.043
- F_0 is the mean extraterrestrial solar irradiance, here $F_{0(385)}$=94.5, $F_{0(415)}$=170, $F_{0(445)}$=192.8, $F_{0(490)}$=192.2, $F_{0(515)}$=183.1, $F_{0(555)}$=184.1, $F_{0(675)}$=151.6 (from [Labs and Neckel 1970])

- L_u is the sub-surface upwelling radiance calculated from optical profile
- E_d is the sub-surface downwelling irradiance calculated from optical profile
- m is the refractive index of sea water, here = 1.34
- r is the water-air reflectance for totally diffuse irradiance, here = 0.48
- Q is the ratio of the upwelling radiance to the upwelling irradiance towards the zenith, here = 5.07

The sub-surface irradiance, radiance, and normalized water leaving radiance are shown in Table 3 and the spectra for the downcast and the upcast are shown in Figure 7.

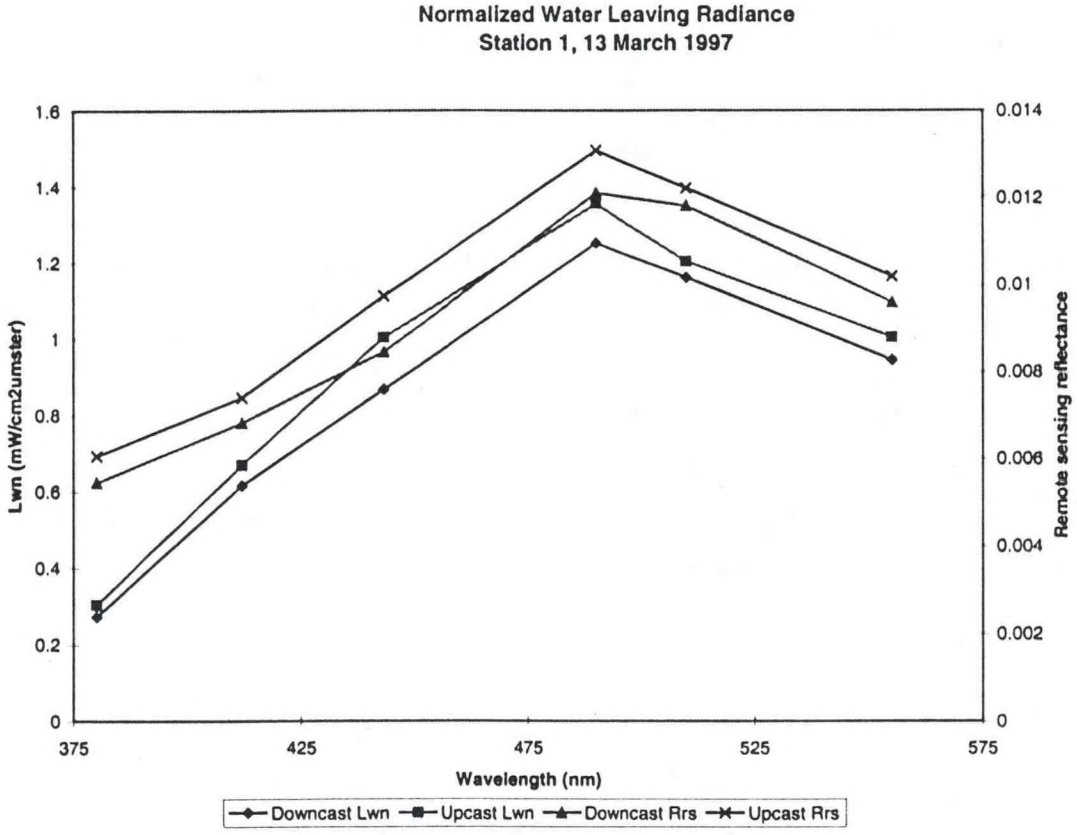

Figure 7. Spectra of Normalized Water Leaving Radiance and Remote Sensing Reflectance

Table 3. Normalized Water Leaving Radiance and Remote Sensing Reflectance

Wave-length	Downcast E_d	upcast E_d	down-cast L_u	upcast L_u	downcast L_{WN}	upcast L_{WN}	downcast R_{rs}	upcast R_{rs}
380	53.22	59.46	0.29	0.36	0.2723	0.303007	0.005449	0.006054
412	87.93	102.62	0.6	0.76	0.615508	0.669004	0.006824	0.007406
443	104.13	126.22	0.88	1.23	0.868041	1.004181	0.008451	0.009745
490	115.58	142.85	1.4	1.87	1.251708	1.356086	0.012113	0.013091
510	114.27	147.29	1.35	1.8	1.162166	1.203399	0.011814	0.012221
555	112.52	142.24	1.08	1.45	0.944097	1.004189	0.009598	0.010194

V. References

Gordon, H. R., O. B. Brown, R. H. Evans, J. W. Brown, R. C. Smith, K. S. Baker and D. K. Clark (1988). "A Semianalytic Radiance Model of Ocean Color." *Journal of Geophysical Research* **93**(D9): 10909-10924.

Labs, D. and H. Neckel (1970). "Transformation of the Absolute Solar Radiation Data Into The International Practical Temperature Scale Of 1968." *Solar Physics* **15**: 79.

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.

VI. Metadata

The metadata, including point of contacts, types of analyses, for the cruise is given below.

A. Core Documentation

Identification_Information
Citation
Citation_Information
Originator: National Oceanic and Atmospheric Administration Coastal Services Center
Publication_Date: 1997
Title: NOAA CSC/CRS Cruise MAR97OCC: OCTS Calibration Cruise
Online Linkage: http://www.csc.noaa.gov/crs/cruises/mar97occ/index.html

Description
Abstract: See Abstract, page iii

Purpose: See Objectives, page 1

Supplemental_Information:
StartDate: 19971303
StopDate: 19971303
Preview: http://www.csc.noaa.gov/crs/cruises/index.html

Time_Period_of_Content
Time_Period_Information
Single_Date/Time
Calendar_Date: 1997
Currentness_Reference: Publication Date

Status
Progress: Complete
Maintenance_and_Update_Frequency: Unknown

Spatial Domain
Bounding Coordinates:
West Bounding Coordinate: -76.652
East Bounding Coordinate: -76.652
North Bounding Coordinate: 34.433
South Bounding Coordinate: 34.433

Keywords
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Theme_Keyword: bio-optical
Theme_Keyword: turbidity
Theme_Keyword: blooms
Theme_Keyword: resuspension
Theme_Keyword: river plumes
Theme_Keyword: coastal water optics
Theme_Keyword: case II algorithms
Theme_Keyword: absorption
Theme_Keyword: attenuation
Theme_Keyword: in-situ optical profiling
Theme_Keyword: ocean color satellites
Theme_Keyword: coastal ocean algorithm development
Place
Place_Keyword_Thesaurus: None
Place_Keyword: Onslow Bay
Place_Keyword: Beaufort, NC
Place_Keyword: South Atlantic Bight
Place_Keyword: United States
Time
Temporal_Keyword: Spring
Temporal_Keyword: March, 1997
Parameters measured
Parameter_Keyword: spectral downwelling irradiance
Parameter_Keyword: spectral upwelling radiance
Parameter_Keyword: temperature

Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: NOAA Coastal Services Center
Contact_Person: Dr. A. Subramaniam
Contact_Address:
Address_Type: mailing and physical
Address: 2234 South Hobson Avenue
City: Charleston
State: South Carolina
Postal_Code: 29405-2413
Country: USA
Contact_Voice_Telephone: (800)789-2234
Contact_Electronic_Mail_Address: crs@csc.noaa.gov
Hours_of_Service: 8 a.m.-5 p.m., M-F

B. Citation Information

Source Citation: Subramaniam, A., E.M. Armstrong, K.J. Waters, J.C. Brock, P.A. Tester, and E. Haugen. 1997. NOAA CSC/CRS Cruise MAR97OCC: OCTS Calibration Cruise. CSC Technical Report CSC/5-97/001. NOAA Coastal Services Center. Charleston, SC. Pp18

Currentness: May 1997

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.

C. Data Quality

Process Description: See Methods, page 2

Spectroradiometer measurements: Spectral downwelling irradiance, spectral upwelling radiance, temperature

Instrument: PRR600s, PRR610
Operator: Ajit Subramaniam
Address: see point of contact
Manufacturer: Biospherical Instruments, Inc.
Address: 5340 Riley Street
San Diego, CA 92110-2621
Phone: (619) 686.1888

Chlorophyll measurements:

Methods reference: Parsons, T. R., Y. Maita and C. M. Lalli (1984). *A manual for chemical and biological methods for seawater analysis*, Pergamon Press. Pp107-110.
Variations: 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.
Analyst: Elin Haugen
Address: National Marine Fisheries Service
Southeast Fisheries Science Center - Beaufort Laboratory
101 Pivers Island Road
Beaufort, NC 28516-9722
Telephone: (919) 728.2747

Attribute Accuracy: See Appendix B

Spectroradiometer Calibration:

1st Calibration:	1/24/96
2nd Calibration:	3/26/96
3rd Calibration:	2/10/97

Horizontal Positional Accuracy: 400 m

Entity and Attribute Overview Description: See Methods, page 2

D. Metadata Reference Information

Metadata Date:

Contact Organization: NOAA/Coastal Services Center

Contact Person: Beth Lovett

Full Address: see point of contact

The core documentation section is designed for the purposes of the Coastal Information Directory (CID). The metadata in this section is used in building the CID's database.

VII. Appendix A - Example Profile Header information

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

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date 03-13-1997
day_of_year 72
day_since_010192 1899
file_created 11:03:50
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longitude 76 39.137
latitude 34 25.975
sky_state clear
operator_name ajit
sun_position 2
cruise_id cope i sep96cop cruise
session_started 11:04:02
session_stopped 11:07:29
depth_offset .32
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cal_date_sfc9644 021097
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upcast_ended 11:07:27.558 340
yoyo no
closest_CTD_cast none
sun_intensity bright
cloud_type 30% clouds on horizon
cloud_amt 30% (high clouds)
wind_speed_and_dir 20 kts? north-northeast
swell 5-6ft
collection_software_version prrprof_002086c
number_units 1
collection_cal_file 96439644.cfl;prr-600 #9643/9644 calibration file 2/10/96 cac
lcd_calib_file 0 /csc/nep1/coors/bbops/BUILD/calib/unit0_021097.cfl
1 /csc/nep1/coors/bbops/BUILD/calib/unit1_021097.cfl
2 /csc/nep1/coors/bbops/BUILD/calib/unit2_021097.cfl
lcdfile_created Mar 19 1997 16:59:38

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p970313a.ub1	2.2900000e+02	2.2900000e+02	1.4603000e+01
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1ed555 0 -0.022801 0.00048
1par 0 -9.05594 0.000371
1edgnd 0 1 0
1temp 0 0.1421 0.0889
1depth 0. 9.38300e-01 8.31773e+01 2.65899e+01 0.9383 83.1773 26.9099 0
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1tilt 0 0.04178 2.68617
1roll 0 0.041514 2.69727
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2lu412 0 -0.498479 -0.000103
2lu443 0 -0.90121 0.000203
2lu490 0 -0.996381 0.00016
2lu510 0 -1.24348 0.00033
2lu555 0 -1.74733 0.000162
2lu683 0 -1.52118 0.000105
2lugnd 0 1 0
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3es412 0 -0.03211 -0.000879
3es443 0 -0.033785 -2.1e-05
3es490 0 -0.032938 -0.000256
3es510 0 -0.032641 -0.000241
3es555 0 -0.032326 0.000203
3par 0 -10.5311 -6.9e-05
3edgnd 0 1 0
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d-1temp
d-d-1temp
m-d-d-1temp
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ptsbin_0.5
kc-1ed380
kc-1ed412
kc-1ed443
kc-1ed490
kc-1ed510

<filters_used>

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bbopradq -fa 1ed412 1.000000e-04 p970313a.lcd outqp970313a.lcd
bbopradq -fa 1ed443 1.000000e-04 p970313a.lcd outqp970313a.lcd
bbopradq -fa 1ed490 1.000000e-04 p970313a.lcd outqp970313a.lcd
bbopradq -fa 1ed510 2.000000e-04 p970313a.lcd outqp970313a.lcd
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bbopangq 1Tilt 1Roll 10 2 inqp970313a.lcd outqp970313a.lcd
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bbopdespike -d d-1temp 0.05 10 indqp970313a.lcd outdqp970313a.lcd
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bbopbin -b 0.5 mdqp970313a.lcd
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bbopkc -s 1ed443 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
bbopkc -s 1ed490 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
bbopkc -s 1ed510 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
```

VIII. Appendix B - Calibration Certificates

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Calibration Date: 2/10/97 **Form:** 2/10/97
Model Number: PRV-600S
Serial Number: 9643
Operator: TMM
Standard Lamp: 94531 (01/02/97) for Irradiance, 94532 (10/11/95) for Radiance.

Ch	Tag	λ (nm)	Lamp Irradiance	Immersion Coefficient	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/μW)	Calibration Factor - Wet (V/μW)	Max E (Dry)	
		DOWNWELLING IRRADIANCE CHANNELS				Irradiance Units: μW/cm²·nm, E = Irradiance				
1	0	380	1.578	0.671	0.000146	-0.019400	-0.012390	-0.008317	807.1	
2	0	412	2.595	0.677	0.000551	-0.081300	-0.031541	-0.021345	317.0	
3	0	443	4.003	0.682	0.000189	-0.128186	-0.032071	-0.021874	311.8	
4	0	490	6.647	0.690	0.000282	-0.221058	-0.033297	-0.022980	300.3	
5	0	510	7.880	0.694	0.000171	-0.253324	-0.032171	-0.022313	310.8	
6	0	555	10.730	0.701	0.000480	-0.348378	-0.032511	-0.022801	307.6	
7	0	PAR[4]	0.0154	0.686	0.000371	-0.202865	-13.204159	-9.055940	0.757	[4]
8	0	Gnd.[5]	0.000318	Volts						

Calibration Factor: WET = ((Light - Dark) x Immers. Coeff.)/Lamp Output
DRY = (Light - Dark)/Lamp Output

Ch	Tag	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient	Plaque Reflectivity	Radiance[6]	Calibration Voltage - Dark	Calibration Voltage - Blocked[3]	Calibration Voltage - Light	Calibration Factor - Wet (V/μW)	Max L (Wet)
		UPWELLING RADIANCE CHANNELS				Radiance Units: μW/cm²·nm·sr, L = Radiance					
1	1	380	1.308	1.765	0.988	0.011	0.000198	0.000206	-0.002858	-0.151929	65.8
2	1	412	2.275	1.758	0.989	0.020	-0.000103	-0.000098	-0.017526	-0.498479	20.1
3	1	443	3.514	1.752	0.990	0.031	0.000203	0.000203	-0.048370	-0.901210	11.1
4	1	490	5.911	1.745	0.990	0.052	0.000160	0.000151	-0.089873	-0.996381	10.0
5	1	510	7.038	1.743	0.990	0.062	0.000330	0.000321	-0.133200	-1.243485	8.0
6	1	555	9.746	1.738	0.991	0.085	0.000162	0.000123	-0.259162	-1.747331	5.7
7	1	683	16.755	1.730	0.990	0.147	0.000105	0.000026	-0.385980	-1.521184	6.6
8	1	Gnd.[5]	0.000179	Volts							

Dry Radiance = (Lamp Output x Plaque Reflectivity x Lamp Distance Factor)/π
Lamp Distance Factor = (50 cm)²/(300 cm)²
Calibration Factor: WET = (Light - Dark)/(Dry Radiance x Immersion Coefficient)

9	0	TEMPERATURE[7, 9]	Temperature (°C) = (Voltage - Offset)/Scale
		Scale	0.1421
		Offset	0.0889
10	0	PRESSURE/DEPTH[8, 9]	Pressure/Depth (dbars or meters) = (a x Voltage²) + (b x Voltage) + c
		Scale Factor "a"	0.9383
		Scale Factor "b"	83.1773
		Offset "c"	26.9099

NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS[9] (For use with external sensors, only, see manual)

	Irr. Array	Rad. Array	
Scale Factor	1.057679	1.074227	(Calibrated on 3-96)
Offset	0.000205	0.000278	
Full Scale Voltage	9.4547	9.3090	

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:
1. Annual calibration is recommended.
2. Calibrations were performed at approximately 20 to 30 °C.
3) "Dark" irradiance and "Blocked" radiance values represent a blocking of the calibration source. These values should not be used as the "Offset" when entering values into the calibration file. Use the totally dark sensor values obtained at the temperature where the instrument will be used.
4) PAR irradiance units are μEinsteins/cm²·sec.
5) Nominal/Typical value(s).
6) For conversion of area to solid angle, a factor (divisor) of Pi is incorporated.
7) Water temperature sensor.
8) A change in depth of 1 meter in seawater corresponds to approximately a 1 dbar change in pressure.
9) These channels/sensors were not evaluated during this service period.

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 2/10/97 Form: 2/10/97
Model Number: PRV-600S
Serial Number: 9643
Operator: TMM

OPTIONAL CHANNELS

Ch	Tag			
11	0	Transmissometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
12	0	Scalar PAR: QSP-200 S/N 4443[2]	quanta/(cm^2·sec) = (Voltage - Offset)/Scale	
		Scale Factor (Wet)	-1.020E-17	Volts/(quanta/cm^2·sec)
		Offset	0.0009	Volts
13	0	AXIS 1 ANGLE SENSOR - "TILT"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0418	(Calibrated on 3-96)
		Offset	2.6862	
14	0	AXIS 2 ANGLE SENSOR - "ROLL"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0415	(Calibrated on 3-96)
		Offset	2.6973	
15	0	Light Scattering Sensor[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
16	0	Fluorometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts

Notes:

1) These sensors are not calibrated at BSI. When applicable, see the manufacturers' specifications.

2) These channels/sensors were not evaluated during this service period.

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 2/10/97 **Form:** 2/10/97
Model Number: PRV-610
Serial Number: 9644
Operator: TMM
Standard Lamp: 95431 (01/02/97)

Ch	Tag	λ (nm)	Lamp Output	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Max E (Dry)
SURFACE IRRADIANCE CHANNELS					Irradiance Units: µW/cm²·nm, E = Irradiance		
1	2	380	1.578	0.000240	-0.049332	-0.031424	318.2
2	2	412	2.595	-0.000879	-0.084205	-0.032110	311.4
3	2	443	4.003	-0.000021	-0.135255	-0.033785	296.0
4	2	490	6.647	-0.000256	-0.219210	-0.032938	303.6
5	2	510	7.880	-0.000241	-0.257444	-0.032641	306.4
6	2	555	10.730	0.000203	-0.346664	-0.032326	309.4
7	2	PAR[4]	0.0154	0.000069	-0.162024	-10.531115	0.950 [4]
8	2	Gnd.[5]	0.000101	Volts			

Calibration Factors: DRY = (Light - Dark)/Lamp Output

NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS (For use with external sensors, only, see manual)

	Irr. Array	
Scale	1.061494	(Calibrated on 1-96)
Offset	0.000049	
Full Scale Voltage	9.4207	

FIRMWARE VERSION

	Tag 2
Surface ROM	2106B

Notes:
1. Annual calibration is recommended.
2. Calibrations were made at approximately 20 to 30 °C.
3) Dark values represent a blocking of the calibration source. These values should not be used as the 'offset' when entering values into the calibration file. Use the totally dark sensor values obtained at the temperature where the instrument will be used.
5) Typical value(s).

Biospherical Instruments Inc.

EVALUATION FORM for PRR Spectroradiometer

Calibration Date: 3/26/96 **Form:** 7/11/96

Model Number: PRV-600S

Serial Number: 9643

Operator: JCE/LFG

Standard Lamp: 94531 (10/11/95) for Irradiance, 94532 (10/11/95) for Radiance.

Ch	Tag	λ (nm)	Lamp Irradiance	Immersion Coefficient	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Calibration Factor - Wet (V/µW)	Max E (Dry)	
DOWNWELLING IRRADIANCE CHANNELS							Irradiance Units: µW/cm²·nm, E = Irradiance			
1	0	380	1.486	0.671	0.000160	-0.019050	-0.012927	-0.008677	773.6	
2	0	412	2.559	0.677	0.000095	-0.081553	-0.031907	-0.021592	313.4	
3	0	443	3.906	0.682	0.000116	-0.126520	-0.032421	-0.022113	308.4	
4	0	490	6.483	0.690	0.000272	-0.218429	-0.033732	-0.023280	296.5	
5	0	510	7.683	0.694	0.000108	-0.250415	-0.032609	-0.022617	306.7	
6	0	555	10.536	0.701	0.000459	-0.345228	-0.032809	-0.023010	304.8	
7	0	PAR[4]	0.0152	0.686	0.000337	-0.200664	-13.196577	-9.050741	0.758	[4]
8	0	Gnd.[5]	0.000309	Volts						

Calibration Factor: WET = ((Light - Dark) x Immers. Coeff.)/Lamp Output

DRY = (Light - Dark)/Lamp Output

Ch	Tag	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient	Plaque Reflectivity	Radiance[6]	Calibration Voltage - Dark	Calibration Voltage - Blocked[3]	Calibration Voltage - Light	Calibration Factor - Wet (V/µW)	Max L (Wet)
UPWELLING RADIANCE CHANNELS							Radiance Units: µW/cm²·nm·sr, L = Radiance				
1	1	380	1.308	1.765	0.985	0.011	0.000133	0.000133	-0.002922	-0.151959	65.8
2	1	412	2.275	1.758	0.985	0.020	0.000209	0.000202	-0.017559	-0.509911	19.6
3	1	443	3.514	1.752	0.985	0.031	0.000192	0.000186	-0.048676	-0.911266	11.0
4	1	490	5.911	1.745	0.984	0.051	0.000122	0.000106	-0.090184	-1.005825	9.9
5	1	510	7.038	1.743	0.984	0.061	0.000272	0.000261	-0.133038	-1.248987	8.0
6	1	555	9.746	1.738	0.984	0.085	0.000124	0.000083	-0.258677	-1.755312	5.7
7	1	683	16.755	1.730	0.984	0.146	0.000027	-0.000057	-0.392216	-1.555169	6.4
8	1	Gnd.[5]	0.000124	Volts							

Dry Radiance = (Lamp Output x Plaque Reflectivity x Lamp Distance Factor)/π

Lamp Distance Factor = $(50\ cm)^2/(300\ cm)^2$

Calibration Factor: WET = (Light - Dark)/(Dry Radiance x Immersion Coefficient)

9	0	TEMPERATURE[7, 9]	Temperature (°C) = (Voltage - Offset)/Scale
		Scale	0.1419
		Offset	0.0801
10	0	PRESSURE/DEPTH[8, 9]	Pressure/Depth (dbars or meters) = (a x Voltage²) + (b x Voltage) + c
		Scale Factor "a"	0.9374
		Scale Factor "b"	83.8842
		Offset "c"	26.9636

NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS[5] (For use with external sensors, only, see manual)

	Irr. Array	Rad. Array
Scale Factor	1.067679	1.074227
Offset	0.000206	0.000278
Full Scale Voltage	9.4547	9.3090

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:

1. Annual calibration is recommended.
2. Calibrations were performed at approximately 20 to 30 °C.
3) "Dark" irradiance and "Blocked" radiance values represent a blocking of the calibration source. These values should not be used as the "Offset" when entering values into the calibration file. Use the totally dark sensor values obtained at the temperature where the instrument will be used.
4) PAR irradiance units are µEinsteins/cm²·sec.
5) Nominal/Typical value(s).
6) For conversion of area to solid angle, a factor (divisor) of PI is incorporated.
7) Water temperature sensor.
8) A change in depth of 1 meter in seawater corresponds to approximately a 1 dbar change in pressure.
9) These channels/sensors were not evaluated during this service period.

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 3/26/96 **Form:** 7/11/96
Model Number: PRV-600S
Serial Number: 9643
Operator: JCE/LFG

OPTIONAL CHANNELS

Ch	Tag			
11	0	Transmissometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
12	0	Scalar PAR: QSP-200 S/N 4443[2]	quanta/(cm^2·sec) = (Voltage - Offset)/Scale	
		Scale Factor (Wet)	-1.161E-17	Volts/(quanta/cm^2·sec)
		Offset	0.0009	Volts
13	0	AXIS 1 ANGLE SENSOR - "TILT"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0418	
		Offset	2.6862	
14	0	AXIS 2 ANGLE SENSOR - "ROLL"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0416	
		Offset	2.6973	
15	0	Light Scattering Sensor[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
16	0	Fluorometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts

Notes:

1) These sensors are not calibrated at BSI. When applicable, see the manufacturers' specifications.

2) These channels/sensors were not evaluated during this service period.

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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CALIBRATION DATA

Calibration Date: 1/23/96 **Form:** 1/24/96
Model Number: PRV-600S
Serial Number: 9643
Operator: JCE/LFG
Standard Lamp: 91771 (05/30/95)

Ch	Tag	λ (nm)	Lamp Irradiance	Immersion Coefficient	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Calibration Factor - Wet (V/µW)	Max E (Dry)	
DOWNWELLING IRRADIANCE CHANNELS						Irradiance Units: µW/cm²·nm, E = Irradiance				
1	0	380	1.397	0.671	0.000132	-0.018129	-0.013074	-0.008775	764.9	
2	0	412	2.411	0.677	0.000516	-0.077541	-0.032371	-0.021906	308.9	
3	0	443	3.701	0.682	0.000113	-0.120950	-0.032714	-0.022313	305.7	
4	0	490	6.159	0.690	0.000302	-0.209334	-0.034039	-0.023491	293.8	
5	0	510	7.302	0.694	0.000168	-0.240489	-0.032957	-0.022859	303.4	
6	0	555	10.041	0.701	0.000465	-0.332822	-0.033194	-0.023279	301.3	
7	0	PAR[4]	0.014	0.686	0.000330	-0.194557	-13.767821	-9.442522	0.726	[4]
8	0	Gnd.[5]	0.000291	Volts						

Calibration Factor: WET = ((Light - Dark) x Immers. Coeff.)/Lamp Output
DRY = (Light - Dark)/Lamp Output

Ch	Tag	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient	Plaque Reflectivity	Radiance[6]	Calibration Voltage - Dark	Calibration Voltage - Blocked[3]	Calibration Voltage - Light	Calibration Factor - Wet (V/µW)	Max L (Wet)
UPWELLING RADIANCE CHANNELS						Radiance Units: µW/cm²·nm·sr, L = Radiance					
1	1	380	1.397	1.765	0.985	0.012	0.000221	0.000214	-0.003021	-0.150639	66.4
2	1	412	2.411	1.758	0.985	0.021	-0.000068	-0.000079	-0.018727	-0.505131	19.8
3	1	443	3.701	1.752	0.985	0.032	0.000233	0.000215	-0.050659	-0.900887	11.1
4	1	490	6.159	1.745	0.984	0.054	0.000180	0.000150	-0.092345	-0.988998	10.1
5	1	510	7.302	1.743	0.984	0.064	0.000363	0.000337	-0.136471	-1.235454	8.1
6	1	555	10.041	1.738	0.984	0.087	0.000180	0.000128	-0.263356	-1.734900	5.8
7	1	683	16.897	1.730	0.984	0.147	0.000095	-0.000003	-0.394184	-1.550051	6.5
8	1	Gnd.[5]	0.00019	Volts							

Dry Radiance = (Lamp Output x Plaque Reflectivity x Lamp Distance Factor)/π
Lamp Distance Factor = $(50\ cm)^2/(300\ cm)^2$
Calibration Factor: WET = (Light - Dark)/(Dry Radiance x Immersion Coefficient)

9	0	TEMPERATURE[7]	Temperature (°C) = (Voltage - Offset)/Scale
		Scale	0.1419
		Offset	0.0801
10	0	PRESSURE/DEPTH[8]	Pressure/Depth (dbars or meters) = (a x Voltage²) + (b x Voltage) + c
		Scale Factor "a"	0.9374
		Scale Factor "b"	83.8842
		Offset "c"	26.9635

NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS (For use with external sensors, only, see manual)

	Irr. Array	Rad. Array
Scale Factor	1.057679	1.074227
Offset	0.000205	0.000278
Full Scale Voltage	9.4547	9.3090

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:

1. Annual calibration is recommended.
2. Calibrations were performed at approximately 20 to 30 °C.
3) "Dark" irradiance and "Blocked" radiance values represent a blocking of the calibration source. These values should not be used as the "Offset" when entering values into the calibration file. Use the totally dark sensor values obtained at the temperature where the instrument will be used.
4) PAR irradiance units are µEinsteins/cm²·sec.
5) Typical value(s).
6) For conversion of area to solid angle, a factor (divisor) of Pi is incorporated.
7) Water temperature sensor.
8) A change in depth of 1 meter in seawater corresponds to approximately a 1 dbar change in pressure.

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 1/23/96 Form: 1/24/96
Model Number: PRV-600S
Serial Number: 9643
Operator: JCE/LFG

OPTIONAL CHANNELS

Ch	Tag			
11	0	Transmissometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
12	0	Scalar PAR: QSP-200 S/N 4443	quanta/(cm^2·sec) = (Voltage - Offset)/Scale	
		Scale Factor (Wet)	-1.161E-17	Volts/(quanta/cm^2·sec)
		Offset	0.0009	Volts
13	0	AXIS 1 ANGLE SENSOR - "TILT"	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0418	
		Offset	2.6862	
14	0	AXIS 2 ANGLE SENSOR - "ROLL"	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0415	
		Offset	2.6973	
15	0	Light Scattering Sensor[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
16	0	Fluorometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts

Notes:

1) These sensors are not calibrated at BSI. When applicable, see the manufacturers' specifications.

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 1/24/96 **Form:** 1/25/96
Model Number: PRV-610
Serial Number: 9644
Operator: JCE/LFG
Standard Lamp: 91771 (05/30/95)

Ch	Tag	λ (nm)	Lamp Output	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Max E (Dry)	
SURFACE IRRADIANCE CHANNELS						Irradiance Units: µW/cm²·nm, E = Irradiance		
1	2	380	1.397	0.000205	-0.045775	-0.032918	303.8	
2	2	412	2.411	-0.000888	-0.079748	-0.032704	305.8	
3	2	443	3.701	-0.000036	-0.126600	-0.034201	292.4	
4	2	490	6.159	-0.000291	-0.206142	-0.033424	299.2	
5	2	510	7.302	-0.000277	-0.242508	-0.033173	301.5	
6	2	555	10.041	0.000142	-0.328101	-0.032691	305.9	
7	2	PAR[4]	0.0142	-0.000040	-0.153967	-10.874195	0.920	[4]
8	2	Gnd.[5]	0.000095	Volts				

Calibration Factors: DRY = (Light - Dark)/Lamp Output

NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS (For use with external sensors, only, see manual)

	Irr. Array
Scale	1.061494
Offset	0.000049
Full Scale Voltage	9.4207

FIRMWARE VERSION

	Tag 2
Surface ROM	2106B

Notes:

1. Annual calibration is recommended.
2. Calibrations were made at approximately 20 to 30 °C.
3) Dark values represent a blocking of the calibration source. These values should not be used as the 'offset' when entering values into the calibration file. Use the totally dark sensor values obtained at the temperature where the instrument will be used.
4) PAR irradiance units are µEinsteins/cm²·sec.
5) Typical value(s).