OCTS and SeaWIFS Bio-Optical Algorithm and Product Validation and Intercomparison in U.S. Coastal Waters

Year End Draft Technical Memorandum
For Period of Performance: July 21, 1997 - July 20, 1998

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SCOPE
This year end draft technical memorandum reviews the work performed by Principal Investigators Christopher W. Brown and John C. Brock for the Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project entitled “OCTS and SeaWIFS Bio-Optical Algorithm and Product Validation and Intercomparison in U.S. Coastal Waters” during the period extending from July 21, 1997 to July 20, 1998 in accordance with Article 8 (Reporting Requirements) described in the Statement of Work of Order #S-97879-F.

INTRODUCTION
The successful launch of the National Space Development Agency of Japan (NASDA) Ocean Color and Temperature Sensor (OCTS) in August 1996, and the launch of Orbital Science Corporation’s (OSC) Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) in August 1997 signaled the beginning of a new era for ocean color research and application. These data may be used to remotely evaluate 1) water quality, 2) transport of sediments and adhered pollutants, 3) primary production, upon which commercial
shellfish and finfish populations depend for food, and 4) harmful algal blooms which pose
a threat to public health and economies of affected areas. Several US government agencies
have recently expressed interest in monitoring U.S. coastal waters using optical remote
sensing. This renewed interest is broadly driven by 1) resource management concerns over
the impact of coastward shifts in population and land use on the ecosystems of estuaries,
wetlands, nearshore benthic environments and fisheries, 2) recognition of the need to
understand short time scale global change due to urbanization of sensitive land-margin
ecosystems, and 3) national security issues. Satellite ocean color sensors have the potential
to furnish data at the appropriate time and space scales to evaluate and resolve these
concerns and problems.

In this draft technical memorandum, we outline our progress during the first year of
our SIMBIOS project to evaluate ocean color bio-optical algorithms and products generated
using OCTS and SeaWiFS data in coastal US waters.

PROPOSAL REVIEW

The objectives of this investigation were to validate and compare bio-optical
algorithms and ocean color products using Ocean Color and Temperature Sensor (OCTS)
and Sea-viewing Wide-Field-of-View Sensor (SeaWiFS) data in coastal US waters. The
specific objectives of the funded NOAA SIMBIOS project were to:

1. Collect and compile high quality, in-situ bio-optical observations in US coastal waters.
   This includes rescuing, reformatting, and compiling existing historical biological,
optical, and water quality data;
2. Evaluate and compare the performance of NASDA/OCTS and NASA/SeaWiFS
   standard bio-optical algorithms for the diverse Case I and Case II waters of the coastal
   US and,
3. Validate and compare ocean color products generated using OCTS and SeaWiFS data
   and NASDA and NASA standard bio-optical and atmospheric correction techniques in
   coastal US waters.

With the failure of ADEOS on June 30, 1997, and consequent lack of OCTS data
after this date, we were unable to perform Objectives #2 and #3 activities with OCTS data.

In support of Objective #1, in-situ bio-optical data were collected during five
cruises in diverse U.S. Case 2 and Case 1 coastal waters of the eastern US (Table 1). Two
of these cruises -- Mar97OCC and May97OB -- were conducted before initiation of our
SIMBIOS Project (July 21, 1997). The following bio-optical measurements were collected
using a Biospherical Instrument’s spectroradiometer PRR600s (S/N# 9643) and surface
(PRR610, S/N #9644) on all FY97 cruises: above surface spectral downwelling irradiance,
in-water spectral downwelling irradiance and upwelling radiance, and colored dissolved
organic matter and particulate absorption. Accompanying geophysical measurements
included total suspended solids concentration, and chlorophyll and pigment concentrations
from fluorometric and High Pressure Liquid Chromatography (HPLC) techniques.
Radiometric and HPLC data from four of these five cruises have been submitted to the
SIMBIOS Project for inclusion in the SeaWiFS Bio-optical Archive and Storage System
(SeaBASS). Data reports for cruises Mar97OCC and May97OB have also been submitted
(Appendix A and B), with the reports of the remaining Sep97SAB and Nov97SAB in
preparation (Table 1). The Jul98NAN cruise will be conducted during July 6 - 10, 1998.

In support of bio-optical algorithm validation (Objective #2), SeaWiFS chlorophyll
and pigment concentrations were estimated by applying the standard SeaWiFS algorithms,
t.e. OC2, to remote sensing reflectances computed from in-water optical profiles and above
water, downwelling irradiance measurements. These values were compared against in-situ
measurements of chlorophyll and pigment concentration at 23 stations (Table 2).
Differences ranged from 6% to 639% for OC2 chlorophyll concentration and from 3% to 369% for CZCS pigment concentration during cruises May97OB, Sep97SAB, and Nov97SAR. Preliminary results indicate that the OC2 algorithm overestimates chlorophyll concentration in coastal waters, but performs relatively well in mid-shelf and open ocean waters. This analysis will also be performed for data from cruise Jul98NAN.

Verification of SeaWiFS products was performed in support of Objective #3. High resolution (1 km) HRPT SeaWiFS data acquired at Goddard Space Flight Center (GSFC) or the Coastal Services Center were received and processed to Level-2 products using near-real time meteorological and ozone ancillary data and standard atmospheric correction and product algorithms implemented in the SeaWiFS Data Analysis System (SeaDAS). SeaWiFS-derived chlorophyll-a, CZCS pigment, and K490 of contemporaneous, cloud-free imagery were extracted at ship sampling locations of cruises Sep97SAB and Nov97SAR. The in-situ measurements and satellite-derived estimates of chlorophyll-a and CZCS pigment were compared (Table 3). Preliminary examination indicates that satellite-derived estimates of these two geophysical parameters are from 30% to 300% greater than in-situ measurements. This analysis will also be performed for contemporaneous, cloud-free data collected during the Jul98NAN cruise.

In addition to conducting activities in support of the above Objectives, personnel associated with this SIMBIOS project participated in the first SIMBIOS Science Team Meeting held August 6-8, 1997 in Solomons, MD. Also, two World Wide Web accessible homepages reporting on activities associated with the project were developed, one at NOAA/CSC (http://www.csc.noaa.gov/crs/cruises/) and one at NOAA/ORA (http://orbit17i.nesdis.noaa.gov/~chrisb/docs/SIMBIOS.html).

The following scientific presentations resulted from data collected from this SIMBIOS Project:


CAMPAIGN SUMMARIES

A summary of station date, time, and location for each the four cruises conducted to date for this SIMBIOS project are presented in Table 4. Vertical profiles of in-situ spectral downwelling irradiance and upwelling radiance, and above surface spectral downwelling irradiance at seven channels were collected using a Biospherical Instrument, Inc.'s spectroradiometer PRR600s (S/N# 9643) and surface unit (PRR610, S/N #9644), respectively, on all FY97 cruises. The PRR600s irradiance and radiance sensors were mounted such that the collectors were on the same horizontal plane. PRR data was processed using the Bermuda Bio-Optics Project (BBOP) processing software (Siegel et al., 1995). Accompanying geophysical measurements that were collected included temperature, total suspended solids concentration (TSS), and chlorophyll-a and pigment concentrations. Chlorophyll-a and pigment concentrations were estimated using fluorometric and High Pressure Liquid Chromatography (HPLC) techniques. TSS concentration was measured as described by Parsons et al. (1984).
Radiometric and HPLC data from four of these five cruises have been submitted to the SIMBIOS Project for inclusion in the SeaWiFS Bio-optical Archive and Storage System (SeaBASS) (Table 1). Reports for cruises Mar97OCC and May97OB, detailing all activities and comments of these cruises, are attached in Appendix A and B, respectively. Cruise reports are also available on-line at “http://www.csc.noaa.gov/crs/cruises/SCROL.html”. Similar cruise reports for Sep97SAB, Nov97SAR, and Jul98NAN, that will include a log or record of each cruise, are forthcoming.

Biospherical Instruments, Inc. PRR-600s (S/N#9643) and PRR-610 (S/N#9644) were factory calibrated two times in the last year, i.e. February 10, 1997 and January 7, 1998. Calibration certificates for these instruments since January 23, 1996 are attached in Appendix C.

DELIVERABLE REVIEW

The primary deliverables resulting from our SIMBIOS project, as stated in the funded NOAA proposal, are:

1. A World Wide Web accessible Coastal Bio-optical data Analysis and Storage System (CoBASS), containing both historical B/O/WQ data and newly acquired in-situ bio-optical measurements from disparate U.S. coastal provinces;
2. Quantitative evaluation and comparison of the NASDA and NASA standard in-water algorithms for the seasonally and regionally varying Case 1 and Case 2 waters of the US coastal ocean and large embayments; and

In support of Deliverable #1, radiometric and geophysical data from four of the five FY97 cruises have been submitted to the SIMBIOS Project for inclusion in the SeaWiFS Bio-optical Archive and Storage System (SeaBASS). During the teleconferenced review of our SIMBIOS project on June 3, 1998, SIMBIOS Project representatives agreed this submission to SeaBASS fulfills the stated requirement.

In lieu of extensive in-water radiative transfer modeling to validate algorithm performance, standard SeaWiFS algorithms for chlorophyll and CZCS pigment concentrations were evaluated by generating estimates of these parameters using remote sensing reflectances computed from in-water optical profiles and above water, downwelling irradiance measurements and comparing them with in-situ measurements. This analysis was not performed for the SeaWiFS diffuse attenuation coefficient (K 490) algorithm. A compilation of results from data collected during our FY97 cruises is presented in Table 2. The failure of ADEOS, and consequent lack of OCTS imagery after this date, prevent us from performing this analysis and intersensor algorithm comparison for data collected after on June 30, 1997.

Product validation of SeaWiFS-derived chlorophyll-a and CZCS pigment was performed for appropriate station data collected during cruises Sep97SAB and Nov97SAR (Table 3). Validation for normalized water-leaving radiances was not performed because of oversight. Validation for diffuse attenuation coefficient (K 490) was also not performed because a method of estimate a comparable value from in-situ radiometer measurements was not agreed upon. Both of these deficiencies will be remedied retrospectively over the next year. Unavailability of adequately processed, high resolution OCTS imagery coincident with the Mar97OCC and May97OB cruises prevented validation for similar
OCTS products. If and when appropriate OCTS imagery becomes available, these analyses will be performed.

PLANS FOR NEXT YEAR

We plan to continue fulfilling the stated objectives of our funded proposal in FY98. Tentative dates and locations of cruises planned for the next year are listed in Table 5.

Table 5. Tentative dates and locations of cruises planned for NOAA SIMBIOS Project in FY1998.

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<th>Date</th>
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<th>Affiliation/Ship Name</th>
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<td>Cape Hatteras</td>
</tr>
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At the request of Dr. Charles McClain, personnel from our SIMBIOS Project will assist Dave Eslinger with his SIMBIOS project entitled “High-latitude Intercomparison and Validation Experiment (HIVE)”.

The WWW accessible homepages (mentioned above) on activities associated with the Project will likely be expanded.

ISSUES AND CONCERNS

Insufficient funds were provided to perform standard algorithm evaluation as described in our original proposal. We request that the method of evaluating the standard SeaWiFS algorithms in our contract be changed from analysis by radiative transfer modeling to our present method of applying the standard SeaWiFS algorithms to remote sensing reflectances computed from in-water optical profiles and comparing them with in-situ measurements.

REFERENCES


Table 1. Summary of cruises conducted and dates of relevant data submission to the SIMBIOS Project Office. HPLC = High Pressure Liquid Liquid Chromatography.

<table>
<thead>
<tr>
<th>Cruise Name</th>
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<th>Month of Cruise Report Submission</th>
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* Match up data only
** Projected Submission Date
Table 2. Chlorophyll and CZCS-pigment concentration algorithm evaluation. Latitude and longitude are given in decimal degrees. Diff. = difference (%).

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<th>OC2 Chrom.</th>
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<th>OC2 CZCS Pigment</th>
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Table 3. Chlorophyll and CZCS-pigment concentration product validation. A comparable value of diffuse attenuation coefficient (K 490) was not estimated from \textit{in-situ} radiometric measurements. Latitude and longitude are given in decimal degrees. Diff. = difference (%).

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<tr>
<th>Cruise Name</th>
<th>Date</th>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>In-situ Chl-a</th>
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Appendix A. Report for Cruise MAR97OCC: Onslow Bay.
CSC Technical Report CSC/5-97/001

NOAA CSC/CRS Cruise MAR97OCC: OCTS Calibration Cruise

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May 1997
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.
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

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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 \(-9.9 \times 10^{35}\). 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°C Celsius (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 \(\text{a}\) concentration at the surface at Station 1 was 0.539 \(\mu\)g Chlorophyll \(\text{a/l}\) (Chl \(\text{a/l}\)) (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 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
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Normalized water leaving radiance, as defined by Gordon et al. 1988, was calculated as:

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

where:
- \((L_w)_N\) is the normalized water leaving radiance
- \(\rho\) 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.

![Graph](https://via.placeholder.com/150)

**Figure 7.** Spectra of Normalized Water Leaving Radiance and Remote Sensing Reflectance
### Table 3. Normalized Water Leaving Radiance and Remote Sensing Reflectance

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## V. References


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

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
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East Bounding Coordinate: -76.652
North Bounding Coordinate: 34.433
South Bounding Coordinate: 34.433
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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
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  Place_Keyword: Beaufort, NC
  Place_Keyword: South Atlantic Bight
  Place_Keyword: United States
Time
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  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


Currentness: May 1997

Access Constraints: None

Use Constraints: This data was acquired for scientific research and is applicable for algorithm validation purposes only.

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:

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: Lauren Parker

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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latitude 34 25.975
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sun_position 2
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session_stopped 11:07:29
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cal_date_sfc9644 021097
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cloud_amt 30% (high clouds)
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2 /csc/nepl/coors/bbops/BUILD/calib/unit2_021097.cfl
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A 17
VIII. Appendix B - Calibration Certificates

The following pages contain the calibration history of the PRR600 instrument.
**Biospherical Instruments Inc.**  
**CALIBRATION CERTIFICATE for PRR Spectroradiometer**

**Calibration Date:** 1/23/96  
**Form:** 7/11/96  
**Model Number:** PRR-600S  
**Serial Number:** 9643  
**Operator:** JCE/LFG  
**Standard Lamp:** 91771 (05/30/95)

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<th>Scale</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1419</td>
<td>0.0891</td>
</tr>
</tbody>
</table>

### Pressure/Depth Calibration

<table>
<thead>
<tr>
<th>Scale Factor &quot;a&quot;</th>
<th>Scale Factor &quot;b&quot;</th>
<th>Offset &quot;c&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2874</td>
<td>83.8842</td>
<td>26.9635</td>
</tr>
</tbody>
</table>

### Nominal to Actual Voltage Conversion Factors

<table>
<thead>
<tr>
<th>Irr. Array</th>
<th>Rad. Array</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.076879</td>
<td>1.074227</td>
</tr>
<tr>
<td>0.000208</td>
<td>0.000278</td>
</tr>
<tr>
<td>8.4547</td>
<td>8.3090</td>
</tr>
</tbody>
</table>

### Firmware Versions

<table>
<thead>
<tr>
<th>Tag 0</th>
<th>Tag 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2766B</td>
<td>2043A</td>
</tr>
</tbody>
</table>

**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 μEinstein/cm²·sec.
5. Nominal/Typical value(s).
6. For conversion of area to solid angle, a factor (divisor) of π 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.
**Biospherical Instruments Inc.**

**CALIBRATION CERTIFICATE for PRR Spectroradiometer**

**Calibration Date:** 1/23/96  
**Model Number:** PRV-600S  
**Serial Number:** 9643  
**Operator:** JCE/LFG  
**Form:** 7/11/96

### OPTIONAL CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Ch Tag</th>
<th>Output = (Voltage - Offset)/Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 0</td>
<td>Transmissometer&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>Scale Factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>12 0</td>
<td>Scalar PAR: QSP-200 S/N 4443</td>
<td>Scale Factor (Wet)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1.18E-17</td>
</tr>
<tr>
<td>13 0</td>
<td>AXIS 1 ANGLE SENSOR - &quot;TILT&quot;</td>
<td>Degrees = (Voltage - Offset)/Scale</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scale Factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0418</td>
</tr>
<tr>
<td>14 0</td>
<td>AXIS 2 ANGLE SENSOR - &quot;ROLL&quot;</td>
<td>Degrees = (Voltage - Offset)/Scale</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scale Factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0415</td>
</tr>
<tr>
<td>15 0</td>
<td>Light Scattering Sensor&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>Scale Factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>16 0</td>
<td>Fluorometer&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>Scale Factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Notes:**

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

### DOWNWELLING IRRADIANCE CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Tag</th>
<th>( \lambda ) (nm)</th>
<th>Lamp Irradiance</th>
<th>Immersion Coefficient</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Factor</th>
<th>Dry Factor - Wet</th>
<th>Calibration Light</th>
<th>Voltage (V/\mu W)</th>
<th>Calibration Irradiance Units: ( \mu W/cm^2-nm ), ( E = \text{irradiance} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>360</td>
<td>1.486</td>
<td>0.671</td>
<td>0.000160</td>
<td>0.019050</td>
<td>-0.012927</td>
<td>-0.008677</td>
<td>773.3</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>412</td>
<td>2.559</td>
<td>0.877</td>
<td>0.000200</td>
<td>0.031907</td>
<td>-0.021592</td>
<td>-0.012927</td>
<td>313.4</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>443</td>
<td>3.906</td>
<td>0.682</td>
<td>0.000116</td>
<td>-0.126520</td>
<td>-0.022113</td>
<td>308.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>4</td>
<td>490</td>
<td>6.483</td>
<td>0.890</td>
<td>0.000111</td>
<td>-0.218429</td>
<td>-0.023280</td>
<td>296.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>5</td>
<td>510</td>
<td>7.683</td>
<td>0.694</td>
<td>0.000108</td>
<td>-0.250415</td>
<td>-0.022617</td>
<td>306.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>555</td>
<td>10.536</td>
<td>0.701</td>
<td>0.000045</td>
<td>-0.345228</td>
<td>-0.023010</td>
<td>304.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>7</td>
<td>PAR(^{4})</td>
<td>0.0152</td>
<td>0.686</td>
<td>0.000337</td>
<td>-0.200664</td>
<td>-13.195777</td>
<td>-0.050741</td>
<td>0.758 (^{3})</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>8</td>
<td>Gnd.(^{5})</td>
<td>0.000309</td>
<td>0.000309</td>
<td>0.000309</td>
<td>0.000309</td>
<td>0.000309</td>
<td>0.000309</td>
<td>0.000309</td>
<td></td>
</tr>
</tbody>
</table>

**Calibration Factor: WET = (Light - Dark x Immersion Coefficient) / Lamp Output**

### UPWELLING RADIANCE CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Tag</th>
<th>( \lambda ) (nm)</th>
<th>Lamp Radiance @ 60 cm</th>
<th>Immersion Coefficient</th>
<th>Plaque Reflectivity</th>
<th>Radiance(^{6})</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Blocked(^{3})</th>
<th>Calibration Light</th>
<th>Voltage (V/\mu W)</th>
<th>Calibration Radiance Units: ( \mu W/cm^2-nm-sr ), ( L = \text{radiance} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>360</td>
<td>1.308</td>
<td>1.765</td>
<td>0.985</td>
<td>0.985</td>
<td>0.000133</td>
<td>0.000133</td>
<td>-0.029229</td>
<td>-0.151959</td>
<td>65.8</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>412</td>
<td>2.275</td>
<td>1.758</td>
<td>0.985</td>
<td>0.985</td>
<td>0.002009</td>
<td>0.000202</td>
<td>-0.017559</td>
<td>-0.509911</td>
<td>19.8</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>443</td>
<td>3.514</td>
<td>1.752</td>
<td>0.984</td>
<td>0.984</td>
<td>0.00108</td>
<td>0.000106</td>
<td>-0.090184</td>
<td>-1.005825</td>
<td>9.9</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>490</td>
<td>5.911</td>
<td>1.745</td>
<td>0.984</td>
<td>0.984</td>
<td>0.00122</td>
<td>0.000106</td>
<td>-0.090184</td>
<td>-1.005825</td>
<td>9.9</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>510</td>
<td>7.038</td>
<td>1.743</td>
<td>0.984</td>
<td>0.984</td>
<td>0.00124</td>
<td>0.000063</td>
<td>-0.255677</td>
<td>-1.755312</td>
<td>5.7</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>555</td>
<td>9.746</td>
<td>1.736</td>
<td>0.984</td>
<td>0.984</td>
<td>0.000072</td>
<td>0.000072</td>
<td>-0.392216</td>
<td>-1.555169</td>
<td>6.4</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>863</td>
<td>16.755</td>
<td>1.730</td>
<td>0.984</td>
<td>0.984</td>
<td>0.000277</td>
<td>0.000277</td>
<td>-0.392216</td>
<td>-1.555169</td>
<td>6.4</td>
</tr>
</tbody>
</table>

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

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

### TEMPERATURE\(^{7}\)

<table>
<thead>
<tr>
<th>Scale</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1419</td>
<td>0.0801</td>
</tr>
</tbody>
</table>

### PRESSURE/DEPTH\(^{8}\)

| Scale Factor "a" | 0.9374 |
| Scale Factor "b" | 83.3842 |
| Offset "c" | 28.9235 |

### NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS\(^{9}\)

**Irr. Array**

| Scale Factor | 1.057679 | 1.074227 |
| Offset | 0.000206 | 0.000279 |
| Full Scale Voltage | 9.4547 | 9.3090 |

**Rad. Array**

### FIRMWARE VERSIONS

<table>
<thead>
<tr>
<th>Underwater ROM</th>
<th>Tag 0</th>
<th>Tag 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>27659</td>
<td>2043A</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Annual calibration is recommended.
2. Calibrations were performed at approximately 20°C 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 \( \mu \text{Einsteins/cm}^2 \text{sec} \).
5. Nominal/Typical value(s).
6. For conversion of area to solid angle, a factor (divisor) of \( 4\pi \) is incorporated.
7. Water temperature sensor.
8. A change in depth of 1 meter in seawater corresponds to approximately 1 dbar change in pressure.
9. These channels/sensors were not evaluated during this service period.
## CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

### OPTIONAL CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Transmissometer&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Output = (Voltage - Offset)/Scale</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 0</td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Scalar PAR: QSP-200 S/N 4443&lt;sup&gt;2)&lt;/sup&gt;</th>
<th>Output = (Voltage - Offset)/Scale</th>
<th>Scale Factor (Wet)</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 0</td>
<td>quanta/(cm²·sec) = (Voltage - Offset)/Scale</td>
<td>-1.161E-17 Volt/(quanta/cm²·sec)</td>
<td>0.0009 Volts</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>AXIS 1 ANGLE SENSOR - &quot;TILT&quot;&lt;sup&gt;3)&lt;/sup&gt;</th>
<th>Degrees = (Voltage - Offset)/Scale</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 0</td>
<td></td>
<td>0.0418</td>
<td>2.6862</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>AXIS 2 ANGLE SENSOR - &quot;ROLL&quot;&lt;sup&gt;3)&lt;/sup&gt;</th>
<th>Degrees = (Voltage - Offset)/Scale</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 0</td>
<td></td>
<td>0.0415</td>
<td>2.6973</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Light Scattering Sensor&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Output = (Voltage - Offset)/Scale</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 0</td>
<td></td>
<td>1.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Fluorometer&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Output = (Voltage - Offset)/Scale</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 0</td>
<td></td>
<td>1.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

**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  

Calibration Date: 2/10/97  
Form: 2/18/97  

Model Number: PRV-600S  
Serial Number: 9643  
Operator: TMM  

Standard Lamp: 94531 (01/02/97) for Irradiance, 94532 (10/11/95) for Radiance.

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>λ (nm)</th>
<th>Irradiance</th>
<th>Immersion Coefficient</th>
<th>Calibration</th>
<th>Calibration</th>
<th>Calibration</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Voltage - Dark ( \text{Watt/m}^2 \text{sr} )</td>
<td>Voltage - Dry Factor - Wet ( \text{Watt/m}^2 \text{sr} )</td>
<td>Voltage - Wet ( \text{Watt/m}^2 \text{sr} )</td>
<td>Max E (Dry) ( \text{Watt/m}^2 \text{sr} )</td>
</tr>
</tbody>
</table>

**UPWELLING IRRADIANCE CHANNELS**  
Irradiance Units: \( \mu \text{W/cm}^2 \text{nm} \text{sr} \), E \( = \text{Irradiance} \)

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>λ (nm)</th>
<th>Lamp Distance Factor</th>
<th>Plaque Reflectivity</th>
<th>Radiance ( \text{Watt/m}^2 \text{nm} \text{sr} )</th>
<th>Calibration Factor ( \text{Watt/m}^2 \text{nm} \text{sr} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lamp Output ( \text{Watt/m}^2 \text{nm} \text{sr} ) x Plaque Reflectivity x Lamp Distance Factor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Gnd.**  

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>λ (nm)</th>
<th>Lamp Distance Factor</th>
<th>Plaque Reflectivity</th>
<th>Radiance ( \text{Watt/m}^2 \text{nm} \text{sr} )</th>
<th>Calibration Factor ( \text{Watt/m}^2 \text{nm} \text{sr} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lamp Output ( \text{Watt/m}^2 \text{nm} \text{sr} ) x Plaque Reflectivity x Lamp Distance Factor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DOWNWELLING IRRADIANCE CHANNELS**  
Irradiance Units: \( \mu \text{W/cm}^2 \text{nm} \text{sr} \), E \( = \text{Irradiance} \)

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>λ (nm)</th>
<th>Lamp Distance Factor</th>
<th>Plaque Reflectivity</th>
<th>Radiance ( \text{Watt/m}^2 \text{nm} \text{sr} )</th>
<th>Calibration Factor ( \text{Watt/m}^2 \text{nm} \text{sr} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lamp Output ( \text{Watt/m}^2 \text{nm} \text{sr} ) x Plaque Reflectivity x Lamp Distance Factor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 \( \mu \text{Einstein/cm}^2 \text{sec} \).  
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:** 2/10/97  
**Form:** 2/18/97

**Model Number:** PRV-600S  
**Serial Number:** 9643  
**Operator:** TMM

### OPTIONAL CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Description</th>
<th>Scale Factor</th>
<th>Offset</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Transmissometer&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1.0 Volts/Volt</td>
<td>0.0 Volts</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Scalar PAR: QSP-200 S/N 4443</td>
<td>-1.020E-17</td>
<td>0.0009 Volts</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>AXIS 1 ANGLE SENSOR - &quot;TILT&quot;&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.0418</td>
<td>2.6882</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>AXIS 2 ANGLE SENSOR - &quot;ROLL&quot;&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.0416</td>
<td>2.6873</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Light Scattering Sensor&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1.0 Volts/Volt</td>
<td>0.0 Volts</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Fluorometer&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1.0 Volts/Volt</td>
<td>0.0 Volts</td>
<td></td>
</tr>
</tbody>
</table>

**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.
Appendix B. Report for Cruise MAY97OB: Onslow Bay and Pamlico Sound.
NOAA NMFS Cruise MAY97OB:
Onslow Bay and Pamlico Sound Cruise

Ajit Subramaniam
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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 Ocean Color and Temperature Sensor (OCTS) on board the Advanced Earth Observing Satellite (ADEOS). 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. Scientists from the Southeast Fisheries Science Center at NOAA/National Marine Fisheries Service undertook two one-day cruises out of Beaufort, North Carolina. Five stations were occupied on May 5, 1997 in Onslow Bay and four stations were occupied on May 8, 1997 in Pamlico Sound respectively. In-situ measurements of temperature, spectral downwelling irradiance, and spectral upwelling radiance were made along with above surface spectral downwelling irradiance. Surface chlorophyll $a$ concentration, phytoplankton pigment, and total suspended sediments were also measured.
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Acknowledgments

We thank Captains Doug Willis and the crew of the R/V Onslow Bay and the R/V Chipman respectively for assistance provided. A NOAA Coastal Ocean Program Grant to Dr. Tester and Dr. Rick 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. Scientists use various algorithms 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 Marine Fisheries Service (NMFS) Southeast Fisheries Science Center undertook two one-day cruises in Onslow Bay and Pamlico Sound.

II. Objectives

The objectives of this cruise were to obtain sub-surface downwelling irradiance, upwelling radiance, chlorophyll pigment concentration and total suspended sediment solids concentration in coastal waters. The remote sensing reflectance calculated from these measurements were used to evaluate and validate the SeaWiFS OC2 algorithm.

III. Methods

A. Sampling Location

Five stations (Stations 5C-5G) were occupied on 5 May 1997, and four stations (Stations 8A-8G) were occupied on 8 May 1997 to make optical profile measurements in the water column (Figure 1). Surface samples were also acquired at this location for total suspended solids (TSS) concentration and for chlorophyll analysis by fluorometric and High-Pressure Liquid Chromatography (HPLC) techniques.

B. Sampling Platform

The R/V Onslow Bay, belonging to the NOAA/National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center, was used on 5 May 1997. The R/V Chipman, also belonging to NOAA/NMFS, was used on 8 May 1997.

C. Sample Collection Methods Summary

A 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 chlorophyll analysis.
Figure 1. Location of stations

Figure 2. Deployment of the PRR600s
<table>
<thead>
<tr>
<th>Date</th>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Time</th>
<th>Total Depth (m)</th>
<th>Air Temperature (°C)</th>
<th>ChlF VolFilt (ml)</th>
<th>HPLC VolFilt (ml)</th>
<th>Ap VolFilt (ml)</th>
<th>TSS VolFilt (ml)</th>
<th>PRR File name</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/5/97</td>
<td>5C</td>
<td>34.278</td>
<td>-76.068</td>
<td>14:00</td>
<td>20</td>
<td>20</td>
<td>1000</td>
<td>2000</td>
<td>1000</td>
<td>2000</td>
<td>P970505C</td>
</tr>
<tr>
<td>5/5/97</td>
<td>5D</td>
<td>34.305</td>
<td>-76.280</td>
<td>15:20</td>
<td>18</td>
<td>19</td>
<td>1000</td>
<td>1000</td>
<td>750</td>
<td>2000</td>
<td>P970505D</td>
</tr>
<tr>
<td>5/5/97</td>
<td>5E</td>
<td>34.378</td>
<td>-76.462</td>
<td>16:20</td>
<td>12</td>
<td>19</td>
<td>500</td>
<td>750</td>
<td>400</td>
<td>2000</td>
<td>P970505E</td>
</tr>
<tr>
<td>5/5/97</td>
<td>5F</td>
<td>34.446</td>
<td>-76.622</td>
<td>17:15</td>
<td>19</td>
<td>19</td>
<td>300</td>
<td>1000</td>
<td>300</td>
<td>1500</td>
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</tr>
<tr>
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<td>5G</td>
<td>34.552</td>
<td>-76.650</td>
<td>18:40</td>
<td></td>
<td></td>
<td>200</td>
<td>1000</td>
<td>200</td>
<td>1500</td>
<td>P970505G</td>
</tr>
<tr>
<td>5/8/97</td>
<td>8A</td>
<td>35.247</td>
<td>-76.009</td>
<td>12:40</td>
<td>6</td>
<td>20</td>
<td>100</td>
<td>200</td>
<td>150</td>
<td>500</td>
<td>P970508A</td>
</tr>
<tr>
<td>5/8/97</td>
<td>8C</td>
<td>35.197</td>
<td>-76.084</td>
<td>13:20</td>
<td>13</td>
<td>20</td>
<td>100</td>
<td>200</td>
<td>150</td>
<td>500</td>
<td>P970508C</td>
</tr>
<tr>
<td>5/8/97</td>
<td>8E</td>
<td>35.166</td>
<td>-76.168</td>
<td>13:40</td>
<td>22</td>
<td>100</td>
<td>200</td>
<td>150</td>
<td>500</td>
<td>500</td>
<td>P970508E</td>
</tr>
<tr>
<td>5/8/97</td>
<td>8G</td>
<td>35.083</td>
<td>-76.251</td>
<td>14:10</td>
<td>7</td>
<td>20</td>
<td>100</td>
<td>200</td>
<td>150</td>
<td>500</td>
<td>P970508G</td>
</tr>
</tbody>
</table>
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 [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 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

<table>
<thead>
<tr>
<th>Channel No.</th>
<th>PRR600s Downwelling Light Sensor</th>
<th>PRR600s Upwelling Light Sensor</th>
<th>PRR610 PAR Light Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>380 nm</td>
<td>380 nm</td>
<td>380 nm</td>
</tr>
<tr>
<td>2</td>
<td>412 nm</td>
<td>412 nm</td>
<td>412 nm</td>
</tr>
<tr>
<td>3</td>
<td>443 nm</td>
<td>443 nm</td>
<td>443 nm</td>
</tr>
<tr>
<td>4</td>
<td>490 nm</td>
<td>490 nm</td>
<td>490 nm</td>
</tr>
<tr>
<td>5</td>
<td>510 nm</td>
<td>510 nm</td>
<td>510 nm</td>
</tr>
<tr>
<td>6</td>
<td>555 nm</td>
<td>555 nm</td>
<td>555 nm</td>
</tr>
<tr>
<td>7</td>
<td>PAR</td>
<td>683 nm</td>
<td>PAR</td>
</tr>
</tbody>
</table>

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 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 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 -9.9x10^35. 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

A. Bottle Samples

The analyses of the bottle samples showed that the total suspended sediment concentrations were very high, especially inside Pamlico Sound. The chlorophyll concentrations were low in contrast, indicating that the optical properties of these waters may be dominated by sediments.

<table>
<thead>
<tr>
<th>Table 3. Pigment Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>5/5/97</td>
</tr>
<tr>
<td>5/5/97</td>
</tr>
<tr>
<td>5/5/97</td>
</tr>
<tr>
<td>5/5/97</td>
</tr>
<tr>
<td>5/5/97</td>
</tr>
<tr>
<td>5/8/97</td>
</tr>
<tr>
<td>5/8/97</td>
</tr>
<tr>
<td>5/8/97</td>
</tr>
<tr>
<td>5/8/97</td>
</tr>
</tbody>
</table>

B. Optical data

The optical data were collected in rather shallow waters (Table 1) and the profiles themselves never extended below 18m, often shallower than 10 m. The profiles of downwelling irradiance, upwelling radiance, and PAR are shown in Appendix A (Figures A.1.a – A.18.a). Figures A.1.b – A.18.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 (Es) 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 Es and is shown in Table 4. The large change in Es at stations 5D and 5F appear to be due to a shadow on sensor rather than due to clouds. The relatively large Es at station 5G seems to be due to the very low sun angle at 6:40 PM when the measurements were made. Tilt or roll of greater than 10° do not allow for the robust measurement of downwelling irradiance or upwelling radianace. Profiles 5C1, 5D2, 5E1, 5G2, and 8G2 were not used for algorithm evaluation because they were contaminated by factors such as large tilts or rolls, ship shadow contamination, etc.

Table 4. Summary of Optical Profiles

<table>
<thead>
<tr>
<th>Profile</th>
<th>Depth of First Measurement</th>
<th>Max. C.V Of Es</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>P970505C1</td>
<td>1.65</td>
<td>0.8%</td>
<td>K changes at 4 m, Ed increases with depth</td>
</tr>
<tr>
<td>P970505C2</td>
<td>0.92</td>
<td>2.1%</td>
<td>Uniform, good cast</td>
</tr>
<tr>
<td>P970505D1</td>
<td>1.24</td>
<td>38.9%</td>
<td>Underwater cast good, shadow over surface sensor</td>
</tr>
<tr>
<td>P970505D2</td>
<td>0.74</td>
<td>45.0%</td>
<td>Underwater cast good, shadow over surface sensor</td>
</tr>
<tr>
<td>P970505E1</td>
<td>2.83</td>
<td>2.2%</td>
<td>Mostly uniform cast, discard top 3.8 m</td>
</tr>
<tr>
<td>P970505E2</td>
<td>0.87</td>
<td>5.8%</td>
<td>Uniform, good cast</td>
</tr>
<tr>
<td>P970505F1</td>
<td>2.29</td>
<td>43.0%</td>
<td>Underwater cast good, large change in surface sensor</td>
</tr>
<tr>
<td>P970505F2</td>
<td>0.78</td>
<td>2.0%</td>
<td>Uniform, good cast</td>
</tr>
<tr>
<td>P970505G1</td>
<td>1.27</td>
<td>8.3%</td>
<td>Uniform, good cast. Low sun angle</td>
</tr>
<tr>
<td>P970505G2</td>
<td>0.54</td>
<td>10.0%</td>
<td>Large increase in Ed, Lu near surface. Tilt and Roll &gt; 15°</td>
</tr>
<tr>
<td>P970508A1</td>
<td>0.91</td>
<td>1.4%</td>
<td>Uniform cast, shallow</td>
</tr>
<tr>
<td>P970508A2</td>
<td>0.64</td>
<td>0.5%</td>
<td>Uniform cast, shallow</td>
</tr>
<tr>
<td>P970508C1</td>
<td>0.92</td>
<td>0.9%</td>
<td>Very shallow cast. 0.8-1.7m only</td>
</tr>
<tr>
<td>P970508C2</td>
<td>0.81</td>
<td>0.6%</td>
<td>Very shallow cast. 0.8-2.3m only</td>
</tr>
<tr>
<td>P970508E1</td>
<td>0.98</td>
<td>0.9%</td>
<td>Uniform cast for wavelengths &gt; 443 nm</td>
</tr>
<tr>
<td>P970508E2</td>
<td>0.51</td>
<td>0.1%</td>
<td>Uniform cast for wavelengths &gt; 443 nm</td>
</tr>
<tr>
<td>P970508G1</td>
<td>0.80</td>
<td>0.2%</td>
<td>Uniform, good cast</td>
</tr>
<tr>
<td>P970508G2</td>
<td>0.58</td>
<td>1.2%</td>
<td>Uniform, good cast large Roll near surface</td>
</tr>
</tbody>
</table>

Algorithm Evaluation

The downwelling irradiance and upwelling radianace 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
The upwelling radiance was propagated through water-air interface using a factor of 0.544 (SeaBAM Tech memo). The above water (Ed+) downwelling irradiance and upwelling radiance are shown in Table 5 (Ed+(λ) and Lu+(λ) respectively). The above water downwelling irradiance measured by the reference sensor mounted on the ship are also shown (Esλ) along with the coefficient of variation of this measurement (EsλErr). The difference between the measured downwelling irradiance (Es) and the calculated downwelling irradiance (Ed+) was calculated and shown in Table 5 (dsλ). The remote sensing reflectance (Rrsλ) was calculated using either Es or Ed+, which ever was more appropriate. The SeaWiFS OC2 algorithm (SeaBAM Tech memo) was then used to calculate the satellite estimates of chlorophyll a and CZCS pigment. The ratios of satellite derived to measured quantities for chlorophyll a and CZCS pigment are also shown in Table 5.

<table>
<thead>
<tr>
<th>Station</th>
<th>5C</th>
<th>5D</th>
<th>5E</th>
<th>5F</th>
<th>5F</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time GMT</td>
<td>18:00</td>
<td>19:15</td>
<td>20:15</td>
<td>22:10</td>
<td>22:10</td>
<td>23:40</td>
</tr>
<tr>
<td>Latitude</td>
<td>34.278</td>
<td>34.305</td>
<td>34.378</td>
<td>34.446</td>
<td>34.446</td>
<td>34.552</td>
</tr>
<tr>
<td>Longitude</td>
<td>-76.068</td>
<td>-76.280</td>
<td>-76.462</td>
<td>-76.622</td>
<td>-76.622</td>
<td>-76.650</td>
</tr>
<tr>
<td>TSS mg/L</td>
<td>3.75</td>
<td>5.75</td>
<td>6.25</td>
<td>8.00</td>
<td>8.00</td>
<td>13.67</td>
</tr>
<tr>
<td>ChlF ug/l</td>
<td>0.229</td>
<td>0.256</td>
<td>0.499</td>
<td>0.269</td>
<td>0.269</td>
<td>0.433</td>
</tr>
<tr>
<td>Chla HPLC</td>
<td>0.138</td>
<td>0.151</td>
<td>0.259</td>
<td>0.145</td>
<td>0.145</td>
<td>0.249</td>
</tr>
<tr>
<td>Ed+380</td>
<td>71.2525</td>
<td>57.9345</td>
<td>55.8263</td>
<td>38.6623</td>
<td>32.2810</td>
<td>9.6688</td>
</tr>
<tr>
<td>Ed+412</td>
<td>153.0960</td>
<td>89.7019</td>
<td>92.7574</td>
<td>74.6242</td>
<td>55.7885</td>
<td>18.0764</td>
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<tr>
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<td>164.0670</td>
<td>104.7570</td>
<td>113.7230</td>
<td>105.5370</td>
<td>67.8250</td>
<td>23.5997</td>
</tr>
<tr>
<td>Ed+490</td>
<td>139.4370</td>
<td>128.5790</td>
<td>140.8620</td>
<td>130.8590</td>
<td>76.3379</td>
<td>26.9401</td>
</tr>
<tr>
<td>Ed+510</td>
<td>153.6910</td>
<td>169.2120</td>
<td>138.1630</td>
<td>129.8870</td>
<td>76.5869</td>
<td>26.8790</td>
</tr>
<tr>
<td>Ed+555</td>
<td>162.0340</td>
<td>122.3720</td>
<td>121.1700</td>
<td>131.8190</td>
<td>77.4048</td>
<td>26.0929</td>
</tr>
<tr>
<td>Lu+380</td>
<td>0.8738</td>
<td>0.5479</td>
<td>0.2631</td>
<td>0.2785</td>
<td>0.2634</td>
<td>0.0639</td>
</tr>
<tr>
<td>Lu+412</td>
<td>1.2947</td>
<td>1.0677</td>
<td>0.5910</td>
<td>0.5690</td>
<td>0.5495</td>
<td>0.1576</td>
</tr>
<tr>
<td>Lu+443</td>
<td>1.4229</td>
<td>1.3529</td>
<td>0.8888</td>
<td>0.7674</td>
<td>0.7504</td>
<td>0.2365</td>
</tr>
<tr>
<td>Lu+490</td>
<td>1.3547</td>
<td>1.5615</td>
<td>1.3460</td>
<td>0.9808</td>
<td>0.9676</td>
<td>0.3525</td>
</tr>
<tr>
<td>Lu+510</td>
<td>0.9839</td>
<td>1.1747</td>
<td>1.2111</td>
<td>0.7811</td>
<td>0.7504</td>
<td>0.3173</td>
</tr>
<tr>
<td>Lu+555</td>
<td>0.5018</td>
<td>0.6169</td>
<td>0.8648</td>
<td>0.4509</td>
<td>0.4216</td>
<td>0.2264</td>
</tr>
<tr>
<td>Lu+683</td>
<td>0.0392</td>
<td>0.0398</td>
<td>0.0738</td>
<td>0.0400</td>
<td>0.0362</td>
<td>0.0270</td>
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<tr>
<td>Es380</td>
<td>83.0804</td>
<td>54.0220</td>
<td>52.4726</td>
<td>31.9462</td>
<td>39.4985</td>
<td>12.2564</td>
</tr>
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<td>128.1168</td>
<td>80.9772</td>
<td>82.2762</td>
<td>49.2976</td>
<td>64.1512</td>
<td>20.7618</td>
</tr>
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<td>Es443</td>
<td>150.2051</td>
<td>92.4450</td>
<td>96.9226</td>
<td>57.0165</td>
<td>76.7487</td>
<td>25.7060</td>
</tr>
<tr>
<td>Es490</td>
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<td>Time GMT</td>
<td>Latitude</td>
<td>Longitude</td>
<td>TSS mg/L</td>
<td>ChlF ug/l</td>
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**Values:**
- Es510Err: 2.0% 37.0% 5.8% 39.6% 1.9% 6.8%
- Es555Err: 2.1% 38.9% 5.8% 43.2% 2.0% 8.3%
- ds380: 11% -11% 15% 18%
- ds412: -24% -17% 10% 9%
- ds443: -14% -22% 8% 5%
- ds490: 10% -39% 6% 6%
- ds510: 2% -34% 8% 9%
- ds555: -6% -19% 7% 13%
- Rs490: 0.0045 0.0088 0.0069 0.0088 0.0062 0.0064
- Rs555: 0.0017 0.0036 0.0044 0.0041 0.0026 0.0039
- OC2-Chla: 0.2204 0.2594 0.6679 0.3403 0.2858 0.6023
- CZCS Pig: 0.3044 0.3571 0.9022 0.4660 0.3926 0.8154
- MeasChla: 0.138 0.151 0.259 0.145 0.145 0.249
- sat/meas: 1.60 1.71 2.58 2.34 1.96 2.42
- MeasPig: 0.229 0.256 0.499 0.269 0.269 0.433
- sat/meas: 1.33 1.40 1.81 1.73 1.46 1.88
- Station: 8A 8A 8C 8C 8E 8E 8G
- Latitude: 35.247 35.197 35.197 35.166 35.166 35.083
- Longitude: -76.009 -76.009 -76.009 -76.009 -76.009 -76.009
- TSS mg/L: 18 18 18 18 14 14 9
- Chla HPLC: 2.612 2.612 1.990 1.990 1.803 1.803 2.115
- Ed+380: 329.6600 15.3218 241.1810 267.9270
- Ed+412: 388.4960 347.9610 78.4023 259.1750 397.9440
- Ed+443: 318.4070 300.8500 141.9910 234.4350 425.0650 439.0940
- Ed+490: 262.8080 295.0300 165.3600 204.4010 229.1140 211.2920 301.5530
- Ed+510: 276.5950 301.4110 170.1470 190.5200 217.2920 203.4000 267.6930
- Lu+380: 0.1638 0.8622 0.0198 0.2214 0.1496
- Lu+412: 1.2028 1.5278 0.1863 0.7602 1.0684
- Lu+443: 1.5681 1.7888 0.5517 1.1440 1.1701 1.1627 1.3659
- Lu+490: 2.3009 2.4193 1.4105 2.0313 1.9744 1.9848 2.2159
- Lu+510: 2.6577 2.8237 1.4901 2.4530 2.3679 2.4354 2.5752
- Lu+683: 1.3768 1.3513 0.9825 1.2106 1.2053 1.2251 1.3551
- Es+380: 75.3898 75.1179 80.9012 80.6914 79.3116 79.1145 76.7443
- Es+412: 119.1203 121.7287 123.9480 123.5525 121.2498 120.8742 117.6106
- Es+443: 142.2725 146.4432 145.2907 144.7905 141.5946 141.1014 137.6481
- Es+490: 155.3894 159.9576 154.5753 153.9763 150.7009 150.2226 146.2744
- Es+510: 158.4342 162.5434 155.3863 154.7278 151.9258 151.5209 146.7285
- Es+555: 156.0523 160.7882 151.6197 150.9293 148.6836 148.3307 143.3869
- Es380Err: 0.6% 0.4% 0.5% 0.4% 0.6% 0.2% 0.2%
- Es412Err: 0.8% 0.4% 0.6% 0.5% 0.7% 0.1% 0.2%
- Es443Err: 1.0% 0.4% 0.6% 0.5% 0.7% 0.1% 0.2%
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**Summary**

The waters of Onslow Bay and especially Pamlico Sound are sediment dominated and can be considered typical Case II waters. The OC2 algorithms over-estimate the chlorophyll and CZCS pigment concentrations by a factor of at least 1.5 and up to 15, showing that this algorithm has to be greatly refined to be applicable to shallow coastal sediment dominated waters.

**V. References**


VI. Metadata

The metadata, including point of contacts, parameters measured, and measurement methods for the cruise are given below.

A. Core Documentation

Identification Information
Citation
  Citation Information
    Originator: National Oceanic and Atmospheric Administration Coastal Services Center
    Publication Date: 1998
    Title: NOAA NMFS Cruise MAY97OB: Onslow Bay and Pamlico Sound Cruise
    Online Linkage: http://www.csc.noaa.gov/crs/cruises/may97ob/index.html

Description
  Abstract: See Abstract, page iii
  Purpose: See Objectives, page 1

Supplemental Information:
  Start Date: 19970505
  Stop Date: 19970505
  Preview: http://www.csc.noaa.gov/crs/cruises/SCROL.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
Theme
Theme_Keyword_Thesaurus: None
Theme_Keyword: oceanography
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: Pamlico Sound
Place_Keyword: Beaufort, NC
Place_Keyword: South Atlantic Bight
Place_Keyword: United States

Time
Temporal_Keyword: Spring
Temporal_Keyword: May, 1997

Parameters measured
Parameter_Keyword: spectral downwelling irradiance
Parameter_Keyword: spectral upwelling radiance
Parameter_Keyword: temperature
Parameter_Keyword: total suspended solids
Parameter_Keyword: chlorophyll pigment
Parameter_Keyword: phytoplankton pigments

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: NOAA Science Center, Room 711B
Address: E/RA3
Address: 4700 Silver Hill Road, Stop 9910
City: Washington
State: District of Columbia
Postal_Code: 20233-9910
B. Citation Information


Currentness: February 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.

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:
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

Phytoplankton pigment measurements:
Analyst: Pat Tester
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: Lauren Parker
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.

<cruise_info>
filename p970313a
date 03-13-1997
day_of_year 72
day_since_010192 1899
file_created 11:03:50
cruise station 1
position 76 39.137 34 25.975
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
cal_date_uw9643 021097
cal_date_sfc9644 021097
downcast_ended 11:07:25.738 337
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)
winds_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
castid index 1 prr_record 1depth
p970313a.dtl 9.9000000e+01 9.9000000e+01 1.9616880e+00
p970313a.db1 1.7900000e+02 1.7900000e+02 1.4350000e+01
p970313a.ub1 2.2900000e+02 2.2900000e+02 1.4603000e+01
p970313a.ut1 3.2900000e+02 3.2900000e+02 8.3759400e-02
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led412 0 -0.021345 0.000551
led443 0 -0.021874 0.000189
led490 0 -0.02298 0.000282
led510 0 -0.022313 0.000171
led555 0 -0.022801 0.00048
lpar 0 -9.05594 0.000371
ledgnd 0 1 0
ltemp 0 0.1421 0.0889
ldepth 0 9.38300e-01 8.31773e+01 2.65899e+01 0.9383 83.1773 26.9099 0 0
ltlt 0 0.04178 2.68617
lroll 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
3es380 0 -0.031424 0.00024
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-d-1temp
m-d-d-1temp
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ptbin_0.5
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kc-1ed412
kc-1ed443
kc-1ed490
kc-1ed510
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VIII. Appendix B - Calibration Certificates

The following pages contain the calibration history of the PRR600 instrument.
Figure A.1.a - Station C Downcast

PAR (μEinstines/cm²/sec)

Downwelling Irradiance (μW/cm²/nm)

Radiance (μW/cm²/nm/sr)
Figure A.1.b - Station C1 Downcast

Diffuse Attenuation Coefficient ($k\lambda$)
Figure A.2.a - Station C Upcast

PAR (\(\mu\)Einstein/cm\(^2\)/sec)

Downwelling Irradiance (\(\mu\)W/cm\(^2\)/nm)

Radiance (\(\mu\)W/cm\(^2\)/nm/sr)
Figure A.2.b - Station C Upcast

Tilt (°)

Roll (°)

Diffuse Attenuation Coefficient (kλ)

Depth (m)

Diffuse Attenuation Coefficient (kλ)

Depth (m)

Diffuse Attenuation Coefficient

kEd380 vs Depth
kEd412 vs Depth
kEd443 vs Depth
kEd490 vs Depth
kEd510 vs Depth
kEd555 vs Depth
Figure A.3.a - Station D Downcast

PAR (µEinst/m²·sec)

Downwelling Irradiance (µW/cm²/nm)

Radiance (µW/cm²/nm/sr)
Figure A.3.b - Station D Downcast

Diffuse Attenuation Coefficient ($k_{\alpha}$)
Figure A.4.a - Station D Upcast

PAR (μEinsteins/cm²/sec)

Downwelling Irradiance (μW/cm²/nm)

Radiance (μW/cm²/nm/sr)
Figure A.4.b - Station D Upcast

- Tilt (°)

--- Roll (°)

Diffuse Attenuation Coefficient (kλ)

- kEd380 vs Depth
- kEd412 vs Depth
- kEd443 vs Depth
- kEd490 vs Depth
- kEd510 vs Depth
- kEd555 vs Depth
Figure A.5.a - Station E Downcast

PAR (μEinstein/cm²/sec)

Depth (m)

0.01
0
2
4
6
8
10
12
14
16
18
20

Downwelling Irradiance (μW/cm²/nm)

Ed380 vs Depth
Ed412 vs Depth
Ed443 vs Depth
Ed490 vs Depth
Ed510 vs Depth
Ed555 vs Depth
Es443 vs Depth
EdPAR vs Depth

Radiance (μW/cm²/nm/sr)

Depth (m)

0.01
0.1
1

Lu380 vs Depth
Lu412 vs Depth
Lu443 vs Depth
Lu490 vs Depth
Lu510 vs Depth
Lu555 vs Depth
Lu683 vs Depth

Lu683 vs Depth
Figure A.5.b - Station E Upcast

Tilt (°)

Roll (°)

Diffuse Attenuation Coefficient (kλ)
Figure A.6.a - Station E Upcast

PAR (μEinstein/cm²/sec)

Downwelling Irradiance (μW/cm²/nm)

Radiance (μW/cm²/nm/sr)
Figure A.6.b - Station E Upcast

Diffuse Attenuation Coefficient ($k_\lambda$)
Figure A.7.a - Station F Downcast

PAR (µEinsteins/cm²/sec)

Downwelling Irradiance (µW/cm²/nm)

Radiance (µW/cm²/nm/sr)
Figure A.7.b - Station F Downcast

Diffuse Attenuation Coefficient ($k_{\lambda}$)
Figure A.8.a - Station F Upcast

PAR (\mu\text{Einsteins/cm}^2\text{sec})

Downwelling Irradiance (\mu\text{W/cm}^2/\text{nm})

Radiance (\mu\text{W/cm}^2/\text{nm/sr})
Figure A.8.b - Station F Upcast

- Tilt (°)

- Roll (°)

Diffuse Attenuation Coefficient (kλ)

- kEd380 vs Depth
- kEd412 vs Depth
- kEd443 vs Depth
- kEd490 vs Depth
- kEd510 vs Depth
- kEd555 vs Depth
Figure A.9.a - Station G Downcast

PAR (\(\mu\)Einstens/cm\(^2\)sec)

Depth (m)

Downwelling Irradiance (\(\mu\)W/cm\(^2\)/nm)

Radiance (\(\mu\)W/cm\(^2\)/nm/sr)

- Ed380 vs Depth
- Ed412 vs Depth
- Ed443 vs Depth
- Ed490 vs Depth
- Ed510 vs Depth
- Ed555 vs Depth
- Es443 vs Depth
- EdPAR vs Depth

- Lu380 vs Depth
- Lu412 vs Depth
- Lu443 vs Depth
- Lu490 vs Depth
- Lu510 vs Depth
- Lu555 vs Depth
- Lu683 vs Depth
Figure A.9.b - Station G Downcast

Diffuse Attenuation Coefficient ($k\lambda$)
Figure A.10.a - Station G Upcast

PAR (µEinsteins/cm²/sec)

Downwelling Irradiance (µW/cm²/nm)

Radiance (µW/cm²/nm/sr)
Figure A.10.b - Station G Upcast

- Tilt (°)

Diffuse Attenuation Coefficient ($k\alpha$)

- Depth (m)

- Diffuse Attenuation Coefficient
Figure A.11.a - Station 8A Downcast

PAR (μEinsteins/cm²/sec)

Depth (m)

Downwelling Irradiance (μW/cm²/nm)

Radiance (μW/cm²/nm/sr)

- Ed380 vs Depth
- Ed412 vs Depth
- Ed443 vs Depth
- Ed490 vs Depth
- Ed510 vs Depth
- Ed555 vs Depth
- Es443 vs Depth
- EdPAR vs Depth

- Lu380 vs Depth
- Lu412 vs Depth
- Lu443 vs Depth
- Lu490 vs Depth
- Lu510 vs Depth
- Lu555 vs Depth
- Lu683 vs Depth
Figure A.11.b - Station 8A Downcast

- Tilt (°)

- Roll (°)

Diffuse Attenuation Coefficient (kλ)
Figure A.12.a - Station 8A Upcast

---

**PAR (μEinsteins/cm²·sec)**

**Downwelling Irradiance (μW/cm²/nm)**

**Radiance (μW/cm²/nm/sr)**

- Ed380 vs Depth
- Ed412 vs Depth
- Ed443 vs Depth
- Ed490 vs Depth
- Ed510 vs Depth
- Ed555 vs Depth
- Es443 vs Depth
- EdPAR vs Depth

- Lu380 vs Depth
- Lu412 vs Depth
- Lu443 vs Depth
- Lu490 vs Depth
- Lu510 vs Depth
- Lu555 vs Depth
- Lu683 vs Depth
Figure A.12.b - Station 8A Upcast

![Graph showing Tilt and Roll vs Depth](image)

**Diffuse Attenuation Coefficient (kλ)**

![Graph showing Diffuse Attenuation Coefficient vs Depth](image)
Figure A.13.a - Station 8C Downcast

1. PAR (μEinsteins/cm²/sec)
2. Downwelling Irradiance (μW/cm²/nm)
3. Radiance (μW/cm²/nm/sr)
Figure A.13.b - Station 8C Downcast

Tilt (°)

Roll (°)

Diffuse Attenuation Coefficient (kλ)

Depth (m)

Diffuse Attenuation Coefficient
Figure A.14.a - Station 8C Upcast

Top graph:
- PAR (µEinsteins/cm²/sec)
- Depth (m)
- Ed380 vs Depth
- Ed412 vs Depth
- Ed443 vs Depth
- Ed490 vs Depth
- Ed510 vs Depth
- Ed555 vs Depth
- Ed555 vs Depth
- EdPAR vs Depth

Bottom graph:
- Downwelling Irradiance (µW/cm²/nm)
- Depth (m)
- Lu380 vs Depth
- Lu412 vs Depth
- Lu443 vs Depth
- Lu490 vs Depth
- Lu510 vs Depth
- Lu555 vs Depth
- Lu683 vs Depth

Radiance (µW/cm²/nm/sr)
Figure A.12.b - Station 8A Upcast

- Tilt (°)

- Roll (°)

Diffuse Attenuation Coefficient ($k\lambda$)

- $k\text{Ed}380$ vs Depth
- $k\text{Ed}412$ vs Depth
- $k\text{Ed}443$ vs Depth
- $k\text{Ed}490$ vs Depth
- $k\text{Ed}510$ vs Depth
- $k\text{Ed}555$ vs Depth
Figure A.15.a - Station 8E Downcast

PAR (µEinsteins/cm²/sec)

Downwelling Irradiance (µW/cm²/nm)

Radiance (µW/cm²/nm/sr)
Figure A.15.b - Station 8E Downcast

- Tilt (°)

- Roll (°)

Diffuse Attenuation Coefficient (kλ)
Figure A.16.a - Station 8E Upcast

PAR (µEinstines/cm²/sec)

0.01 0.1

Downwelling Irradiance (µW/cm²/nm)

0.001 0.01 0.1 1 10 100

Radiance (µW/cm²/nm/sr)

0.0001 0.001 0.01 0.1 1 10

--- Ed380 vs Depth
--- Ed412 vs Depth
--- Ed443 vs Depth
--- Ed490 vs Depth
--- Ed510 vs Depth
--- Ed555 vs Depth
--- Es443 vs Depth
--- EdPAR vs Depth
--- Lu380 vs Depth
--- Lu412 vs Depth
--- Lu443 vs Depth
--- Lu490 vs Depth
--- Lu510 vs Depth
--- Lu555 vs Depth
--- Lu683 vs Depth
Figure A.16.b - Station 8E Upcast

- Tilt (°)

- Roll (°)

Diffuse Attenuation Coefficient (kλ)

- kEd380 vs Depth
- kEd412 vs Depth
- kEd443 vs Depth
- kEd490 vs Depth
- kEd510 vs Depth
- kEd555 vs Depth
Figure A.17.a - Station 8G Downcast

**Top Graph:**
- **X-axis:** Depth (m)
- **Y-axis:** PAR (μEinstines/cm²/sec)
- Lines represent different wavelengths:
  - Ed380 vs Depth
  - Ed412 vs Depth
  - Ed443 vs Depth
  - Ed490 vs Depth
  - Ed510 vs Depth
  - Ed555 vs Depth
  - EdPAR vs Depth

**Bottom Graph:**
- **X-axis:** Radiance (μW/cm²/nm/sr)
- **Y-axis:** Depth (m)
- Lines represent different wavelengths:
  - Lu380 vs Depth
  - Lu412 vs Depth
  - Lu443 vs Depth
  - Lu490 vs Depth
  - Lu510 vs Depth
  - Lu555 vs Depth
  - Lu683 vs Depth
Figure A.17.b - Station 8G Downcast

- Tilt (°)

Diffuse Attenuation Coefficient (kλ)
Figure A.18.a - Station 8G Upcast

**PAR (μEinsteins/cm²/sec)**

- **Ed380 vs Depth**
- **Ed412 vs Depth**
- **Ed443 vs Depth**
- **Ed490 vs Depth**
- **Ed510 vs Depth**
- **Ed555 vs Depth**
- **Es443 vs Depth**
- **EdPAR vs Depth**

**Downwelling Irradiance (μW/cm²/nm)**

- **Lu380 vs Depth**
- **Lu412 vs Depth**
- **Lu443 vs Depth**
- **Lu490 vs Depth**
- **Lu510 vs Depth**
- **Lu555 vs Depth**
- **Lu683 vs Depth**
Figure A.18.b - Station 8G Upcast

- Tilt (°)

Depth (m)

- Roll (°)

Diffuse Attenuation Coefficient (kλ)

Depth (m)

Diffuse Attenuation Coefficient
Appendix C. Calibration Certificates for Biospherical Instruments Inc. PRR-600s (S/N# 9643) and PRR-610 (S/N# 9644).
## Calibration Certificate for PRR Spectroradiometer

**Calibration Date:** 1/23/1996  
**Model Number:** PRV-600S  
**Serial Number:** 9643  
**Operator:** JCE/LFG  
**Standard Lamp:** 91771 (05/30/95)

### Calibration Data

#### Downwelling Irradiance Channels

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>λ (nm)</th>
<th>Lamp Irradiance</th>
<th>Immersion Coefficient</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Factor - Dry</th>
<th>Calibration Factor - Wet</th>
<th>Max E (Dry)</th>
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#### Upwelling Radiance Channels

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<th>Immersion Coefficient</th>
<th>Plaque Reflectivity</th>
<th>Calibration Radiance</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Voltage - Blocked</th>
<th>Calibration Factor - Dry</th>
<th>Calibration Factor - Wet</th>
<th>Max L (Wet)</th>
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### Temperature

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<th>Offset</th>
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### Nominal to Actual Voltage Conversion Factors

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### Firmware Versions

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<td>2043A</td>
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**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 π 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.
Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

<table>
<thead>
<tr>
<th>Calibration Date:</th>
<th>1/23/96</th>
<th>Form: 1/24/96</th>
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<tbody>
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<td>Model Number:</td>
<td>PRV-600S</td>
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<tr>
<td>Serial Number:</td>
<td>9643</td>
<td></td>
</tr>
<tr>
<td>Operator:</td>
<td>JCE/LFG</td>
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</tbody>
</table>

OPTIONAL CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Output = (Voltage - Offset)/Scale</th>
</tr>
</thead>
</table>
| 11 0   | Transmissometer
Scale Factor | 0.10 Volts/Volt |
Offset   | 0.0 Volts |
| 12 0   | Scalar PAR: QSP-200 S/N 4443
Scale Factor (Wet) | -1.61E-17 Volts/(quanta/cm²·sec) |
Offset   | 0.0009 Volts |
| 13 0   | AXIS 1 ANGLE SENSOR - "TILT"
Scale Factor | 0.0418 |
Offset   | 2.8862 |
| 14 0   | AXIS 2 ANGLE SENSOR - "ROLL"
Scale Factor | 0.0416 |
Offset   | 2.6973 |
| 15 0   | Light Scattering Sensor
Scale Factor | 1.0 Volts/Volt |
Offset   | 0.0 Volts |
| 16 0   | Fluorometer
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.
Biospherical Instruments Inc.

EVALUATION FORM for PRR Spectroradiometer

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

**Model Number:** PRR-600S  
**Serial Number:** 9643  
**Operator:** JCE/LFG

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

<table>
<thead>
<tr>
<th>Ch</th>
<th>Tag</th>
<th>Lam Radiance @ 50 cm</th>
<th>Immersion Coefficient</th>
<th>Plaque Reflectivity</th>
<th>Radiance &amp;</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Factor - Dry</th>
<th>Calibration Factor - Wet</th>
<th>Max E (Dry)</th>
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**DOWNNELLING IRRADIANCE CHANNELS**

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<th>Immersion Coefficient</th>
<th>Plaque Reflectivity</th>
<th>Radiance</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Factor - Dry</th>
<th>Calibration Factor - Wet</th>
<th>Max E (Dry)</th>
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<tbody>
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**UPWELLING RADIANCE CHANNELS**

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<th>Calibration Factor - Dry</th>
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<td>0.984</td>
<td>0.146</td>
<td>0.000227</td>
<td>-0.00126</td>
<td>-0.250415</td>
<td>8.0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>555</td>
<td>9.746</td>
<td>1.738</td>
<td>0.984</td>
<td>0.146</td>
<td>0.000227</td>
<td>-0.00126</td>
<td>-0.250415</td>
<td>7.7</td>
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<tr>
<td>7</td>
<td>0</td>
<td>PAR</td>
<td>0.0152</td>
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<td>-0.05074</td>
<td>0.758</td>
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**TEMPERATURE**

<table>
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<th>Offset</th>
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<tbody>
<tr>
<td>0.1419</td>
<td>0.0801</td>
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**PRESSURE/DEPTH**

<table>
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<tr>
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<th>Scale Factor &quot;b&quot;</th>
<th>Offset &quot;c&quot;</th>
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</thead>
<tbody>
<tr>
<td>1.9374</td>
<td>83.8842</td>
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</table>

**NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS**

<table>
<thead>
<tr>
<th>Irr. Array Red. Array</th>
<th>Scale Factor</th>
<th>Offset</th>
<th>Full Scale Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.067579</td>
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<tr>
<td>2.042956</td>
<td>20429</td>
<td>0.000273</td>
<td>9.3090</td>
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**FIRMWARE VERSIONS**

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<thead>
<tr>
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<th>Tag</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

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 π 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

<table>
<thead>
<tr>
<th>Calibration Date:</th>
<th>3/26/96</th>
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</thead>
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<td>PRV-600S</td>
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<tr>
<td>Serial Number:</td>
<td>9643</td>
</tr>
<tr>
<td>Operator:</td>
<td>JCE/LFG</td>
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</table>

**OPTIONAL CHANNELS**

<table>
<thead>
<tr>
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<th>Tag</th>
<th>Scale Factor</th>
<th>Offset</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Transmissometer&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Scalar PAR: QSP-200 S/N 4443&lt;sup&gt;2&lt;/sup&gt;</td>
<td>-1.161E-17</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>AXIS 1 ANGLE SENSOR - &quot;TILT&quot;&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.0415</td>
<td>2.8962</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>AXIS 2 ANGLE SENSOR - &quot;ROLL&quot;&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>2.8973</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Light Scattering Sensor&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Fluorometer&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

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.
**Calibration Certificate for PRR Spectroradiometer**

**Biospherical Instruments Inc.**

**Calibration Date:** 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.

### Downwelling Irradiance Channels

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Lamp</th>
<th>Immersion Coefficient</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Factor - Dry</th>
<th>Calibration Factor - Wet</th>
<th>Max E (Dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0</td>
<td>380</td>
<td>1.578</td>
<td>0.000146</td>
<td>-0.019400</td>
<td>-0.012390</td>
<td>-0.008317</td>
<td>807.1</td>
</tr>
<tr>
<td>2 0</td>
<td>412</td>
<td>2.595</td>
<td>0.000551</td>
<td>-0.081300</td>
<td>-0.031541</td>
<td>-0.021345</td>
<td>317.2</td>
</tr>
<tr>
<td>3 0</td>
<td>443</td>
<td>4.003</td>
<td>0.000189</td>
<td>-0.128186</td>
<td>-0.032071</td>
<td>-0.021874</td>
<td>311.8</td>
</tr>
<tr>
<td>4 0</td>
<td>490</td>
<td>6.647</td>
<td>0.000282</td>
<td>-0.221058</td>
<td>-0.033297</td>
<td>-0.022960</td>
<td>300.3</td>
</tr>
<tr>
<td>5 0</td>
<td>510</td>
<td>7.880</td>
<td>0.000171</td>
<td>-0.253324</td>
<td>-0.032171</td>
<td>-0.022313</td>
<td>310.8</td>
</tr>
<tr>
<td>6 0</td>
<td>555</td>
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<td>0.000480</td>
<td>-0.348378</td>
<td>-0.032511</td>
<td>-0.022801</td>
<td>307.6</td>
</tr>
<tr>
<td>7 0</td>
<td>PAR</td>
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<td>0.000371</td>
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<td>-0.032511</td>
<td>-0.022801</td>
<td>307.6</td>
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</table>

### Upwelling Radiance Channels

<table>
<thead>
<tr>
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<th>Immersion Coefficient</th>
<th>Plaque Reflectivity</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Factor - Dry</th>
<th>Calibration Factor - Wet</th>
<th>Max L (Dry)</th>
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</thead>
<tbody>
<tr>
<td>1 1</td>
<td>380</td>
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<tr>
<td>2 1</td>
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<td>-0.000998</td>
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<td>0.000203</td>
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<td>0.991</td>
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<td>0.000321</td>
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<tr>
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<tr>
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<td>Gnd.</td>
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<td>0.000179</td>
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<td>0.000010</td>
<td>0.000026</td>
<td>-0.365980</td>
<td>6.8</td>
</tr>
</tbody>
</table>

### Temperature

\[ \text{Temperature (°C)} = \frac{\text{Voltage} - \text{Offset}}{\text{Scale}} \]

<table>
<thead>
<tr>
<th>Scale</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1421</td>
<td>0.0889</td>
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</tbody>
</table>

### Pressure/Depth

\[ \text{Pressure/Depth (dbars or meters)} = (a \times \text{Voltage}) + (b \times \text{Voltage}) + c \]

<table>
<thead>
<tr>
<th>Scale Factor &quot;a&quot;</th>
<th>Scale Factor &quot;b&quot;</th>
<th>Offset &quot;c&quot;</th>
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</thead>
<tbody>
<tr>
<td>0.9383</td>
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</table>

### Nominal to Actual Voltage Conversion Factors

For use with external sensors, only, see manual

<table>
<thead>
<tr>
<th>Irr. Array</th>
<th>Rad. Array</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale Factor</td>
<td>Offset</td>
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<tr>
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<td>0.000206</td>
</tr>
<tr>
<td>1.074227</td>
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**FIRMWARE VERSIONS**

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<tbody>
<tr>
<td>2755B</td>
<td>2043A</td>
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</table>

**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 \(\mu\text{Einsteins/cm}^2\text{sec}\).
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

<table>
<thead>
<tr>
<th>Calibration Date:</th>
<th>2/10/97</th>
<th>Form:</th>
<th>2/10/97</th>
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<tbody>
<tr>
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<td>PRV-600S</td>
<td>Serial Number:</td>
<td>9643</td>
</tr>
<tr>
<td>Serial Number:</td>
<td></td>
<td>Operator:</td>
<td>TMM</td>
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OPTIONAL CHANNELS

<table>
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<tr>
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<th>Ch Tag</th>
</tr>
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<tbody>
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<td>14</td>
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<tr>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
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<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Scale Factor</th>
<th>Offset</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
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</tr>
<tr>
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<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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

Calibration Date: 2/10/97  
Form: 2/18/97

Model Number: PRV-600S  
Serial Number: 9643  
Operator: TMM

Standard Lamp: 94531 (01/02/97) for Irradiance, 94532 (10/11/95) for Radiance.

### DOWNWELLING IRRADIANCE CHANNELS

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<tr>
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<td>-0.003817</td>
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<tr>
<td>2 0</td>
<td>412</td>
<td>2.595</td>
<td>0.677</td>
<td>0.000551</td>
<td>-0.081300</td>
<td>-0.031541</td>
<td>-0.021345</td>
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<td></td>
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<tr>
<td>3 0</td>
<td>443</td>
<td>4.003</td>
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<td>-0.128186</td>
<td>-0.032071</td>
<td>-0.021874</td>
<td>311.8</td>
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<td></td>
</tr>
<tr>
<td>4 0</td>
<td>490</td>
<td>6.647</td>
<td>0.669</td>
<td>0.000282</td>
<td>-0.221058</td>
<td>-0.033297</td>
<td>-0.022980</td>
<td>300.3</td>
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</tr>
<tr>
<td>5 0</td>
<td>510</td>
<td>7.860</td>
<td>0.694</td>
<td>0.000171</td>
<td>-0.253324</td>
<td>-0.032171</td>
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<tr>
<td>6 0</td>
<td>555</td>
<td>10.730</td>
<td>0.701</td>
<td>0.000480</td>
<td>-0.348378</td>
<td>-0.032511</td>
<td>-0.022801</td>
<td>307.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 0</td>
<td>PAR</td>
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<td>0.686</td>
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</table>

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

### UPWELLING RADIANCE CHANNELS

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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
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<td>1.765</td>
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<td>0.011</td>
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</tr>
<tr>
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<td>0.000330</td>
<td>0.000321</td>
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<td>-1.243485</td>
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<td>1.738</td>
<td>0.991</td>
<td>0.085</td>
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<td>-0.259162</td>
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<tr>
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<td>0.000105</td>
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<td>-0.385980</td>
<td>-1.521184</td>
<td>6.6</td>
</tr>
</tbody>
</table>

### TEMPERATURE

Temperature (°C) = (Voltage - Offset)/Scale

- Scale: 0.1421
- Offset: 0.0889

### PRESSURE/DEPTH

Pressure/Depth (dbars or meters) = (a x Voltage^2) + (b x Voltage) + c

- Scale Factor "a": 0.0383
- Scale Factor "b": 83.1773
- Offset "c": 26.8995

### NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS

- In. Array Rad. Array
- 1.057679 1.074227
- 0.000205 0.000278
- 9.4547 9.3090

### FIRMWARE VERSIONS

<table>
<thead>
<tr>
<th>Underwater ROM</th>
<th>Tag 0</th>
<th>Tag 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2765B</td>
<td>2043A</td>
<td></td>
</tr>
</tbody>
</table>

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 1 dbar change in pressure.
9. These channels/sensors were not evaluated during this service period.
**CALIBRATION CERTIFICATE for PRR Spectroradiometer**

**Calibration Date:** 2/10/97  
**Model Number:** PRV-600S  
**Serial Number:** 9643  
**Operator:** TMM  
**Form:** 2/18/97

### OPTIONAL CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>Transmissometer&lt;sup&gt;11&lt;/sup&gt;</th>
<th>Scalar PAR: QSP-200 S/N 4443</th>
<th>AXIS 1 ANGLE SENSOR - “TILT”&lt;sup&gt;20&lt;/sup&gt;</th>
<th>AXIS 2 ANGLE SENSOR - “ROLL”&lt;sup&gt;22&lt;/sup&gt;</th>
<th>Light Scattering Sensor&lt;sup&gt;13&lt;/sup&gt;</th>
<th>Fluorometer&lt;sup&gt;11&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 0</td>
<td>Output = (Voltage - Offset)/Scale</td>
<td>Scale Factor</td>
<td>Offset</td>
<td>Scale Factor (Wet)</td>
<td>Offset</td>
<td>Scale Factor</td>
</tr>
<tr>
<td></td>
<td>1.0 Volts/Volt</td>
<td>0.0 Volts</td>
<td></td>
<td>-1.020E-17 Volts/(quanta/cm&lt;sup&gt;2&lt;/sup&gt;-sec)</td>
<td>0.0009 Volts</td>
<td>0.0418</td>
</tr>
</tbody>
</table>

**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**

**Calibration Date:** 1/7/98  
**Model Number:** PRV-600S  
**Serial Number:** 9643  
**Operator:** TMM/DAN

**Standard Lamp:** 94531 (01/02/97) for Irradiance, 94532 (10/11/95) for Radiance

### DOWNWELLING IRRADIANCE CHANNELS

<table>
<thead>
<tr>
<th>Ch</th>
<th>Ta</th>
<th>Lamp @ 50 cm</th>
<th>Immersion Coefficient</th>
<th>Calibration</th>
<th>Calibration</th>
<th>Calibration</th>
<th>Calibration</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Irradiance</td>
<td>(Type P6-2)</td>
<td>Voltage &amp; Dark</td>
<td>Voltage &amp; Dark</td>
<td>Factor - Dry</td>
<td>Factor - Wet</td>
<td>Max E (Dry)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>380</td>
<td>1.578</td>
<td>0.671</td>
<td>0.000216</td>
<td>-0.019687</td>
<td>-0.012567</td>
<td>-0.008469</td>
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<tr>
<td>2</td>
<td>0</td>
<td>412</td>
<td>2.595</td>
<td>0.677</td>
<td>0.000144</td>
<td>-0.082185</td>
<td>-0.031725</td>
<td>-0.021469</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>443</td>
<td>4.003</td>
<td>0.682</td>
<td>0.000186</td>
<td>-0.129799</td>
<td>-0.032473</td>
<td>-0.022149</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>490</td>
<td>6.647</td>
<td>0.690</td>
<td>0.000293</td>
<td>-0.223611</td>
<td>-0.031725</td>
<td>-0.021469</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>510</td>
<td>7.880</td>
<td>0.694</td>
<td>0.000160</td>
<td>-0.255997</td>
<td>-0.032473</td>
<td>-0.022149</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>555</td>
<td>10.730</td>
<td>0.701</td>
<td>0.000481</td>
<td>-0.351498</td>
<td>-0.032473</td>
<td>-0.022149</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>PAR</td>
<td>0.01539</td>
<td>0.689</td>
<td>0.000366</td>
<td>-0.204294</td>
<td>-0.132667</td>
<td>-0.092821</td>
</tr>
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### UPWELLING RADIANCE CHANNELS

<table>
<thead>
<tr>
<th>Ch</th>
<th>Ta</th>
<th>Lamp @ 50 cm</th>
<th>Immersion Coefficient</th>
<th>Plaque Reflectivity</th>
<th>Calibration</th>
<th>Calibration</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Irradiance</td>
<td>(BK7 window)</td>
<td>S/N 20166</td>
<td>Voltage &amp; Dark</td>
<td>Voltage &amp; Blocked</td>
<td>Max L (Wet)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>360</td>
<td>1.308</td>
<td>1.765</td>
<td>0.987</td>
<td>0.011</td>
<td>0.0001199</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>412</td>
<td>2.275</td>
<td>1.758</td>
<td>0.990</td>
<td>0.020</td>
<td>-0.000094</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>443</td>
<td>3.514</td>
<td>1.752</td>
<td>0.991</td>
<td>0.030</td>
<td>-0.000239</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>490</td>
<td>5.911</td>
<td>1.745</td>
<td>0.991</td>
<td>0.051</td>
<td>-0.000197</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>510</td>
<td>7.038</td>
<td>1.743</td>
<td>0.991</td>
<td>0.061</td>
<td>-0.000331</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>555</td>
<td>9.746</td>
<td>1.738</td>
<td>0.991</td>
<td>0.084</td>
<td>-0.000171</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>683</td>
<td>16.755</td>
<td>1.730</td>
<td>0.991</td>
<td>0.145</td>
<td>0.000091</td>
</tr>
</tbody>
</table>

### TEMPERATURE

Temperature (°C) = (Voltage - Offset)/Scale

<table>
<thead>
<tr>
<th>Scale</th>
<th>Offset</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1419</td>
<td>0.0919</td>
<td></td>
</tr>
</tbody>
</table>

### PRESSURE/DEPTH

Pressure/Depth (dbars or meters) = (a x Voltage) + (b x Voltage) + c

<table>
<thead>
<tr>
<th>Scale Factor &quot;a&quot;</th>
<th>Scale Factor &quot;b&quot;</th>
<th>Offset &quot;c&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9298</td>
<td>83.3548</td>
<td>26.8924</td>
</tr>
</tbody>
</table>

### NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS

(For use with external sensors, only, see manual)

<table>
<thead>
<tr>
<th>Irr. Array</th>
<th>Rad. Array</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.057679</td>
<td>1.074227</td>
</tr>
<tr>
<td>0.000205</td>
<td>0.000278</td>
</tr>
<tr>
<td>9.4547</td>
<td>9.3960</td>
</tr>
</tbody>
</table>

### FIRMWARE VERSION(S)

Tag 0: 27665  
Tag 1: 2043A

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**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 fully 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.
Biospherical Instruments Inc.
CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 1/7/98  
Model Number: PRV-600S  
Serial Number: 9643  
Operator: TMM/DAN

<table>
<thead>
<tr>
<th>Optional Channels</th>
<th>Output</th>
<th>Scale Factor</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 Transmissometer&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Voltage - Offset)/Scale</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>12 Scalar PAR: QSP-200 S/N 4443&lt;sup&gt;2&lt;/sup&gt;</td>
<td>quanta/(cm² sec) = (Voltage - Offset)/Scale</td>
<td>-1.02E-17</td>
<td>0.0009</td>
</tr>
<tr>
<td>13 AXIS 1 ANGLE SENSOR - &quot;TILT&quot;&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Degrees = (Voltage - Offset)/Scale</td>
<td>0.0418</td>
<td>2.6862</td>
</tr>
<tr>
<td>14 AXIS 2 ANGLE SENSOR - &quot;ROLL&quot;&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Degrees = (Voltage - Offset)/Scale</td>
<td>0.0415</td>
<td>2.6973</td>
</tr>
<tr>
<td>15 Light Scattering Sensor&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Output = (Voltage - Offset)/Scale</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>16 Fluorometer&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Output = (Voltage - Offset)/Scale</td>
<td>1.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

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**

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

### Calibration Data

**Irradiance Channels**

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>λ (nm)</th>
<th>Lamp Output</th>
<th>Dark</th>
<th>Light</th>
<th>Calibration Factor - Dry (V/W)</th>
<th>Max E (Dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>380</td>
<td>1.397</td>
<td>0.000205</td>
<td>-0.045775</td>
<td>-0.032918</td>
<td>303.8</td>
</tr>
<tr>
<td>2</td>
<td>412</td>
<td>2.411</td>
<td>-0.000888</td>
<td>-0.079748</td>
<td>-0.032704</td>
<td>305.8</td>
</tr>
<tr>
<td>3</td>
<td>443</td>
<td>3.701</td>
<td>-0.000036</td>
<td>-0.126600</td>
<td>-0.034201</td>
<td>292.4</td>
</tr>
<tr>
<td>4</td>
<td>490</td>
<td>6.159</td>
<td>-0.000291</td>
<td>-0.206142</td>
<td>-0.033424</td>
<td>299.2</td>
</tr>
<tr>
<td>5</td>
<td>510</td>
<td>7.302</td>
<td>-0.000277</td>
<td>-0.242508</td>
<td>-0.033173</td>
<td>301.5</td>
</tr>
<tr>
<td>6</td>
<td>555</td>
<td>10.041</td>
<td>0.000142</td>
<td>-0.328101</td>
<td>-0.032691</td>
<td>305.9</td>
</tr>
<tr>
<td>7</td>
<td>PAR</td>
<td>0.0142</td>
<td>-0.000040</td>
<td>-0.15367</td>
<td>-10.674195</td>
<td>0.920</td>
</tr>
<tr>
<td>8</td>
<td>Gnd</td>
<td>0.000095</td>
<td>Volts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Nominal to Actual Voltage Conversion Factors**

- **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).
**Biospherical Instruments Inc.**

**CALIBRATION CERTIFICATE for PRR Spectroradiometer**

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

### SURFACE IRRADIANCE CHANNELS

<table>
<thead>
<tr>
<th>Ch</th>
<th>Tag</th>
<th>λ (nm)</th>
<th>Lamp Output</th>
<th>Calibration Voltage - Dark</th>
<th>Calibration Voltage - Light</th>
<th>Calibration Factor - Dry (V/W)</th>
<th>Max E (Dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>380</td>
<td>1.397</td>
<td>0.0000205</td>
<td>-0.045775</td>
<td>-0.032918</td>
<td>303.8</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>412</td>
<td>2.411</td>
<td>-0.000888</td>
<td>-0.079748</td>
<td>-0.032704</td>
<td>305.8</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>443</td>
<td>3.701</td>
<td>-0.000036</td>
<td>-0.126600</td>
<td>-0.034201</td>
<td>292.4</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>490</td>
<td>6.159</td>
<td>-0.000291</td>
<td>-0.206142</td>
<td>-0.033424</td>
<td>299.2</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>510</td>
<td>7.302</td>
<td>-0.000277</td>
<td>-0.242508</td>
<td>-0.033713</td>
<td>301.5</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>555</td>
<td>10.041</td>
<td>0.000142</td>
<td>-0.328101</td>
<td>-0.032691</td>
<td>305.9</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>PAR $^4$</td>
<td>0.0142</td>
<td>-0.000040</td>
<td>-0.153967</td>
<td>-10.874195</td>
<td>0.920</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>Gnd. $^5$</td>
<td>0.000095</td>
<td>Volts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 µEinstein/cm²·sec.
5. Typical value(s).

---

**FIRMWARE VERSION**

- **Tag:** 2
- **Surface ROM:** 2106B

---

**Nominal to Actual Voltage Conversion Factors (For use with external sensors, only, see manual)**

- **Irr. Array:** 1.061494
- **Offset:** 0.000049
- **Full Scale Voltage:** 9.4207

---

**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 µEinstein/cm²·sec.
5. Typical value(s).
**Biospherical Instruments Inc.**

**CALIBRATION CERTIFICATE for PRR Spectroradiometer**

**Calibration Date:** 2/10/97  
**Form:** 2/18/97  
**Model Number:** PRV-610  
**Serial Number:** 9644  
**Operator:** TMM  
**Standard Lamp:** 95431 (01/02/97)

### SURFACE IRRADIANCE CHANNELS

<table>
<thead>
<tr>
<th>Ch Tag</th>
<th>A (nm)</th>
<th>Lamp Output</th>
<th>Calibrated Voltage - Dark&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Calibrated Voltage - Light</th>
<th>Calibration Factor - Dry&lt;sup&gt;1&lt;/sup&gt; (V/μW)</th>
<th>Max E (Dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>380</td>
<td>1.578</td>
<td>0.0002240</td>
<td>-0.049332</td>
<td>-0.031424</td>
<td>318.2</td>
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<tr>
<td>2</td>
<td>412</td>
<td>2.595</td>
<td>-0.000879</td>
<td>-0.084205</td>
<td>-0.032110</td>
<td>311.4</td>
</tr>
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<td>3</td>
<td>443</td>
<td>4.003</td>
<td>-0.000021</td>
<td>-0.135255</td>
<td>-0.033785</td>
<td>296.0</td>
</tr>
<tr>
<td>4</td>
<td>490</td>
<td>6.647</td>
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<td>-0.219210</td>
<td>-0.033338</td>
<td>303.6</td>
</tr>
<tr>
<td>5</td>
<td>510</td>
<td>7.880</td>
<td>-0.000241</td>
<td>-0.257444</td>
<td>-0.032641</td>
<td>306.4</td>
</tr>
<tr>
<td>6</td>
<td>555</td>
<td>10.730</td>
<td>0.000203</td>
<td>-0.346864</td>
<td>-0.032326</td>
<td>309.4</td>
</tr>
<tr>
<td>7</td>
<td>PAR&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.0154</td>
<td>0.000069</td>
<td>-0.162024</td>
<td>-10.531115</td>
<td>0.950</td>
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</table>

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 μEinstein/cm²·sec.
5) Typical value(s).

---

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

<table>
<thead>
<tr>
<th>Scale</th>
<th>Offset</th>
<th>Full Scale Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.061494</td>
<td>0.000049</td>
<td>9.4207</td>
</tr>
</tbody>
</table>

**FIRMWARE VERSION**

<table>
<thead>
<tr>
<th>Tag 2</th>
<th>Surface ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2106B</td>
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</tr>
</tbody>
</table>

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PRR-610 03/15/95
Biospherical Instruments Inc.
CALIBRATION CERTIFICATE for PRR Spectroradiometer

<table>
<thead>
<tr>
<th>Calibration Date: 2/10/97</th>
<th>Form: 2/10/97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Number: PRV-610</td>
<td></td>
</tr>
<tr>
<td>Serial Number: 9644</td>
<td></td>
</tr>
<tr>
<td>Operator: TMM</td>
<td></td>
</tr>
<tr>
<td>Standard Lamp: 95431 (01/02/97)</td>
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</tr>
</tbody>
</table>

**SURFACE IRRADIANCE CHANNELS**

<table>
<thead>
<tr>
<th>Ch</th>
<th>Tag</th>
<th>( \lambda ) (nm)</th>
<th>Lamp Output</th>
<th>Calibration Voltage (-\text{Dark}^3)</th>
<th>Calibration Voltage (-\text{Light})</th>
<th>Calibration Factor (-\text{Dry})</th>
<th>Max E (Dry)</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>2</td>
<td>380</td>
<td>1.578</td>
<td>0.000240</td>
<td>-0.049332</td>
<td>-0.031424</td>
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<td>2</td>
<td>412</td>
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<td>-0.000879</td>
<td>-0.084205</td>
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<tr>
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<td>-0.000211</td>
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<tr>
<td>4</td>
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<tr>
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<td>-0.000241</td>
<td>-0.257444</td>
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</tr>
<tr>
<td>6</td>
<td>2</td>
<td>555</td>
<td>10.730</td>
<td>0.000203</td>
<td>-0.346664</td>
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<td>2</td>
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<td>-10.531115</td>
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<td>8</td>
<td>2</td>
<td>Gnd(^3)</td>
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</tbody>
</table>

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

- **Irr. Array**: 1.061494 (Calibrated on 1-96)
- **Offset**: 0.300049
- **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. Typical value(s).
<table>
<thead>
<tr>
<th>Ch</th>
<th>Tag</th>
<th>λ (nm)</th>
<th>Lamp Output</th>
<th>Calibration Voltage - Dark [(\mu\text{V})]</th>
<th>Calibration Voltage - Light [(\mu\text{V})]</th>
<th>Calibration Factor - Dry [(\text{V}/\mu\text{W})]</th>
<th>Max E (Dry) [(\mu\text{W/cm}^2\text{ nm})]</th>
</tr>
</thead>
<tbody>
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<td>0.000225</td>
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<tr>
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<td>Gnd²</td>
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<td></td>
</tr>
</tbody>
</table>

**SURFACE IRRADIANCE CHANNELS**

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

**NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS**

<table>
<thead>
<tr>
<th>Irr. Array</th>
<th>Scale</th>
<th>Offset</th>
<th>Full Scale Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.061494</td>
<td>0.000049</td>
<td>9.4207</td>
</tr>
</tbody>
</table>

**FIRMWARE VERSION**

<table>
<thead>
<tr>
<th>Tag 2</th>
<th>Surface ROM</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2106B</td>
</tr>
</tbody>
</table>

**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 \(\mu\text{Einsteins/cm}^2\text{ sec}\).
5. Typical value(s).