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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, i.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:

- Geesey, M. Culver, A. Subramaniam, G. DiTullio, and J. Brock. 1998. Optical and Biological variability in the South Atlantic Bight. Presented at a conference for Collaborative Research Activities in the South Atlantic Bight, April 1998.
- Waters, K.J., M. E. Culver, and A. Subramaniam. 1988. Optical closure models applied to coastal and open ocean waters. Abstract submitted to Ocean Optics XIV, Society for Photo-Optical Instrumentation Engineers (SPIE). Conference scheduled for November 1998.

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
3. Quantitative evaluation of ocean color products generated using NASDA/OCTS and NASA/SeaWiFS standard bio-optical and atmospheric correction techniques in coastal US waters.

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.

Date	Location	Affiliation/Ship Name
September/October 1998	Gulf of Mexico	ECOHAB
November 1998	Mid-Atlantic Bight	Cape Hatteras
March 1999	Mid-Atlantic Bight	Cape Hatteras

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

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

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

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

Cruise Name	Date	Location	Vessel	Month of Radiometric Data Submission	Month of HPLC Data Submission	Month of Cruise Report Submission
Mar97OCC	3/13/97	Onslow Bay	R/V Onslow Bay	5/97	5/97	5/97
May97OB	5/5-8/97	Onslow Bay, Pamlico Sound	R/V Onslow Bay	5/98	5/98	6/98
Sep97SAB	9/6-24/97	South Atlantic Bight	Cape Hatteras	5/98*	6/98	In Preparation
Nov97SAR	11/4-6/97	Sargasso Sea	R/V Palmetto	2/98	2/98	In Preparation
Jul98NAN	7/6-10/98	Nantucket Shoals	Gulf Challenger	10/98**	01/99**	TBD

* 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 (%).

Cruise Name	Date	Station	Latitude	Longitude	*In-situ* Chl-a	OC2 Chl-a	Diff. (%)	*In-situ* Pigment	OC2 CZCS Pigment	Diff. (%)
May97OB	5/5/97	5C	34.278	-76.068	0.14	0.22	57	0.23	0.30	30
	5/5/97	5D	34.305	-76.280	0.15	0.26	73	0.26	0.36	38
	5/5/97	5E	34.378	-76.462	0.26	0.67	158	0.50	0.90	80
	5/5/97	5F	34.446	-76.622	0.15	0.29	93	0.27	0.39	44
	5/5/97	5G	34.552	-76.650	0.25	0.60	140	0.43	0.82	91
	5/8/97	8A	35.247	-76.009	2.61	7.89	202	4.54	10.1	122
	5/8/97	8C	35.197	-76.084	1.99	13.7	588	3.67	17.4	374
	5/8/97	8E	35.166	-76.168	1.80	13.3	639	3.60	16.9	369
	5/8/97	8G	35.083	-76.251	2.12	9.42	344	4.30	12.1	181
Sep97SAB	9/6/97	6A	34.652	-76.657	2.75	3.01	9	2.75	3.95	44
	9/6/97	6B	34.439	-76.538	0.69	1.37	99	0.69	1.83	165
	9/13/97	13	30.906	-81.305	3.77	12.2	224	3.77	15.6	314
	9/14/97	14	30.422	-81.372	5.20	6.30	21	5.20	8.12	56
	9/17/97	17	29.916	-81.200	1.97	2.76	40	1.97	3.62	84
	9/19/97	19	30.837	-80.764	0.33	0.31	6	0.33	0.42	27
	9/23/97	23	32.928	-79.290	1.23	2.71	120	1.23	3.56	189
	9/24/97	24	31.868	-79.046	0.45	0.19	58	0.45	0.27	40
Nov97SAR	11/4/97	7	32.545	-79.625	0.20	0.79	295	0.34	1.07	215
	11/4/97	8	32.401	-79.484	0.14	0.35	150	0.23	0.48	109
	11/4/97	9	32.239	-79.339	0.10	0.34	170	0.22	0.47	114
	11/5/97	13	31.092	-78.193	0.03	0.17	467	N/A	0.24	-
	11/5/97	14	31.065	-78.203	0.18	0.15	17	0.16	0.20	25
	11/5/97	16	31.018	-78.237	0.04	0.14	250	0.19	0.20	5

Table 3. Chlorophyll and CZCS-pigment concentration product validation. A comparable value of diffuse attenuation coefficient (K 490) was not estimated from *in-situ* radiometric measurements. Latitude and longitude are given in decimal degrees. Diff. = difference (%).

Cruise Name	Date	Station	Latitude	Longitude	*In-situ* Chl-a	SeaWiFS Chl-a	Diff. (%)	*In-situ* Pigment	SeaWiFS CZCS Pigment	Diff. (%)	SeaWiFS K 490
Sep97SAB	9/19/97	19	30.83	-80.76	0.33	0.45	36	0.33	0.62	85	0.056
	9/23/97	23	32.92	-79.28	1.233	2.05	66	1.23	2.29	85	0
Nov97SAR	11/3/97	1	31.75	-79.07	0.051	0.15	194		0.21		0.039
	11/3/97	2	31.94	-79.00	0.083	0.12	39		0.16		0.036
	11/3/97	3	32.06	-79.04	0.086	0.32	265		0.43		0.054
	11/3/97	4	32.17	-79.17	0.092	0.33	265		0.46		0.060
	11/3/97	5	32.23	-79.29	0.204	0.64	211		0.86		0.089
	11/3/97	6	32.31	-79.47	0.146	0.33	124		0.45		0.062
	11/4/97	7	32.54	-79.62	0.204	0.75	268	0.34	1.01	197	0.129
	11/4/97	8	32.40	-79.48	0.135	0.30	121	0.23	0.41	78	0.066
	11/4/97	9	32.23	-79.33	0.103	0.62	495	0.22	0.83	278	0.088
	11/4/97	UW1	32.09	-79.21	0.143	0.20	36		0.27		0.052
	11/4/97	UW2	31.86	-79.00	0.033	0.14	326		0.20		0.039

Table 4. Station date, time, and location of FY97 SIMBIOS cruises.

Cruise Name	Station	Date	Time (GMT)	Latitude	Longitude
Mar97OCC	1	3/13/97	11:05	34.433	-76.652
May97OB	5C	5/5/97	14:00	34.278	-76.068
	5D	5/5/97	15:20	34.305	-76.280
	5E	5/5/97	16:20	34.378	-76.462
	5F	5/5/97	17:15	34.446	-76.622
	5G	5/5/97	18:40	34.552	-76.650
	8A	5/8/97	12:40	35.247	-76.009
	8C	5/8/97	13:20	35.197	-76.084
	8E	5/8/97	13:40	35.166	-76.168
	8G	5/8/97	14:10	35.083	-76.251
Sep97SAB	6A	9/6/97	15:01	34.652	-76.657
	6B	9/6/97	20:15	34.439	-76.538
	13	9/13/97	15:15	30.906	-81.305
	14	9/14/97	16:15	30.422	-81.372
	17	9/17/97	15:05	29.916	-81.200
	19	9/19/97	15:05	30.837	-80.764
	23	9/23/97	15:51	32.928	-79.290
	24	9/24/97	16:15	31.868	-79.046
Nov97SAR	1	11/3/97	07:00	31.753	-79.070
	2	11/3/97	09:50	31.943	-79.001
	3	11/3/97	11:40	32.066	-79.049
	4	11/3/97	13:10	32.172	-79.172
	5	11/3/97	14:45	32.230	-79.299
	6	11/3/97	16:30	32.310	-79.476
	7	11/4/97	12:15	32.545	-79.625
	8	11/4/97	14:15	32.401	-79.484
	9	11/4/97	16:15	32.239	-79.339
	UW1	11/4/97	18:00	32.097	-79.213
	UW2	11/4/97	20:00	31.862	-79.002
	UW3	11/4/97	22:00	31.620	-78.800
	UW4	11/5/97	00:00	31.423	-78.501
	UW5	11/5/97	02:00	31.184	-78.277
	10	11/5/97	04:00	31.130	-78.223
	11	11/5/97	06:00	31.125	-78.207
	12	11/5/97	08:00	31.110	-78.192
	13	11/5/97	10:00	31.092	-78.193
	14	11/5/97	12:00	31.065	-78.203
	15	11/5/97	16:00	31.032	-78.221
	16	11/5/97	16:00	31.018	-78.237

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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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.

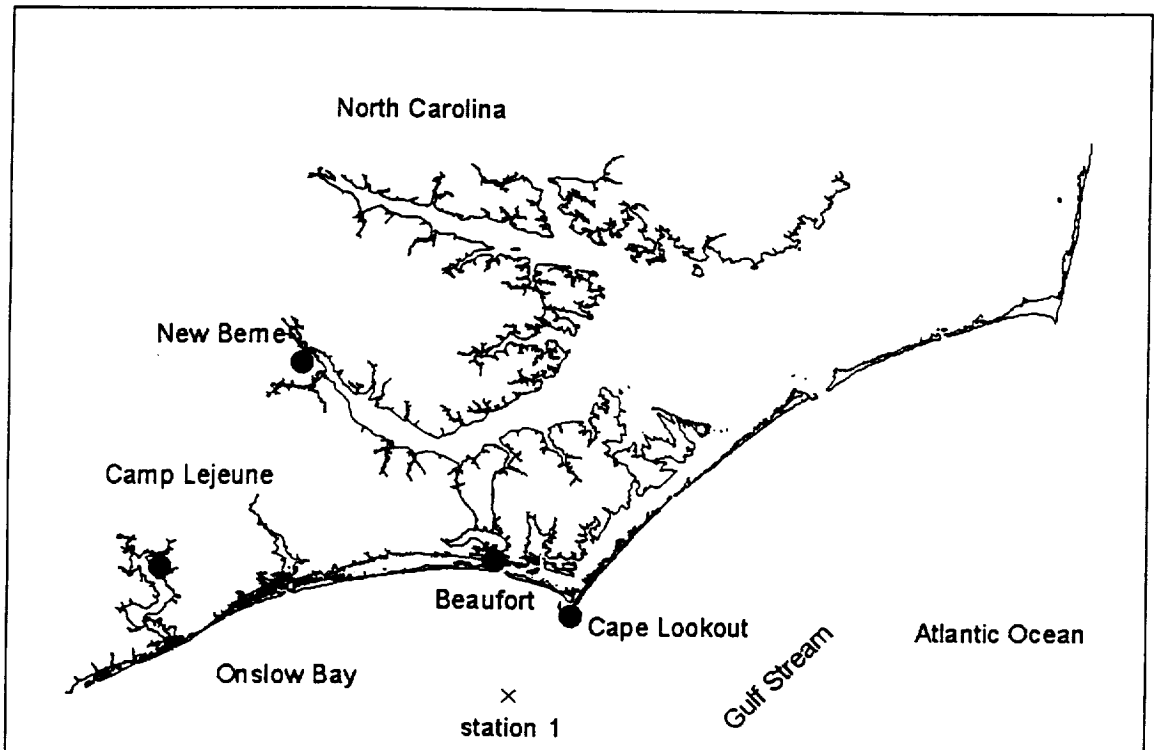

Figure 1. Location of Station 1, Occupied at 11:05 A.M. EST on 13 March 1997.

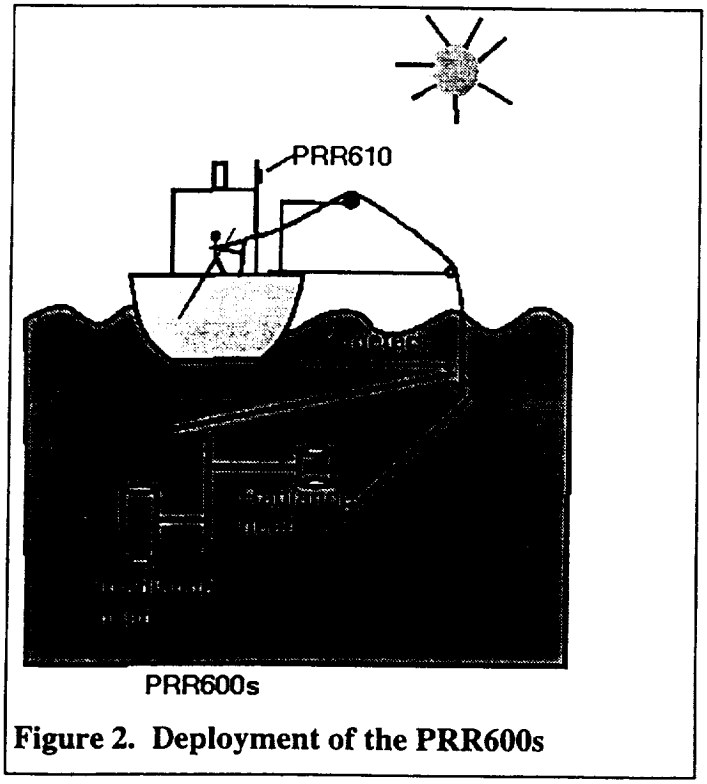

Figure 2. Deployment of the PRR600s

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

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

E. Bottle Samples

The chlorophyll biomass was determined using a Turner Designs fluorometer (Parsons *et al.* 1984). Discrete surface water samples were obtained for chlorophyll analysis using a bucket, at the same time as the PRR cast. In the lab, 1 liter (l) of sea water was filtered through glass fiber GF/F filters which were then stored in 90 percent acetone in a freezer for about 24 hours. Then the filters were ground and the chlorophyll *a* and phaeopigment concentrations were determined using the formula given in Smith *et al.* 1981.

F. Optical Data Processing

The PRR data was processed using the Bermuda Bio-Optics Project (BBOP) processing software (Siegel *et al.* 1995). A least common denominator (LCD) file was created from the binary data files, the cast card files, the calibration files, and cruise notes. The LCD file header contains the metadata for the cast and includes information on the parameters sampled, parameters derived, filters used, and the statistical results of the regression used

to extrapolate to the sub-surface. An example header is presented in Appendix A. The pressure channel data was recalculated using an offset to adjust for the distance of the pressure sensor from the cosine collector. The tops and bottoms of the individual profiles were marked using an interactive Matlab® script and the corresponding record numbers were inserted into the LCD header section. Data less than the dark threshold was replaced by -9.9×10^{35}. Then the data was quality controlled using flags for data with tilt and roll angles greater than 10°, and records in which the surface incident irradiance was not uniform. The temperature channel was despiked, in two passes with a difference threshold. A moving average was calculated for the temperature channel. The data were separated into upcast and downcast profiles and then binned to 0.5-m bins. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface, and spectral attenuation coefficients were calculated for the optical channels over a 5 point moving window.

IV. Results

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

A. Pigment Analyses

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

B. Optical data

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

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

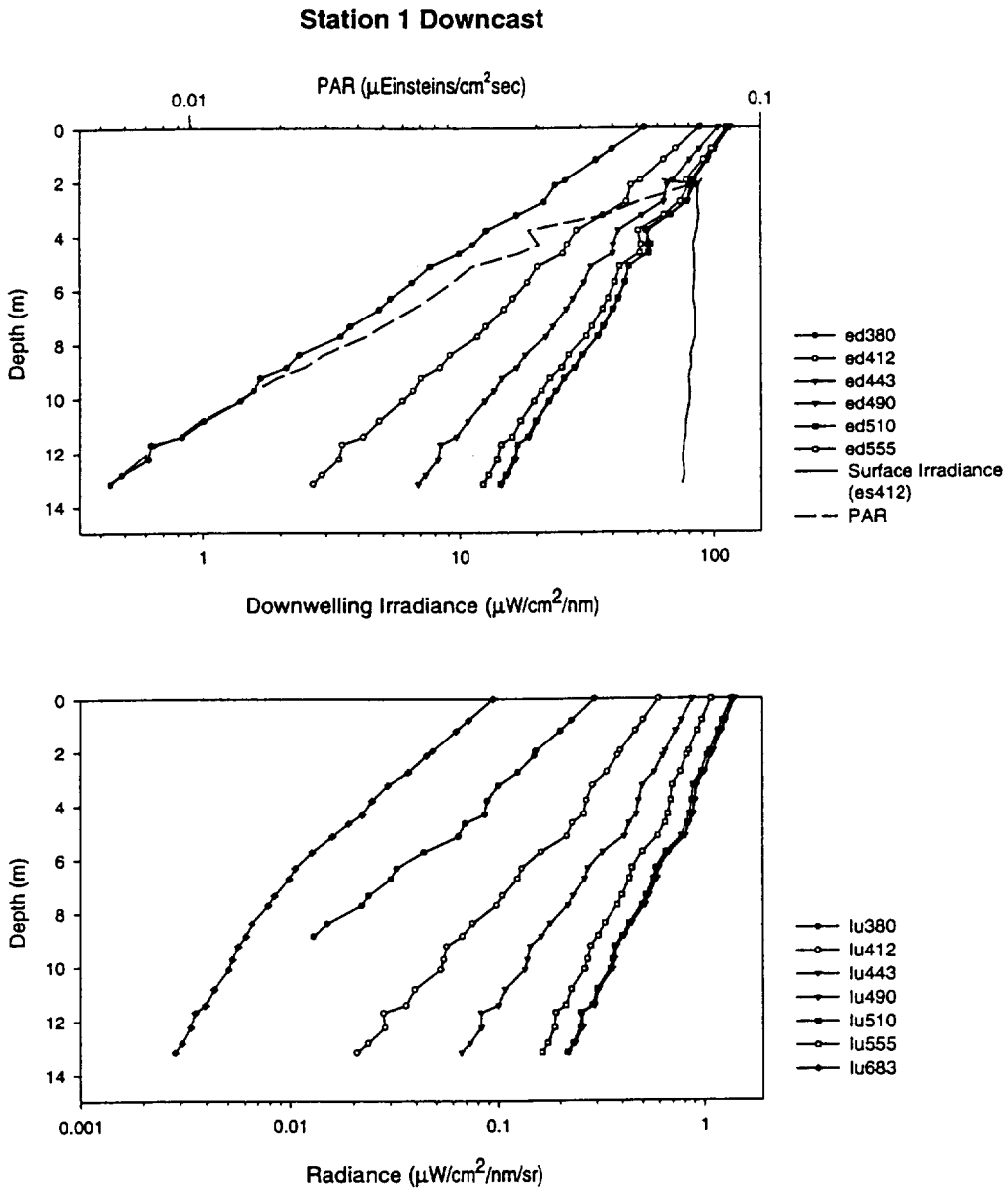

Figure 3. Optical Profiles at Station 1 - Downcast

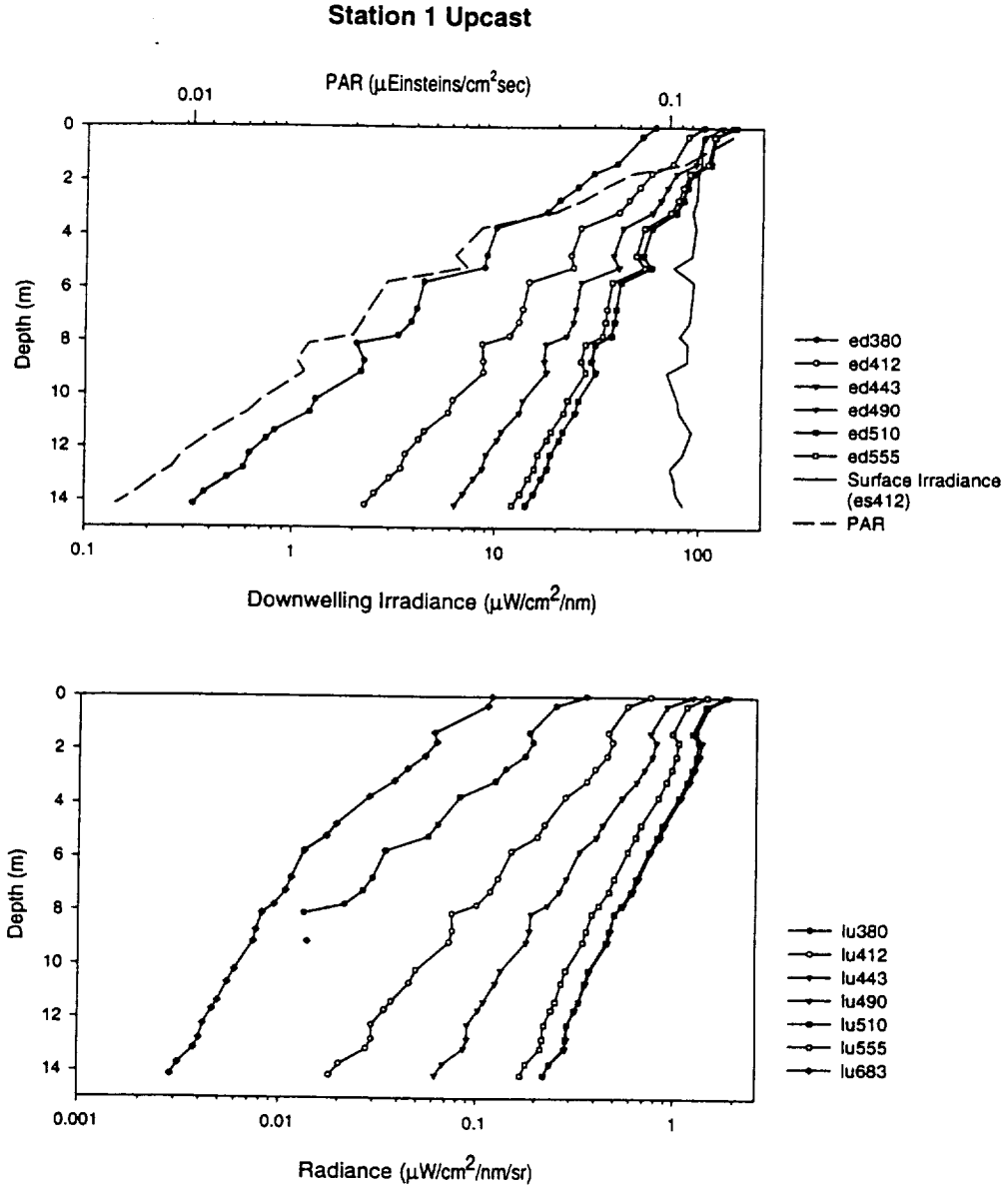

Figure 4. Optical Profiles at Station 1 - Upcast

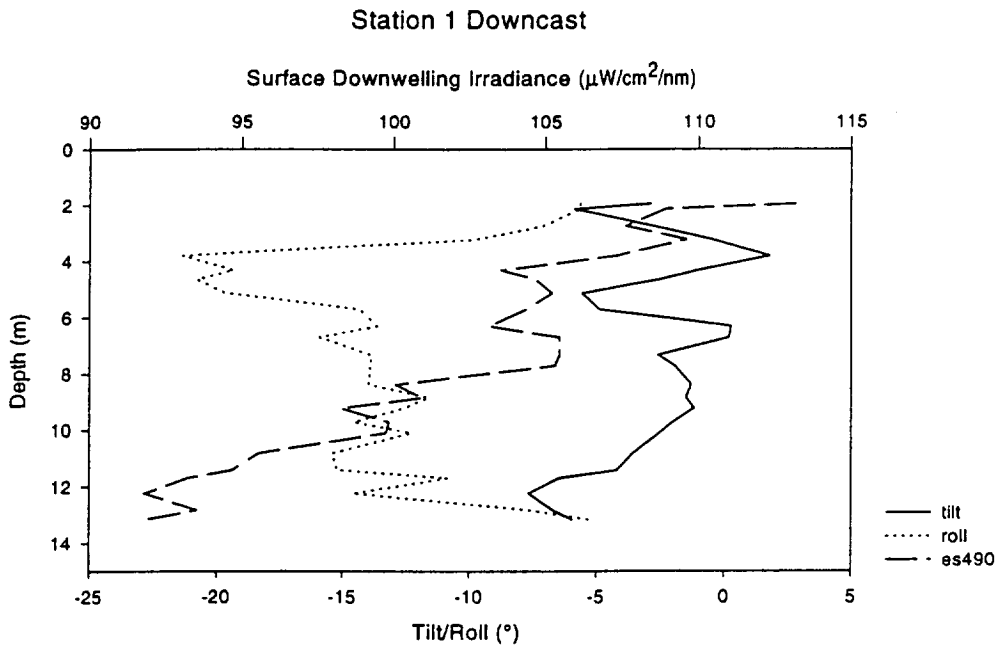

Figure 5. Profiles of Tilt, Roll and Downwelling Surface Irradiance - Downcast

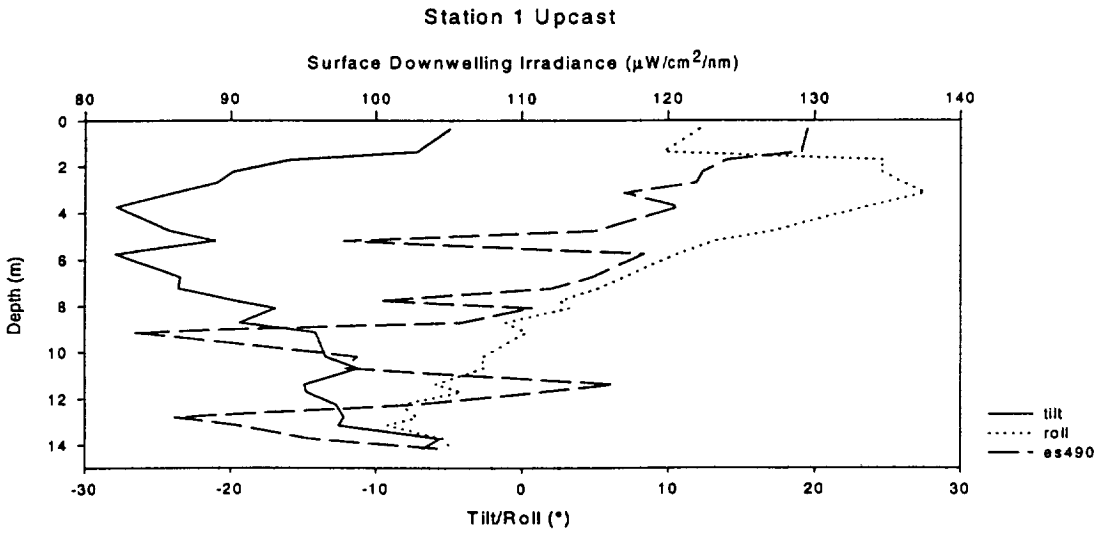

Figure 6. Profiles of Tilt, Roll and Downwelling Surface Irradiance - Upcast

Table 2. Sub-surface Light

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

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

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

where:

- $(L_w)_N$ is the normalized water leaving radiance
- ρ is the Fresnel reflectance of the sea surface for normal incidence, here = 0.021
- $\overline{\rho}$ is the Fresnel reflection albedo of the sea surface for irradiance from the sun and sky, here = 0.043

- F_0 is the mean extraterrestrial solar irradiance, here $F_{0(385)}$=94.5, $F_{0(415)}$=170, $F_{0(445)}$=192.8, $F_{0(490)}$=192.2, $F_{0(515)}$=183.1, $F_{0(555)}$=184.1, $F_{0(675)}$=151.6 (from [Labs and Neckel 1970])
- L_u is the sub-surface upwelling radiance calculated from optical profile
- E_d is the sub-surface downwelling irradiance calculated from optical profile
- m is the refractive index of sea water, here = 1.34
- r is the water-air reflectance for totally diffuse irradiance, here = 0.48
- Q is the ratio of the upwelling radiance to the upwelling irradiance towards the zenith, here = 5.07

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

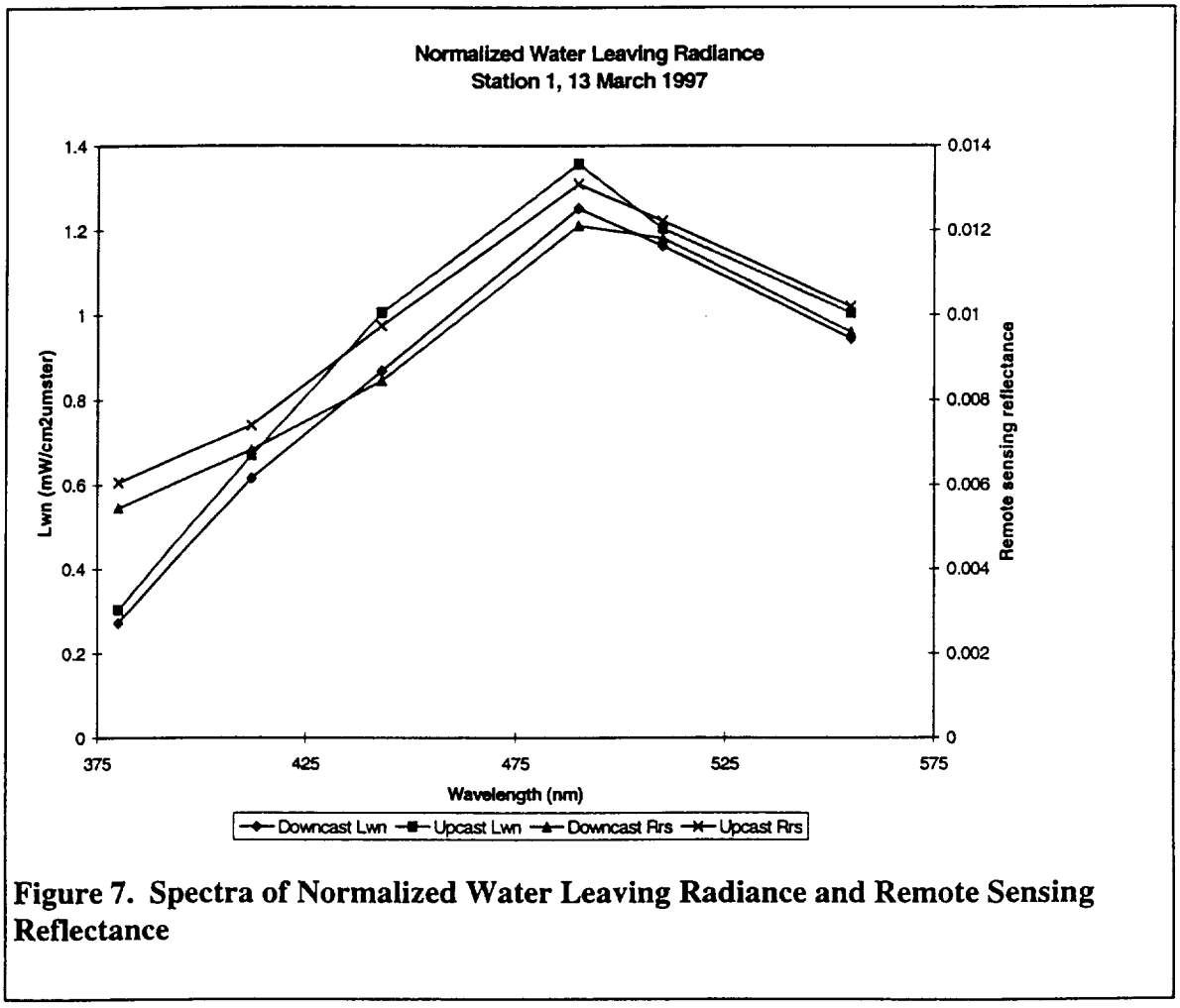

Figure 7. Spectra of Normalized Water Leaving Radiance and Remote Sensing Reflectance

Table 3. Normalized Water Leaving Radiance and Remote Sensing Reflectance

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

V. References

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

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

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

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

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

VI. Metadata

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

A. Core Documentation

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

Description
Abstract: See Abstract, page iii

Purpose: See Objectives, page 1

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

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

Status
Progress: Complete
Maintenance_and_Update_Frequency: Unknown

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

Keywords
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: Beaufort, NC
Place_Keyword: South Atlantic Bight
Place_Keyword: United States
Time
Temporal_Keyword: Spring
Temporal_Keyword: March, 1997
Parameters measured
Parameter_Keyword: spectral downwelling irradiance
Parameter_Keyword: spectral upwelling radiance
Parameter_Keyword: temperature

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

B. Citation Information

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

Currentness: May 1997

Access Constraints: None

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

Methods reference: Parsons, T. R., Y. Maita and C. M. Lalli (1984). *A manual for chemical and biological methods for seawater analysis*, Pergamon Press. Pp107-110.
Variations: Smith, R. C., K. S. Baker and P. Dustan (1981). Fluorometric Techniques for the Measurement of Oceanic Chlorophyll in the Support of Remote Sensing. *SIO Ref. 81-17*, Visibility Laboratory, Scripps Institution of Oceanography, La Jolla, CA 92093, 14 pp.
Analyst: Elin Haugen
Address: National Marine Fisheries Service
Southeast Fisheries Science Center - Beaufort Laboratory
101 Pivers Island Road
Beaufort, NC 28516-9722
Telephone: (919) 728.2747

Attribute Accuracy: See Appendix B

Spectroradiometer Calibration:

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

Horizontal Positional Accuracy: 400 m

Entity and Attribute Overview Description: See Methods, page 2

D. Metadata Reference Information

Metadata Date:

Contact Organization: NOAA/Coastal Services Center

Contact Person: 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)
wind_speed_and_dir 20 kts? north-northeast
swell 5-6ft
collection_software_version prrprof_002086c
number_units 1
collection_cal_file 96439644.cfl;prr-600 #9643/9644 calibration file 2/10/96 cac
lcd_calib_file 0 /csc/nep1/coors/bbops/BUILD/calib/unit0_021097.cfl
1 /csc/nep1/coors/bbops/BUILD/calib/unit1_021097.cfl
2 /csc/nep1/coors/bbops/BUILD/calib/unit2_021097.cfl
lcdfile_created Mar 19 1997 16:59:38

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p970313a.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

<sampled_parameters>
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1ed510 0 -0.022313 0.000171
1ed555 0 -0.022801 0.00048
1par 0 -9.05594 0.000371
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1tilt 0 0.04178 2.68617
1roll 0 0.041514 2.69727
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2lu490 0 -0.996381 0.00016
2lu510 0 -1.24348 0.00033
2lu555 0 -1.74733 0.000162
2lu683 0 -1.52118 0.000105
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3es490 0 -0.032938 -0.000256
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m-d-d-1temp
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ptsbin_0.5
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kc-1ed412
kc-1ed443
kc-1ed490
kc-1ed510

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bbopradq -fa 3es380 1.000000e-04 p970313a.lcd outqp970313a.lcd
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bbopradq -fa 3es443 1.000000e-03 p970313a.lcd outqp970313a.lcd
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bbopradq -fa 2lu412 1.000000e-02 p970313a.lcd outqp970313a.lcd
bbopradq -fa 2lu443 1.000000e-03 p970313a.lcd outqp970313a.lcd
bbopradq -fa 2lu490 1.000000e-03 p970313a.lcd outqp970313a.lcd
bbopradq -fa 2lu510 1.000000e-03 p970313a.lcd outqp970313a.lcd
bbopradq -fa 2lu555 2.000000e-04 p970313a.lcd outqp970313a.lcd
bbopradq -fa 2lu683 2.000000e-04 p970313a.lcd outqp970313a.lcd
bbopangq 1Tilt 1Roll 10 2 inqp970313a.lcd outqp970313a.lcd
bbopdespike -d 1temp 0.05 10 indqp970313a.lcd outdqp970313a.lcd
bbopdespike -d d-1temp 0.05 10 indqp970313a.lcd outdqp970313a.lcd
bbopmovavg -f d-d-1temp 5.0 dqp970313a.lcd mdqp970313a.lcd
bbopbin -b 0.5 mdqp970313a.lcd
bbopkc -s 1ed380 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
bbopkc -s 1ed412 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
bbopkc -s 1ed443 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
bbopkc -s 1ed490 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1
bbopkc -s 1ed510 5 inkbmdqp970313a.lcd.1 outkbmdqp970313a.lcd.1

VIII. Appendix B - Calibration Certificates

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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

Ch	Tag	λ (nm)	Lamp Irradiance	Immersion Coefficient	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/μW)	Calibration Factor - Wet (V/μW)	Max E (Dry)	
DOWNWELLING IRRADIANCE CHANNELS						Irradiance Units: μW/cm²·nm, E = Irradiance				
1	0	380	1.397	0.671	0.000132	-0.018129	-0.013074	-0.008775	764.9	
2	0	412	2.411	0.677	0.000516	-0.077541	-0.032371	-0.021906	308.9	
3	0	443	3.701	0.682	0.000113	-0.120950	-0.032714	-0.022313	305.7	
4	0	490	6.159	0.690	0.000302	-0.209334	-0.034039	-0.023491	293.8	
5	0	510	7.302	0.694	0.000168	-0.240489	-0.032957	-0.022859	303.4	
6	0	555	10.041	0.701	0.000465	-0.332822	-0.033194	-0.023279	301.3	
7	0	PAR[4]	0.0142	0.686	0.000330	-0.194557	-13.767821	-9.442522	0.726	[4]
8	0	Gnd.[5]	0.000291	Volts						

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

Ch	Tag	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient	Plaque Reflectivity	Radiance[6]	Calibration Voltage - Dark	Calibration Voltage - Blocked[3]	Calibration Voltage - Light	Calibration Factor - Wet (V/μW)	Max L (Wet)
UPWELLING RADIANCE CHANNELS						Radiance Units: μW/cm²·nm·sr, L = Radiance					
1	1	380	1.397	1.765	0.985	0.012	0.000221	0.000214	-0.003021	-0.150639	66.4
2	1	412	2.411	1.758	0.985	0.021	-0.000068	-0.000079	-0.018727	-0.505131	19.8
3	1	443	3.701	1.752	0.985	0.032	0.000233	0.000215	-0.050659	-0.900887	11.1
4	1	490	6.159	1.745	0.984	0.054	0.000180	0.000150	-0.092345	-0.988998	10.1
5	1	510	7.302	1.743	0.984	0.064	0.000363	0.000337	-0.136471	-1.235454	8.1
6	1	555	10.041	1.738	0.984	0.087	0.000180	0.000128	-0.263356	-1.734900	5.8
7	1	683	16.897	1.730	0.984	0.147	0.000095	-0.000003	-0.394184	-1.550051	6.5
8	1	Gnd.[5]	0.000190	Volts							

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

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

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

	Irr. Array	Rad. Array
Scale Factor	1.057679	1.074227
Offset	0.000206	0.000278
Full Scale Voltage	9.4547	9.3090

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

OPTIONAL CHANNELS

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

Notes:

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

Biospherical Instruments Inc.

EVALUATION FORM for PRR Spectroradiometer

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

Model Number: PRV-600S

Serial Number: 9643

Operator: JCE/LFG

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

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

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

DRY = (Light - Dark)/Lamp Output

Ch	Tag	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient	Plaque Reflectivity	Radiance[6]	Calibration Voltage - Dark	Calibration Voltage - Blocked[3]	Calibration Voltage - Light	Calibration Factor - Wet (V/μW)	Max L (Wet)
UPWELLING RADIANCE CHANNELS						Radiance Units: μW/cm²·nm·sr, L = Radiance					
1	1	380	1.308	1.765	0.985	0.011	0.000133	0.000133	-0.002922	-0.151959	65.8
2	1	412	2.275	1.758	0.985	0.020	0.000209	0.000202	-0.017559	-0.509911	19.6
3	1	443	3.514	1.752	0.985	0.031	0.000192	0.000186	-0.048676	-0.911268	11.0
4	1	490	5.911	1.745	0.984	0.051	0.000122	0.000106	-0.090184	-1.005825	9.9
5	1	510	7.038	1.743	0.984	0.061	0.000272	0.000261	-0.133038	-1.248987	8.0
6	1	555	9.746	1.738	0.984	0.085	0.000124	0.000083	-0.258677	-1.755312	5.7
7	1	683	16.755	1.730	0.984	0.146	0.000027	-0.000057	-0.392216	-1.555169	6.4
8	1	Gnd.[5]	0.000124	Volts							

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

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

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

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

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

	Irr. Array	Rad. Array
Scale Factor	1.057679	1.074227
Offset	0.000206	0.000278
Full Scale Voltage	9.4647	9.3090

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2766B	2043A

Notes:

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

OPTIONAL CHANNELS

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

Notes:

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

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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.

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

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

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

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

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

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

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

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

Form: 2/18/97

OPTIONAL CHANNELS

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

Notes:

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

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

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

CSC Technical Report CSC/2-98/001

NOAA NMFS Cruise MAY97OB: Onslow Bay and Pamlico Sound Cruise

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February 1998

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

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.

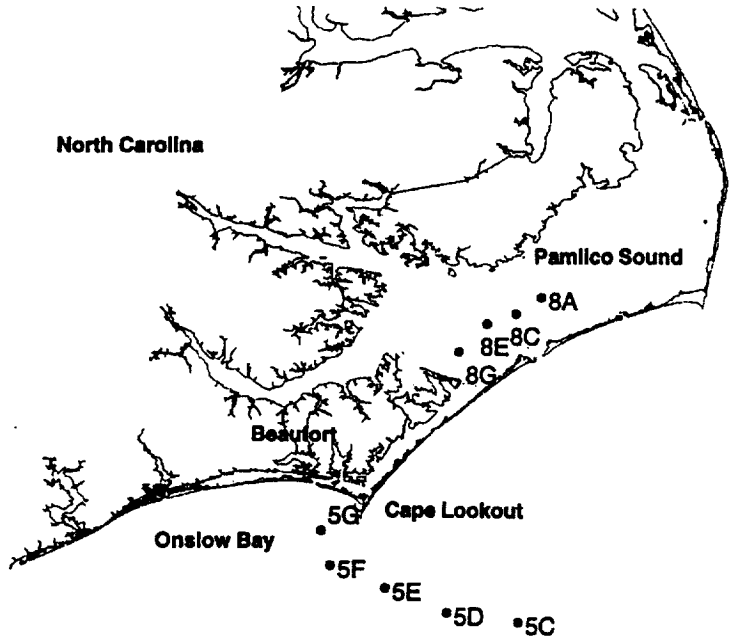

Figure 1. Location of stations

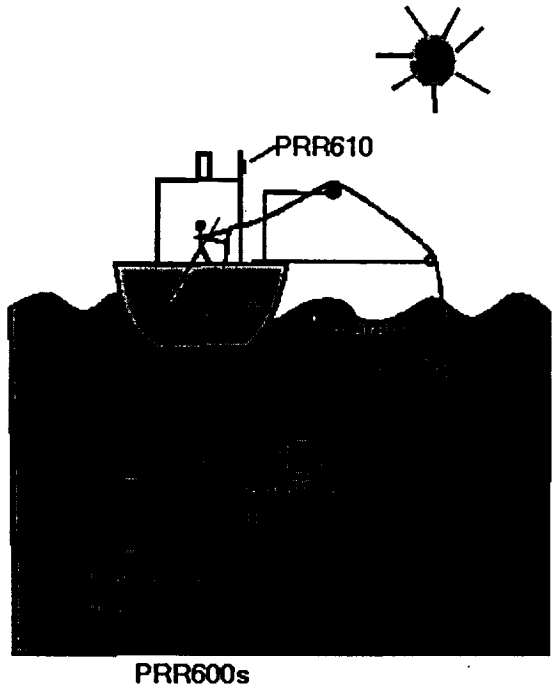

Figure 2. Deployment of the PRR600s

Table 1. Station locations

Date	Station	Latitude	Longitude	Time	Total Depth (m)	Air Temperature (C)	ChlF VolFilt (ml)	HPLC VolFilt (ml)	Ap VolFilt (ml)	TSS VolFilt (ml)	PRR File name
5/5/97	5C	34.278	-76.068	14:00	20	20	1000	2000	1000	2000	P970505C
5/5/97	5D	34.305	-76.280	15:20	18	19	1000	1000	750	2000	P970505D
5/5/97	5E	34.378	-76.462	16:20	12	19	500	750	400	2000	P970505E
5/5/97	5F	34.446	-76.622	17:15	19	19	300	1000	300	1500	P970505F
5/5/97	5G	34.552	-76.650	18:40			200	1000	200	1500	P970505G
5/8/97	8A	35.247	-76.009	12:40	6	20	100	200	150	500	P970508A
5/8/97	8C	35.197	-76.084	13:20	13	20	100	200	150	500	P970508C
5/8/97	8E	35.166	-76.168	13:40	22		100	200	150	500	P970508E
5/8/97	8G	35.083	-76.251	14:10	7	20	100	200	150	500	P970508G

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

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

E. Bottle Samples

The chlorophyll biomass was determined using a Turner Designs fluorometer (Parsons *et al.* 1984). The TSS concentration was measured as described by Parsons *et al.* (1984). Phytoplankton pigment concentrations were determined 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 -9.9×10^{35}. Then the data was quality controlled using flags for data with tilt and roll angles greater than 10°, and records in which the surface incident irradiance was not uniform. The temperature channel was despiked, in two passes with a difference threshold. A moving average was calculated for the temperature channel. The data were separated into upcast and downcast profiles and then binned to 0.5-m bins. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface, and spectral attenuation coefficients were calculated for the optical channels over a 5 point moving window.

IV. Results

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 3. Pigment Analyses

Date	Station	Latitude	Longitude	TSS	Chl	Fuco	19'-hex	Didino	Zea	chl – a	beta-car
				mg/L	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
5/5/97	5C	34.278	-76.068	3.75	0.229	0.038	0.013	0.016	0.012	0.138	0.000
5/5/97	5D	34.305	-76.280	5.75	0.256	0.040	0.006	0.036	0.017	0.151	0.0116
5/5/97	5E	34.378	-76.462	6.25	0.499	0.133	0.006	0.053	0.000	0.259	0.000
5/5/97	5F	34.446	-76.622	8.00	0.269	0.051	0.017	0.035	0.020	0.145	0.000
5/5/97	5G	34.552	-76.650	13.67	0.433	0.109	0.000	0.060	0.020	0.249	0.000
5/8/97	8A	35.247	-76.009	18	4.538	0.406	0.000	0.235	0.253	2.612	0.172
5/8/97	8C	35.197	-76.084	18	3.673	0.372	0.000	0.216	0.327	1.990	0.169
5/8/97	8E	35.166	-76.168	14	3.592	0.381	0.000	0.156	0.403	1.803	0.157
5/8/97	8G	35.083	-76.251	9	4.302	0.449	0.000	0.222	0.445	2.115	0.184

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

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

Algorithm Evaluation

The downwelling irradiance and upwelling radiance were extrapolated to the null depth just below the surface (E_{0^-}) by the BBOP software. The downwelling irradiance was propagated through the water-air interface using a transmission loss of 4% (SeaBAM

Tech memo). The upwelling radiance was propagated through water-air interface using a factor of 0.544 (SeaBAM Tech memo). The above water (E_0+) downwelling irradiance and upwelling radiance are shown in Table 5 (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 5 Algorithm Evaluation

Station	5C	5D	5E	5F	5F	5G
Date	5/5/97	5/5/97	5/5/97	5/5/97	5/5/97	5/5/97
Time GMT	18:00	19:15	20:15	22:10	22:10	23:40
Latitude	34.278	34.305	34.378	34.446	34.446	34.552
Longitude	-76.068	-76.280	-76.462	-76.622	-76.622	-76.650
TSS mg/L	3.75	5.75	6.25	8.00	8.00	13.67
ChlF ug/l	0.229	0.256	0.499	0.269	0.269	0.433
Chla HPLC	0.138	0.151	0.259	0.145	0.145	0.249
Ed+380	71.2525	57.9345	55.8263	38.6623	32.2810	9.6688
Ed+412	153.0960	89.7019	92.7574	74.6242	55.7885	18.0764
Ed+443	164.0670	104.7570	113.7230	105.5370	67.8250	23.5997
Ed+490	139.4370	128.5790	140.8620	130.8590	76.3379	26.9401
Ed+510	153.6910	169.2120	138.1630	129.8870	76.5869	26.8790
Ed+555	162.0340	122.3720	121.1700	131.8190	77.4048	26.0929
Lu+380	0.8738	0.5479	0.2631	0.2785	0.2634	0.0639
Lu+412	1.2947	1.0677	0.5910	0.5690	0.5495	0.1576
Lu+443	1.4229	1.3529	0.8888	0.7674	0.7504	0.2365
Lu+490	1.3547	1.5615	1.3460	0.9808	0.9676	0.3525
Lu+510	0.9839	1.1747	1.2111	0.7811	0.7504	0.3173
Lu+555	0.5018	0.6169	0.8648	0.4509	0.4216	0.2264
Lu+683	0.0392	0.0398	0.0738	0.0400	0.0362	0.0270
Es380	83.0804	54.0220	52.4726	31.9462	39.4985	12.2564
Es412	128.1168	80.9772	82.2762	49.2976	64.1512	20.7618
Es443	150.2051	92.4450	96.9226	57.0165	76.7487	25.7060
Es490	161.1108	96.0821	105.0866	60.4339	84.7890	29.7159
Es510	162.8269	96.4733	106.8868	61.1946	86.7237	30.7507
Es555	159.0002	93.2918	105.5142	59.6442	86.5069	31.2249
Es380Err	1.6%	25.3%	4.0%	21.4%	1.4%	1.8%
Es412Err	1.8%	29.0%	4.5%	27.0%	1.6%	3.3%
Es443Err	1.9%	32.0%	4.9%	31.6%	1:8%	4.3%
Es490Err	2.0%	35.9%	5.6%	37.7%	1.9%	6.0%

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%	
Rrs490	0.0045	0.0088	0.0069	0.0088	0.0062	0.0064	
Rrs555	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
Date	5/8/97	5/8/97	5/8/97	5/8/97	5/8/97	5/8/97	5/8/97
Time GMT	17:40	17:40	18:25	18:25	18:40	18:40	19:10
Latitude	35.247	35.247	35.197	35.197	35.166	35.166	35.083
Longitude	-76.009	-76.009	-76.084	-76.084	-76.168	-76.168	-76.251
TSS mg/L	18	18	18	18	14	14	9
ChlF ug/l	4.538	4.538	3.673	3.673	3.592	3.592	4.302
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	234.1050	269.8040	245.0660	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
Ed+555	257.6770	247.4940	157.9700	169.5560	189.4350	178.1250	231.9300
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+555	3.2769	3.5099	2.6968	3.2705	3.1114	3.1965	3.2732
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%

Es490Err	1.3%	0.5%	0.7%	0.6%	0.8%	0.1%	0.2%
Es510Err	1.4%	0.5%	0.8%	0.6%	0.9%	0.1%	0.2%
Es555Err	1.3%	0.5%	0.9%	0.6%	0.9%	0.1%	0.2%
ds380	-355%		80%	-211%			-263%
ds412	-239%	-197%	34%	-118%			-252%
ds443	-133%	-114%	-2%	-68%	-98%	-81%	-232%
ds490	-76%	-92%	-11%	-38%	-58%	-46%	-114%
ds510	-82%	-93%	-14%	-28%	-49%	-40%	-90%
ds555	-72%	-60%	-8%	-17%	-33%	-25%	-68%
Rrs490	0.0080	0.0082	0.0049	0.0071	0.0071	0.0071	0.0082
Rrs555	0.0113	0.0118	0.0096	0.0117	0.0113	0.0116	0.0123
OC2-Chla	7.3411	7.8825	31.3484	13.7258	12.1142	13.2971	9.4240
CZCS Pig	9.4526	10.1353	39.2099	17.4539	15.4431	16.9194	12.0741
MeasChla	2.612	2.612	1.990	1.990	1.803	1.803	2.115
sat/meas	2.81	3.02	15.75	6.90	6.72	7.37	4.46
MeasPig	4.538	4.538	3.673	3.673	3.592	3.592	4.302
sat/meas	2.08	2.23	10.67	4.75	4.30	4.71	2.81

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

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

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

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

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

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:
StartDate: 19970505
StopDate: 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

Country: USA
Contact_Voice_Telephone: (800)789-2234
Contact_Electronic_Mail_Address: crs@csc.noaa.gov
Hours_of_Service: 8 a.m.-5 p.m., M-F

B. Citation Information

Source Citation: Subramaniam, A., M.E. Culver, J.C. Brock, P.A. Tester, E. Haugen, and R.P. Stumpf. 1998. NOAA NMFS Cruise MAY97OB: Onslow Bay and Pamlico Sound Cruise. CSC Technical Report CSC/2-98/001. NOAA Coastal Services Center. Charleston, SC. Pp18.

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:
Methods reference: Parsons, T. R., Y. Maita and C. M. Lalli (1984). *A manual for chemical and biological methods for seawater analysis*, Pergamon Press. Pp107-110.
Variations: Smith, R. C., K. S. Baker and P. Dustan (1981). Fluorometric Techniques for the Measurement of Oceanic Chlorophyll in the Support of Remote Sensing. *SIO Ref. 81-17,* Visibility Laboratory, Scripps Institution of Oceanography, La Jolla, CA 92093, 14 pp.
Analyst: Elin Haugen
Address: National Marine Fisheries Service

Southeast Fisheries Science Center - Beaufort Laboratory
101 Pivers Island Road
Beaufort, NC 28516-9722
Telephone: (919) 728.2747

Phytoplankton pigment measurements:
Methods reference: Tester, P.A., M.E. Geesey, C. Guo. H.W. Paerl and D.F. Millie (1995) Evaluating phytoplankton dynamics in the Newport River estuary (North Carolina, USA) by HPLC-derived pigment profiles. *Mar. Ecol. Prog. Ser.* **124**:237-245.
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)
wind_speed_and_dir 20 kts? north-northeast
swell 5-6ft
collection_software_version prrprof_002086c
number_units 1
collection_cal_file 96439644.cfl;prr-600 #9643/9644 calibration file 2/10/96 cac
lcd_calib_file 0 /csc/nep1/coors/bbops/BUILD/calib/unit0_021097.cfl
1 /csc/nep1/coors/bbops/BUILD/calib/unit1_021097.cfl
2 /csc/nep1/coors/bbops/BUILD/calib/unit2_021097.cfl
lcdfile_created Mar 19 1997 16:59:38
castid index 1prr_record 1depth
p970313a.dt1 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
<sampled_parameters>

1prr_record 1 1 0
1ed380 0 -0.008317 0.000146
1ed412 0 -0.021345 0.000551
1ed443 0 -0.021874 0.000189
1ed490 0 -0.02298 0.000282
1ed510 0 -0.022313 0.000171
1ed555 0 -0.022801 0.00048
1par 0 -9.05594 0.000371
1edgnd 0 1 0
1temp 0 0.1421 0.0889
1depth 0. 9.38300e-01 8.31773e+01 2.65899e+01 0.9383 83.1773 26.9099 0
0
1tilt 0 0.04178 2.68617
1roll 0 0.041514 2.69727
2lu380 0 -0.151929 0.000198
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
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3edgnd 0 1 0
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d-d-1temp
m-d-d-1temp
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kc-1ed490
kc-1ed510

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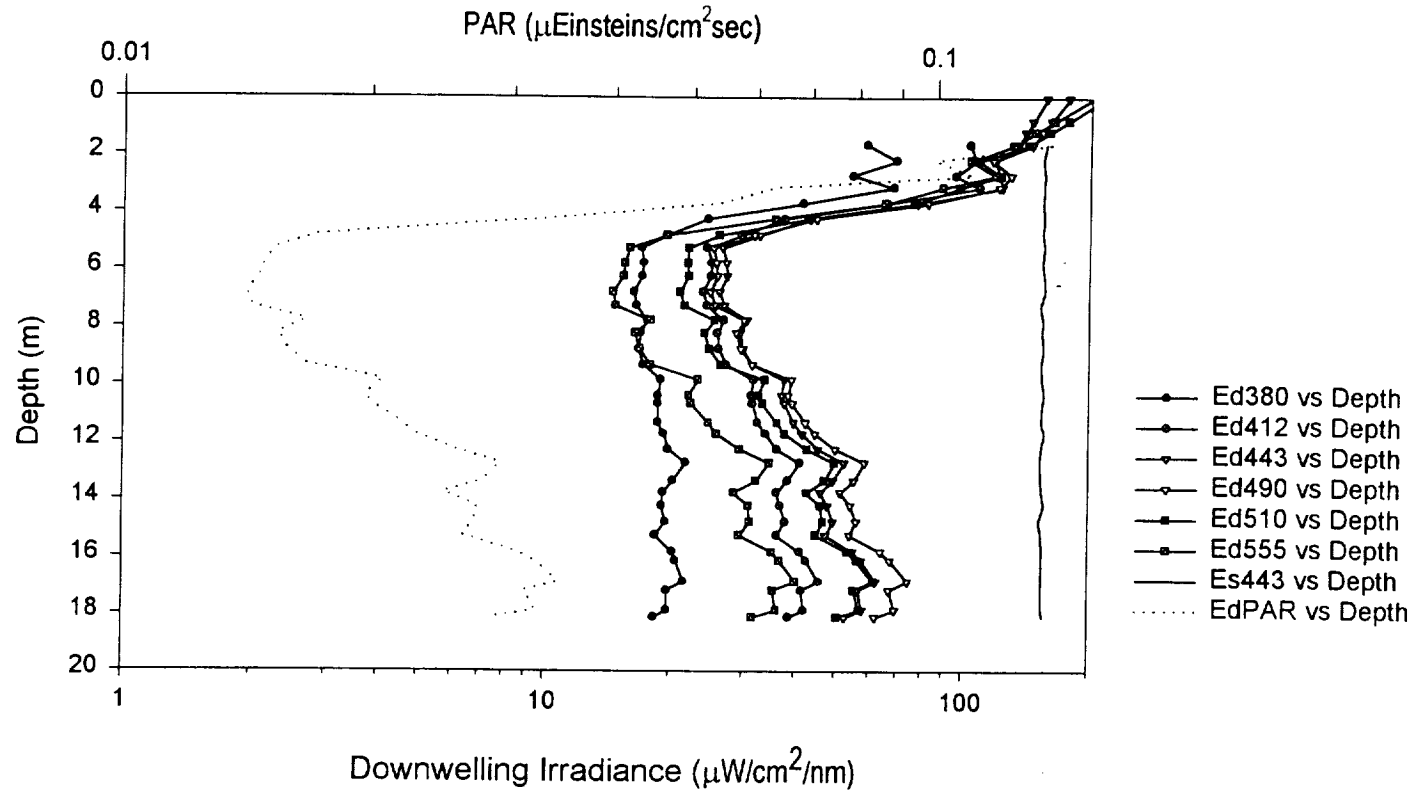
VIII. Appendix B - Calibration Certificates

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

Figure A.1.a - Station C Downcast



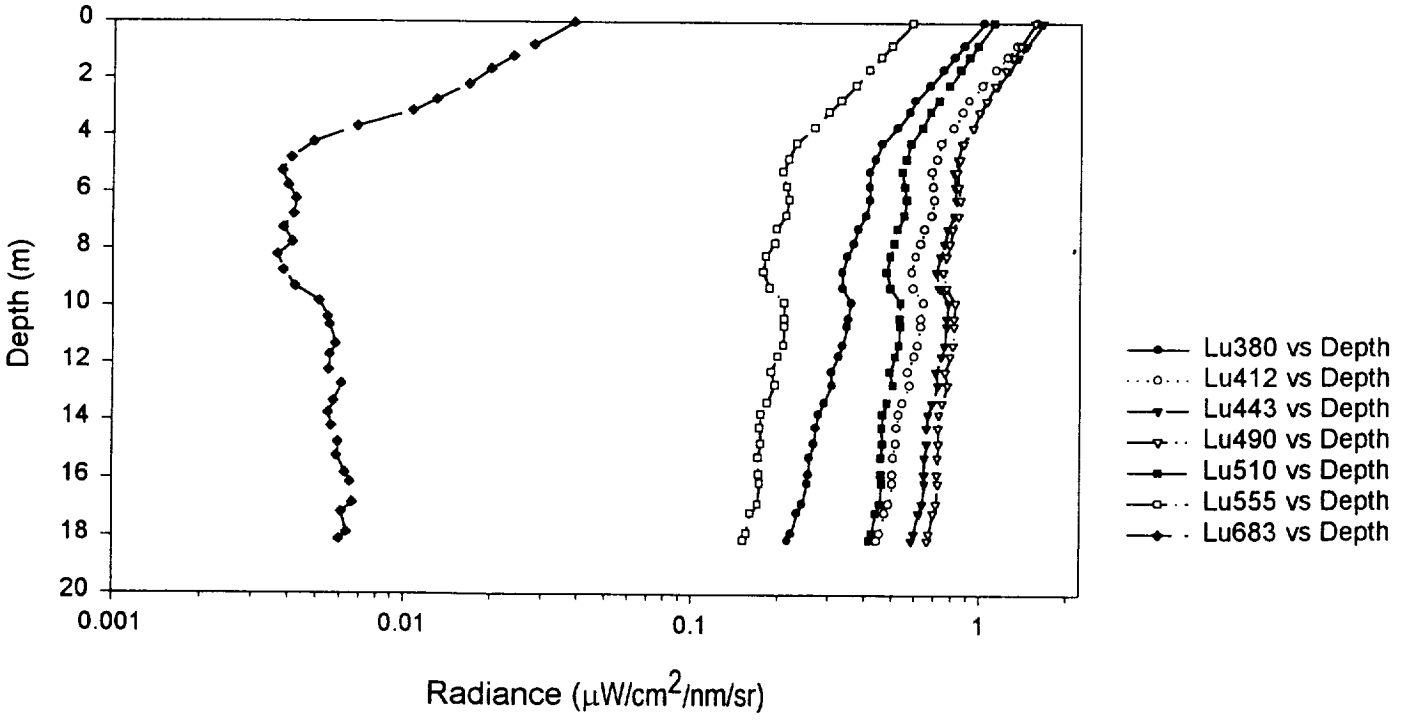
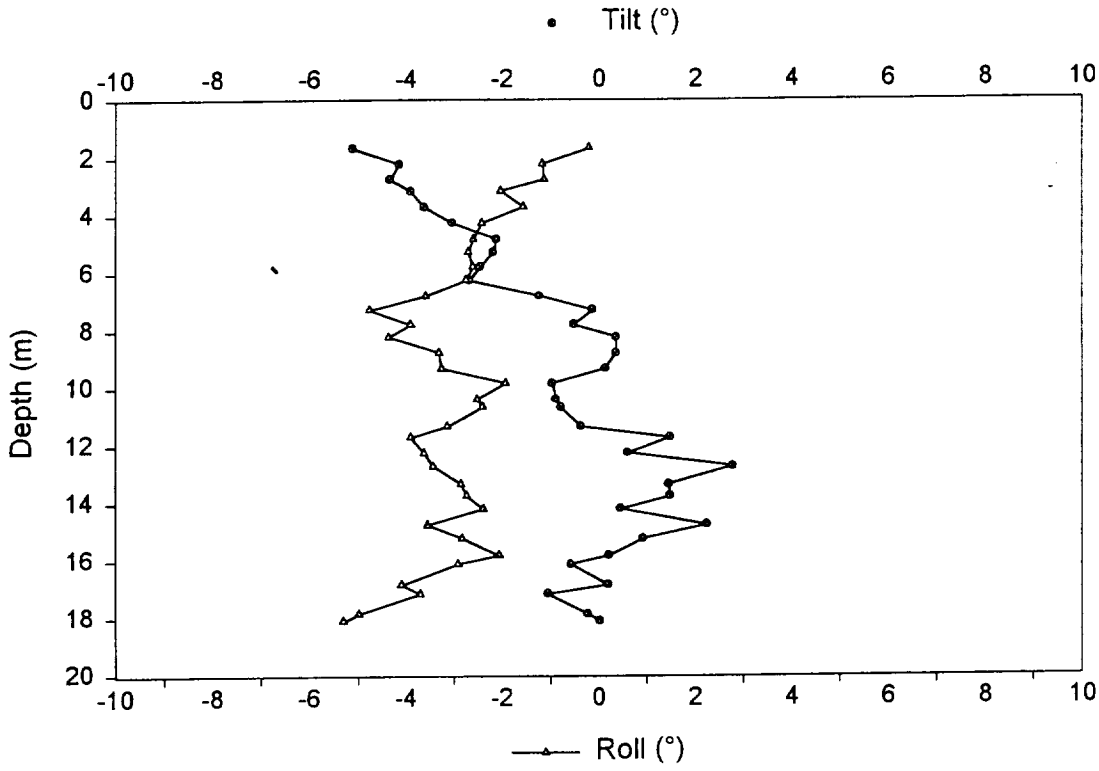


Figure A.1.b - Station C1 Downcast



Diffuse Attenuation Coefficient (kλ)

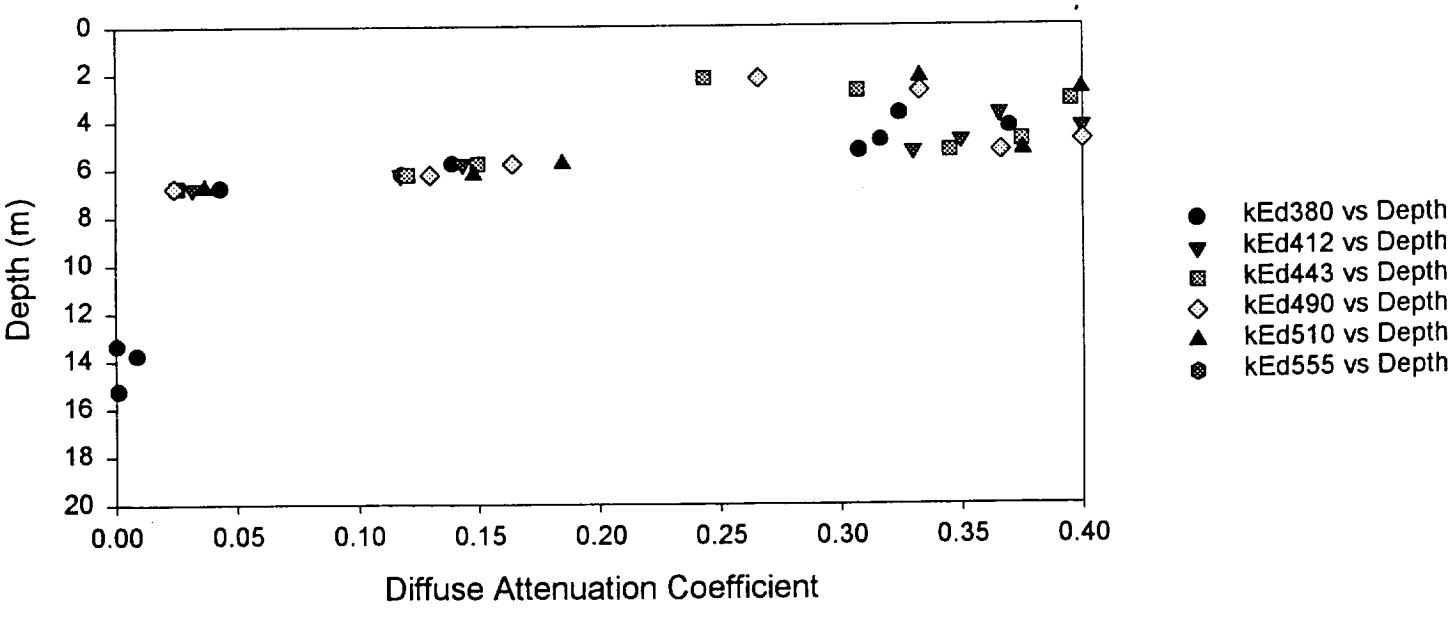
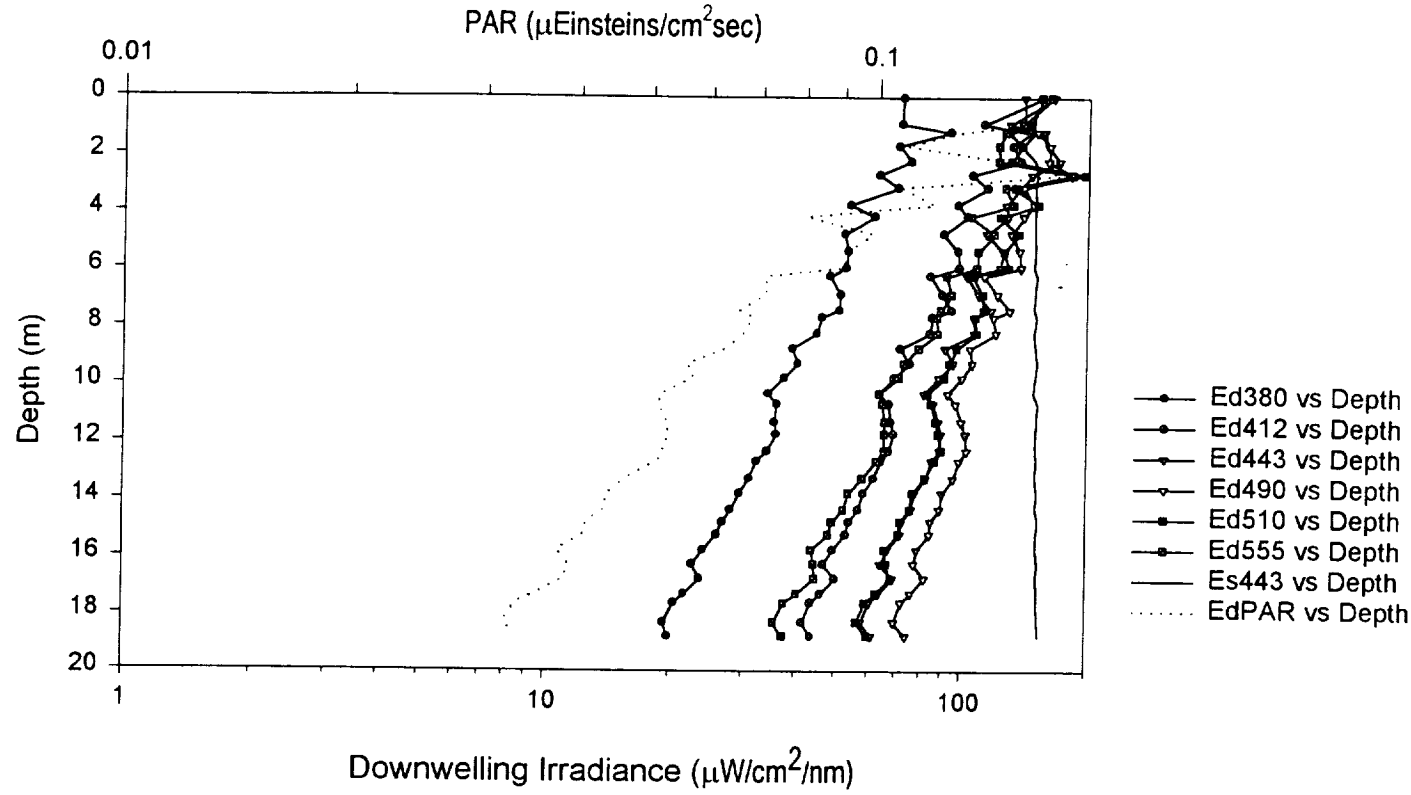


Figure A.2.a - Station C Upcast



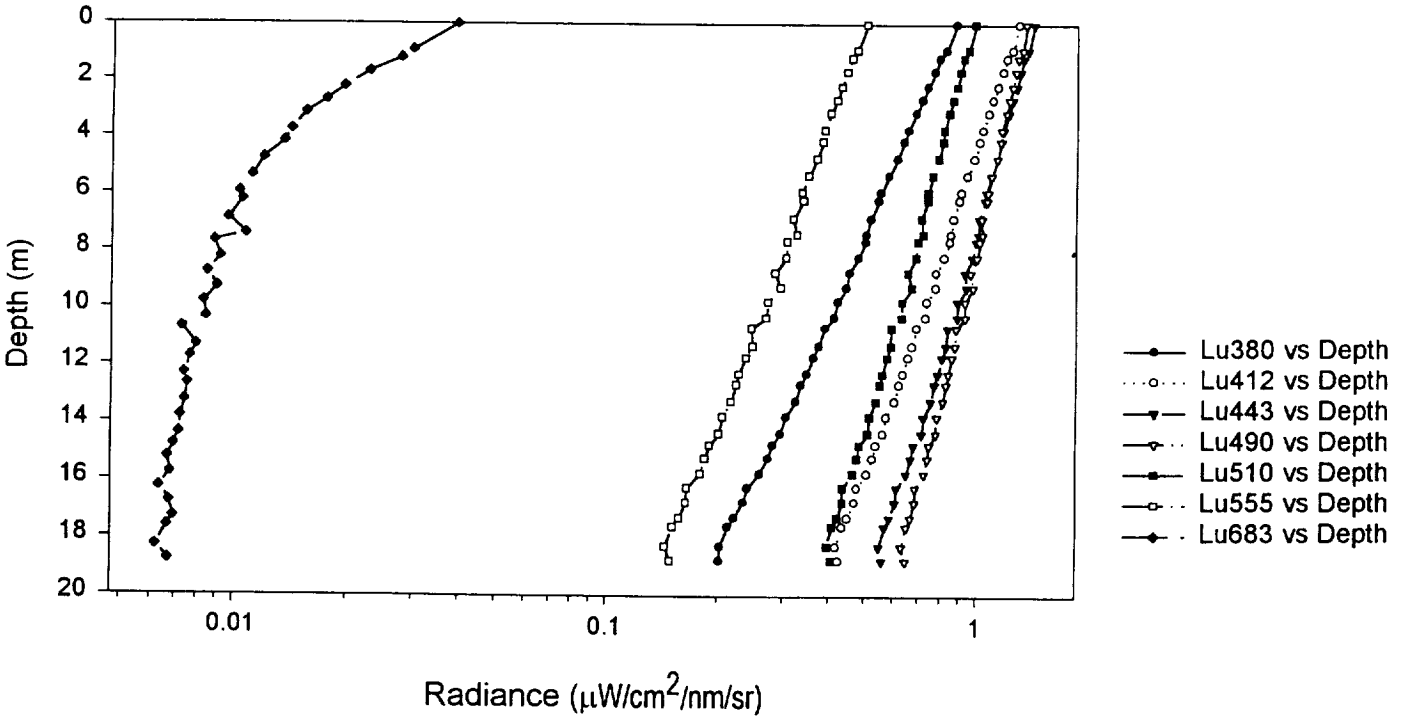
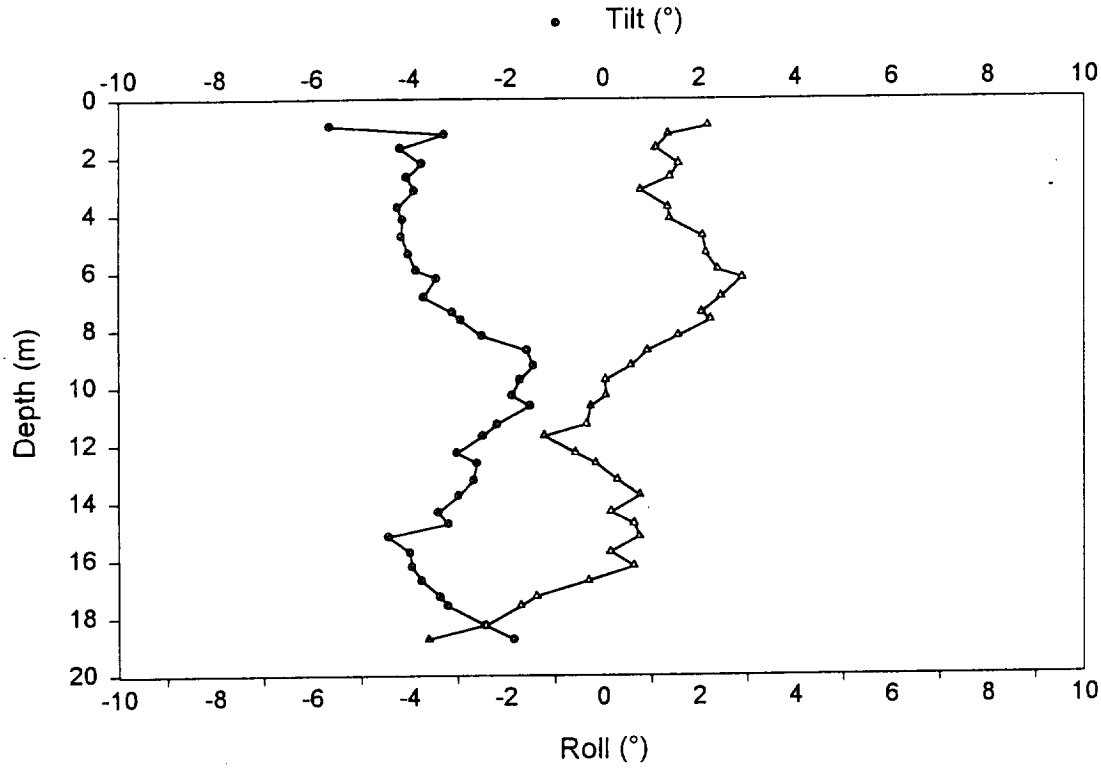


Figure A.2.b - Station C Upcast



Diffuse Attenuation Coefficient (kλ)

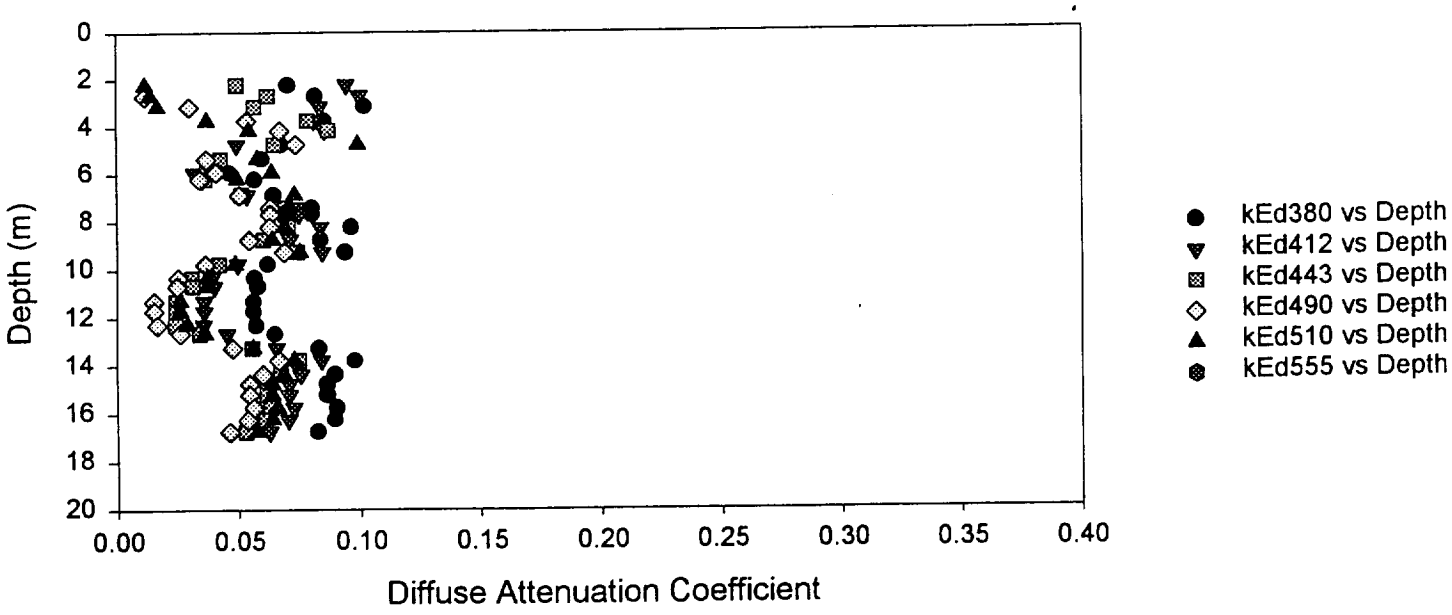
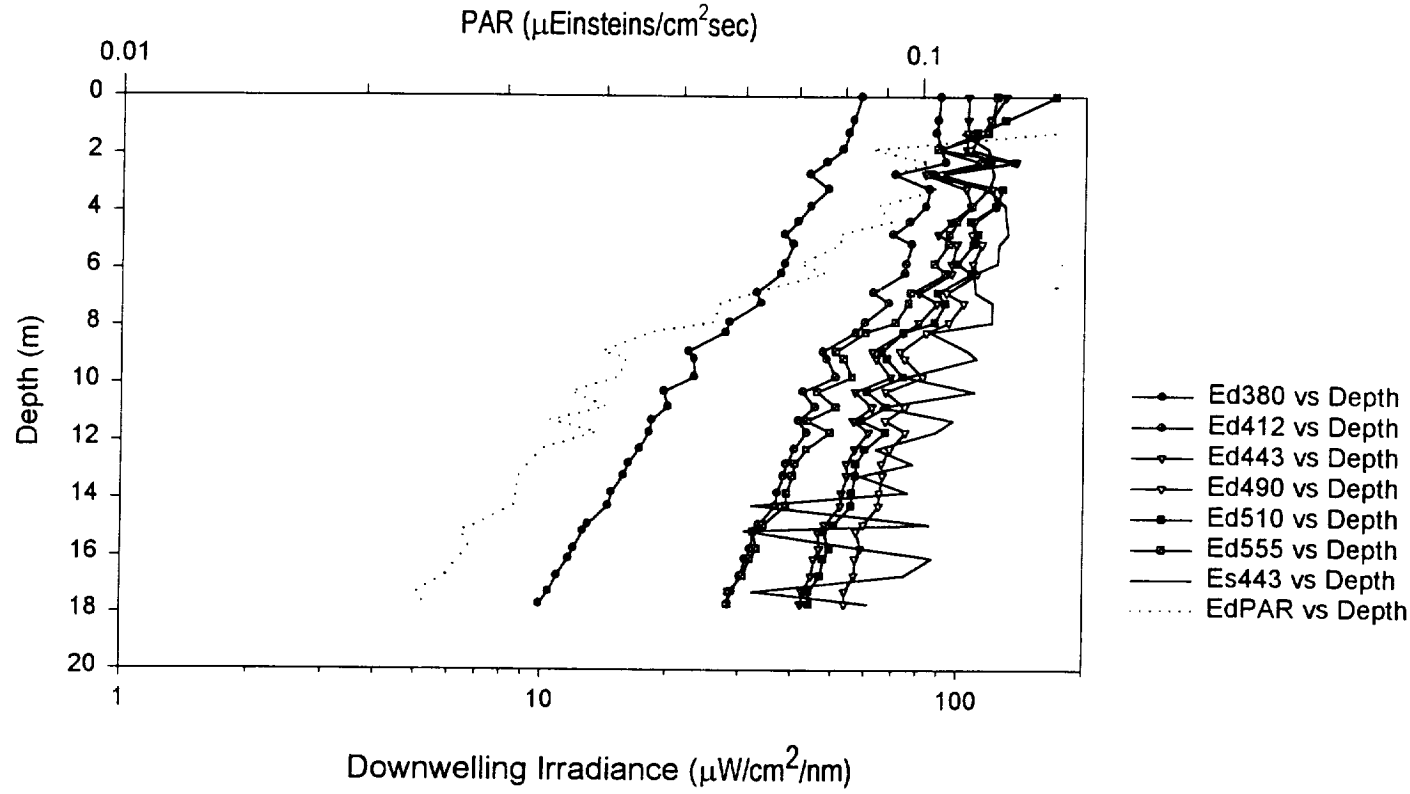


Figure A.3.a - Station D Downcast



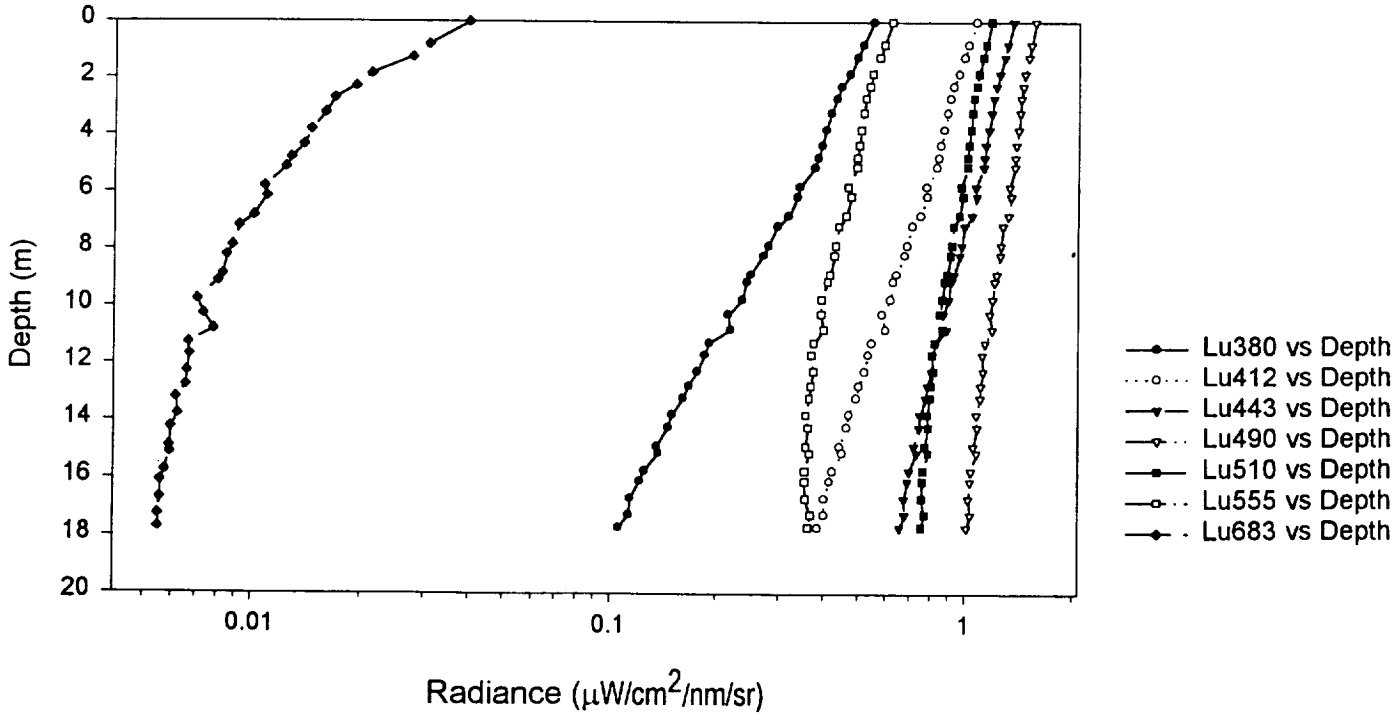
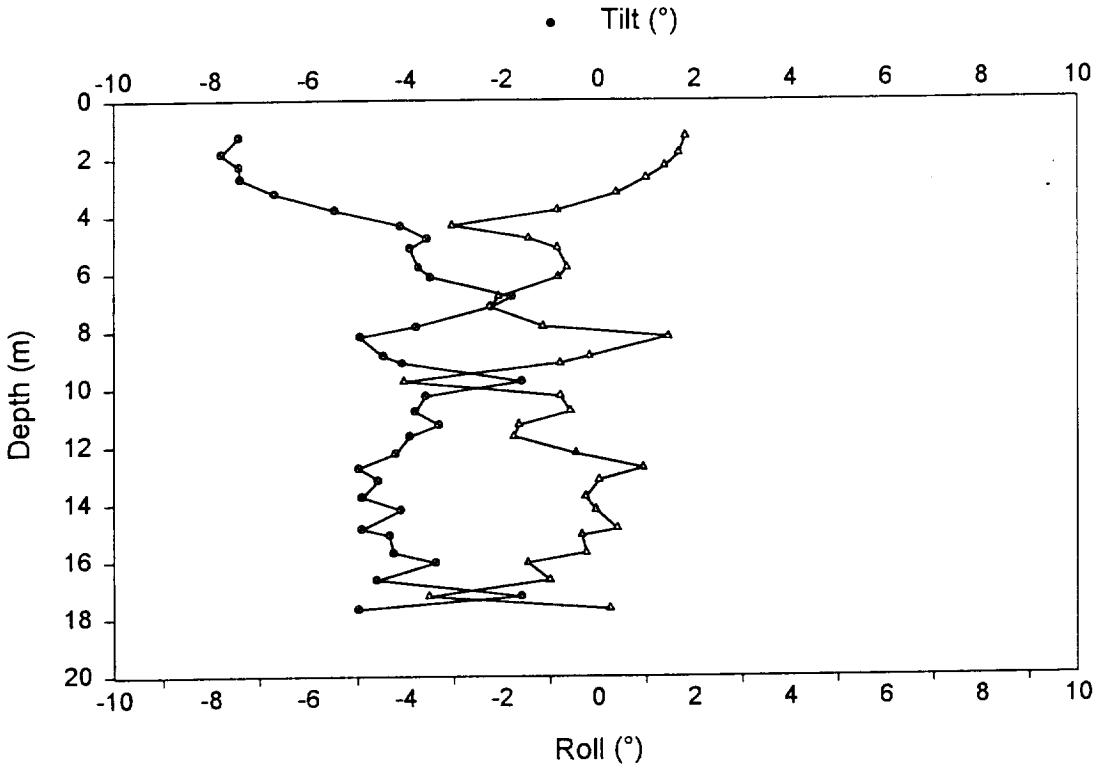


Figure A.3.b - Station D Downcast



Diffuse Attenuation Coefficient (kλ)

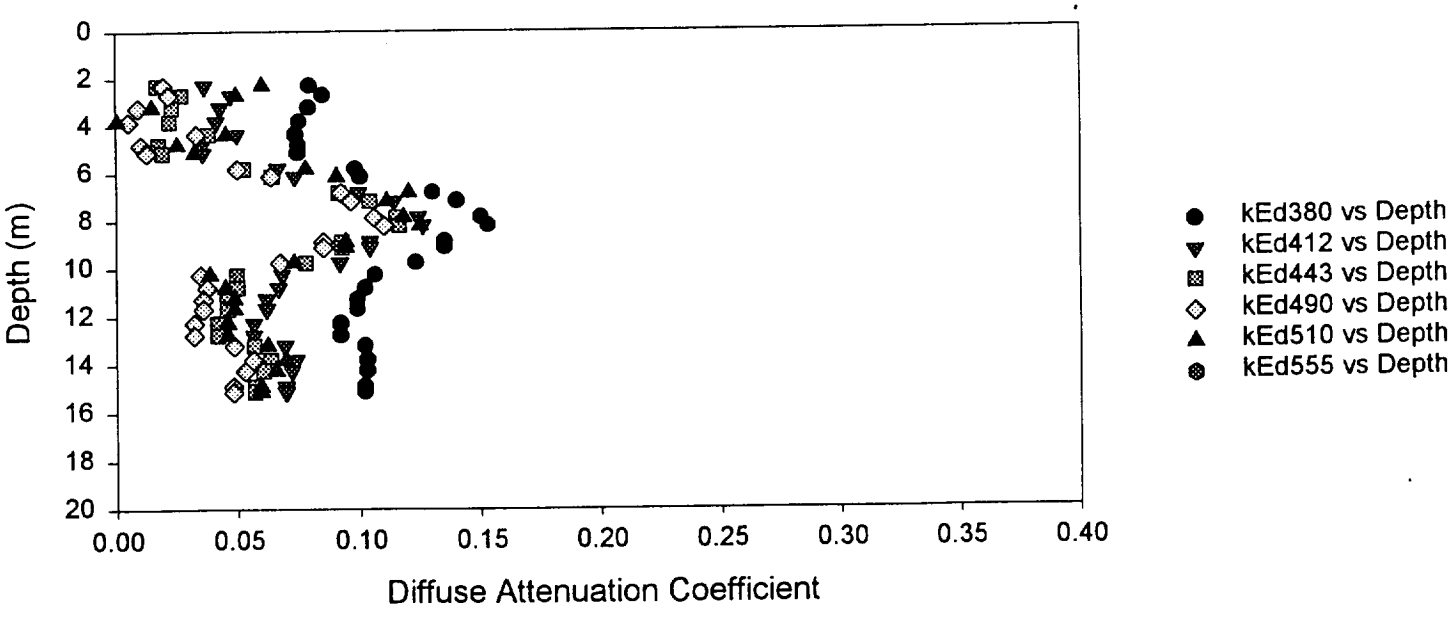
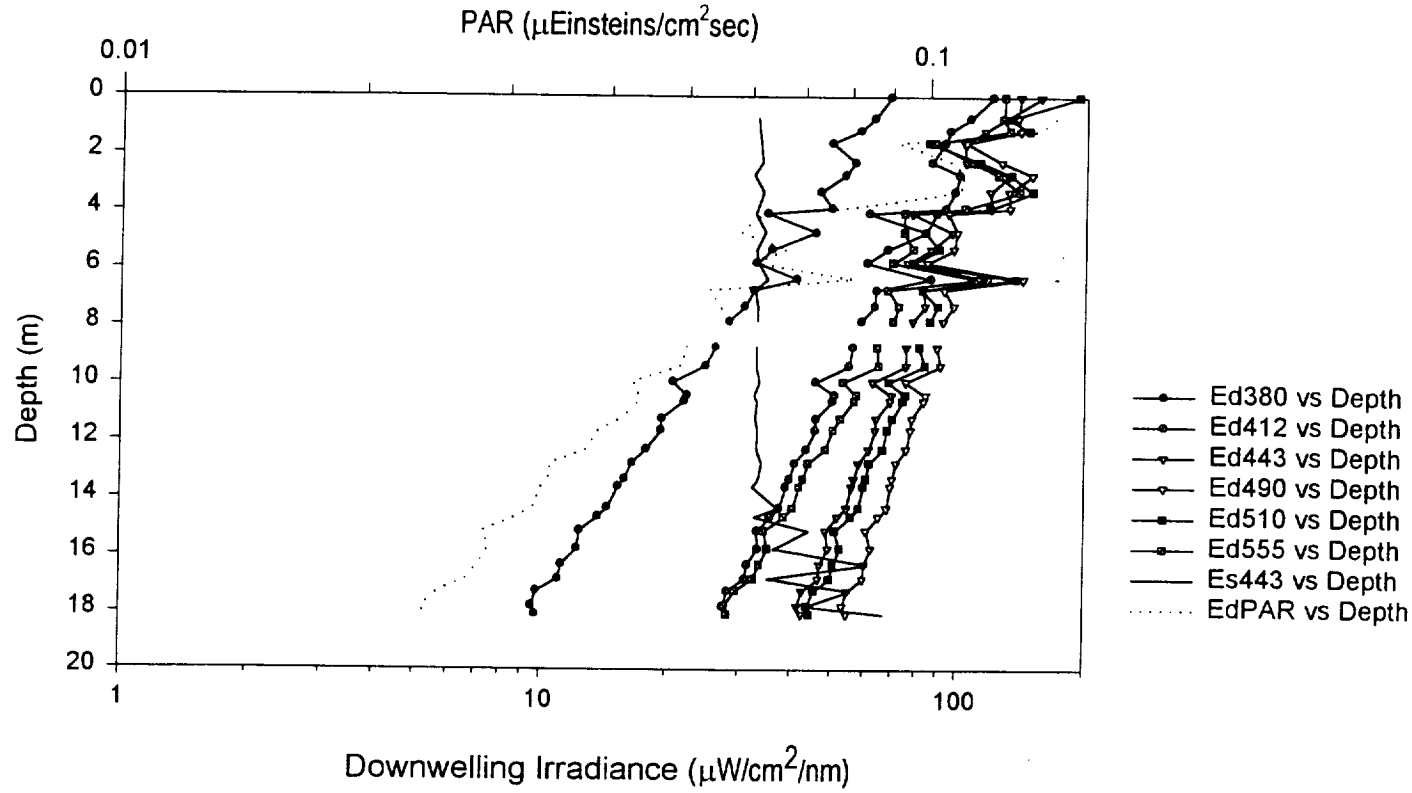


Figure A.4.a - Station D Upcast



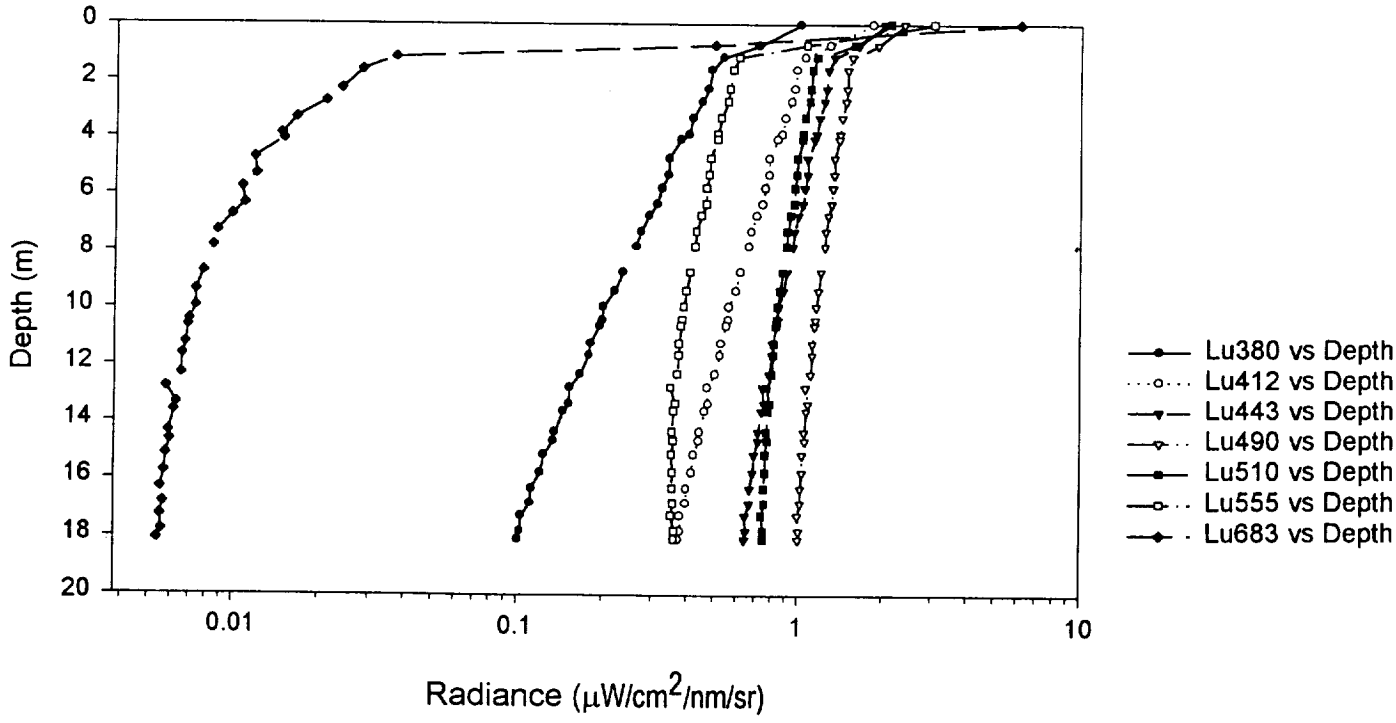
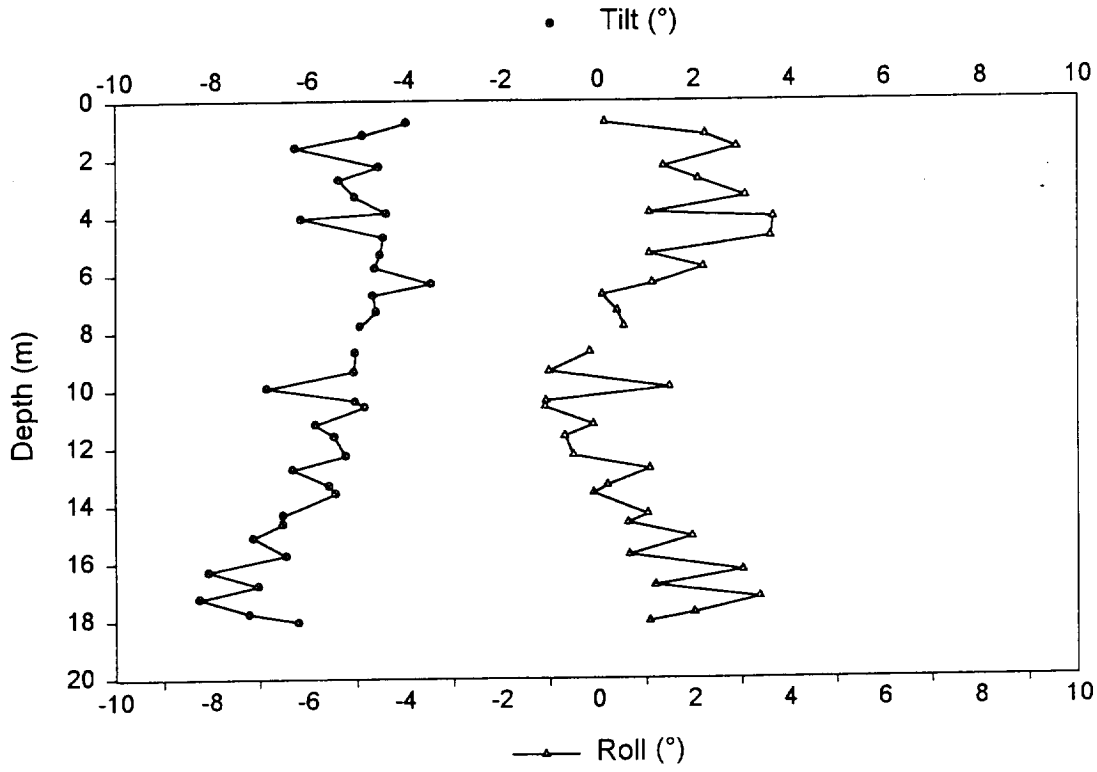


Figure A.4.b - Station D Upcast



Diffuse Attenuation Coefficient (kλ)

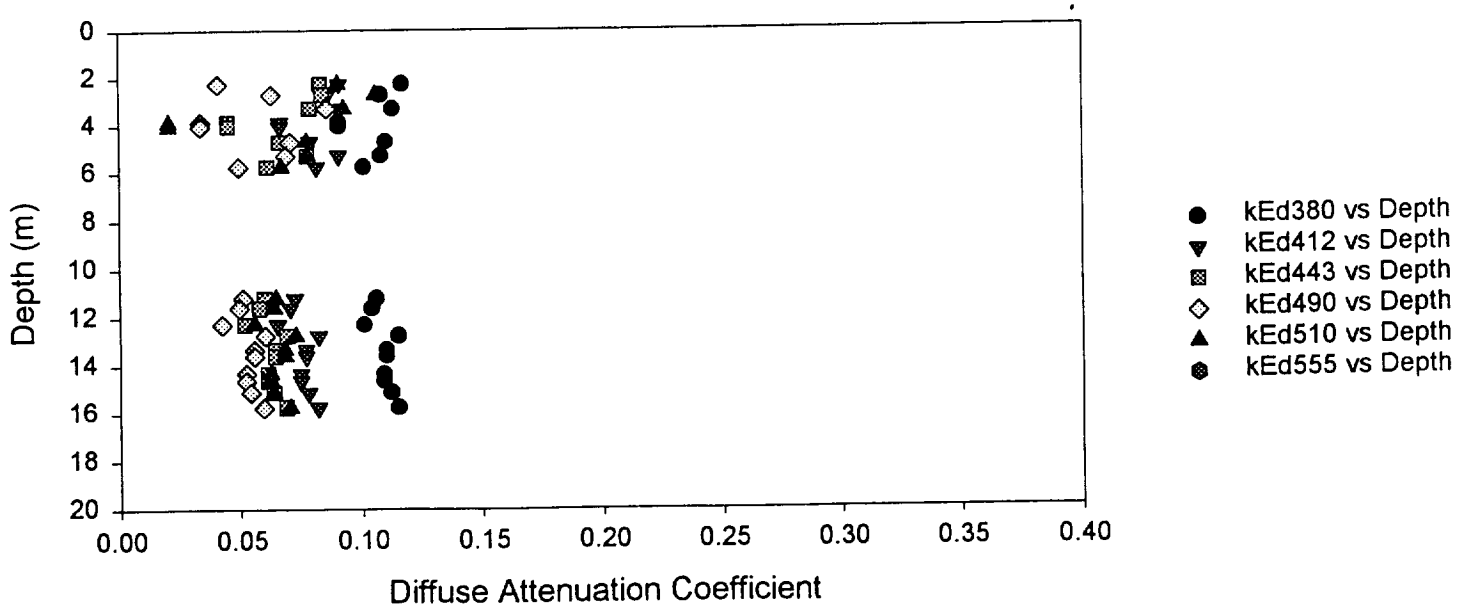
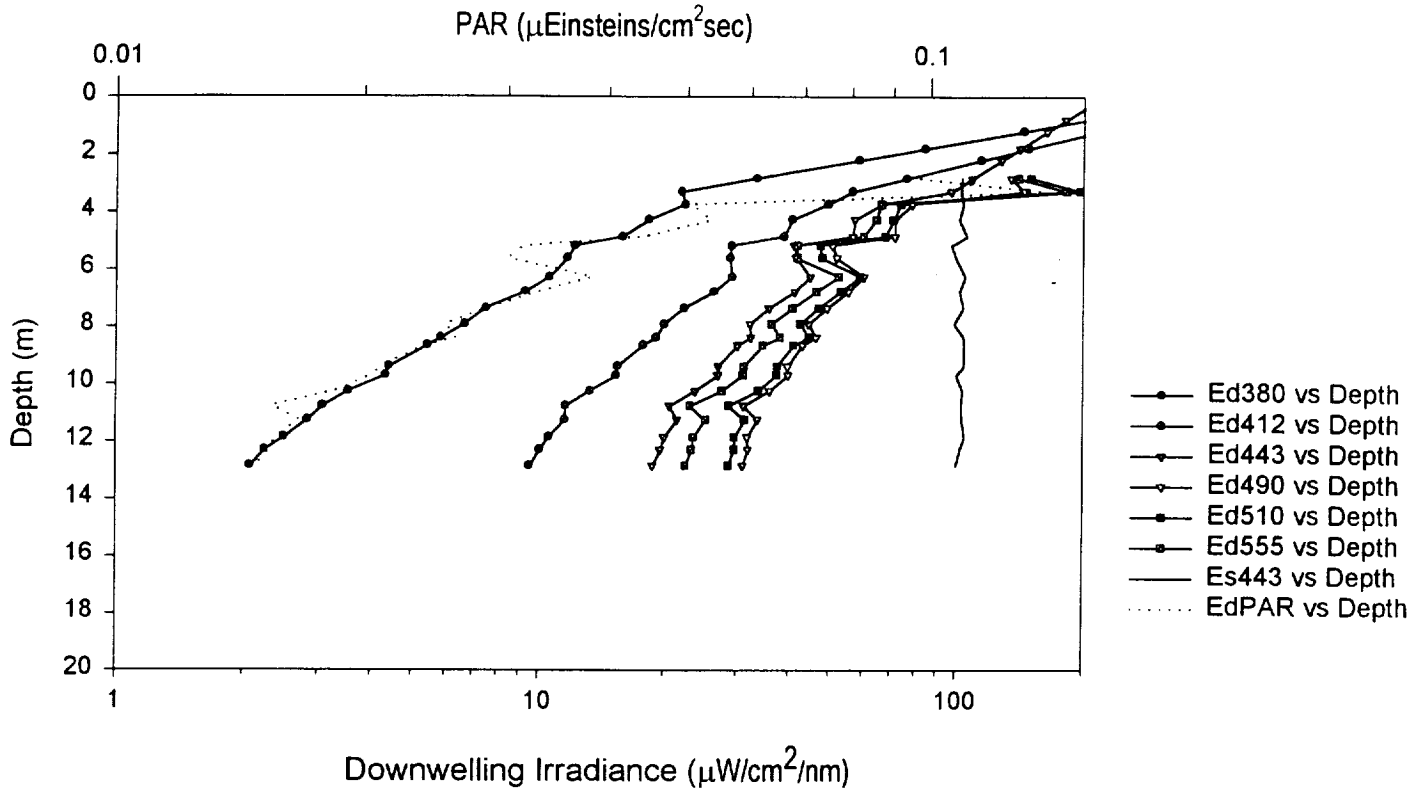


Figure A.5.a - Station E Downcast



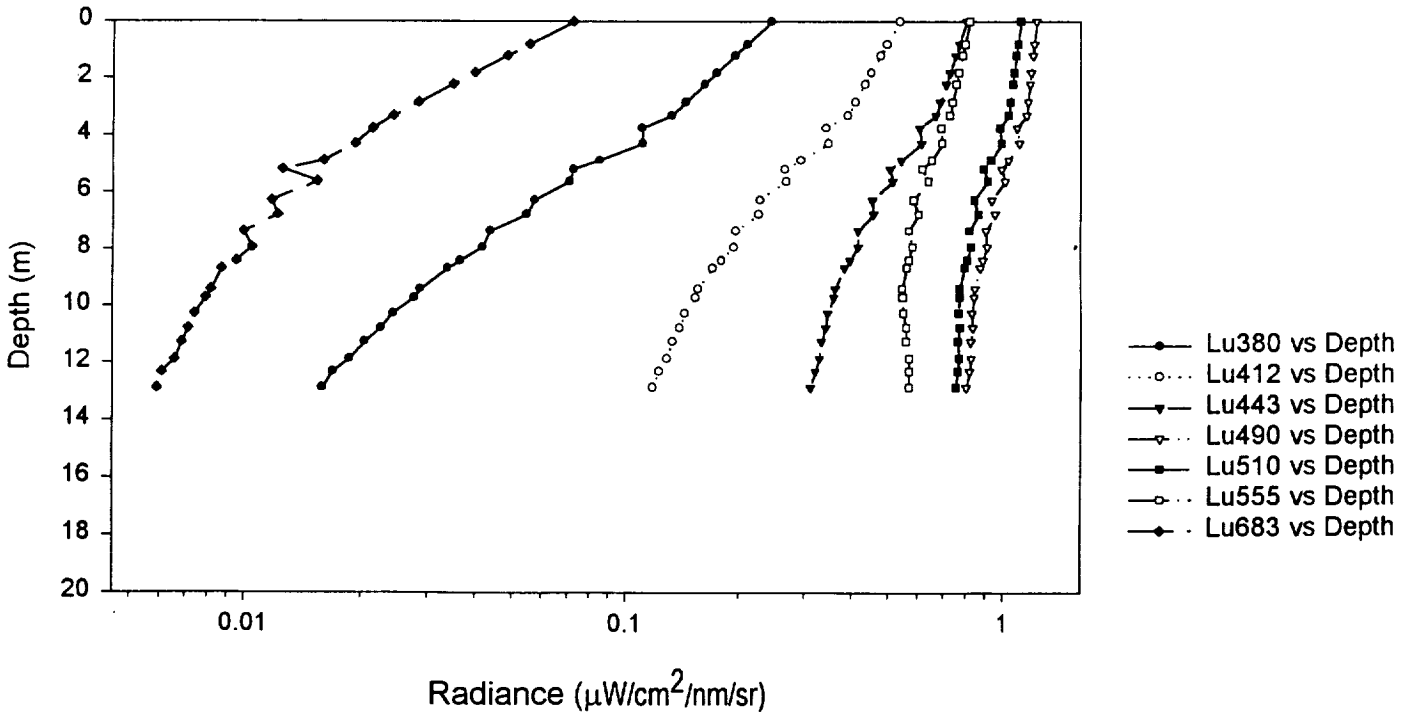
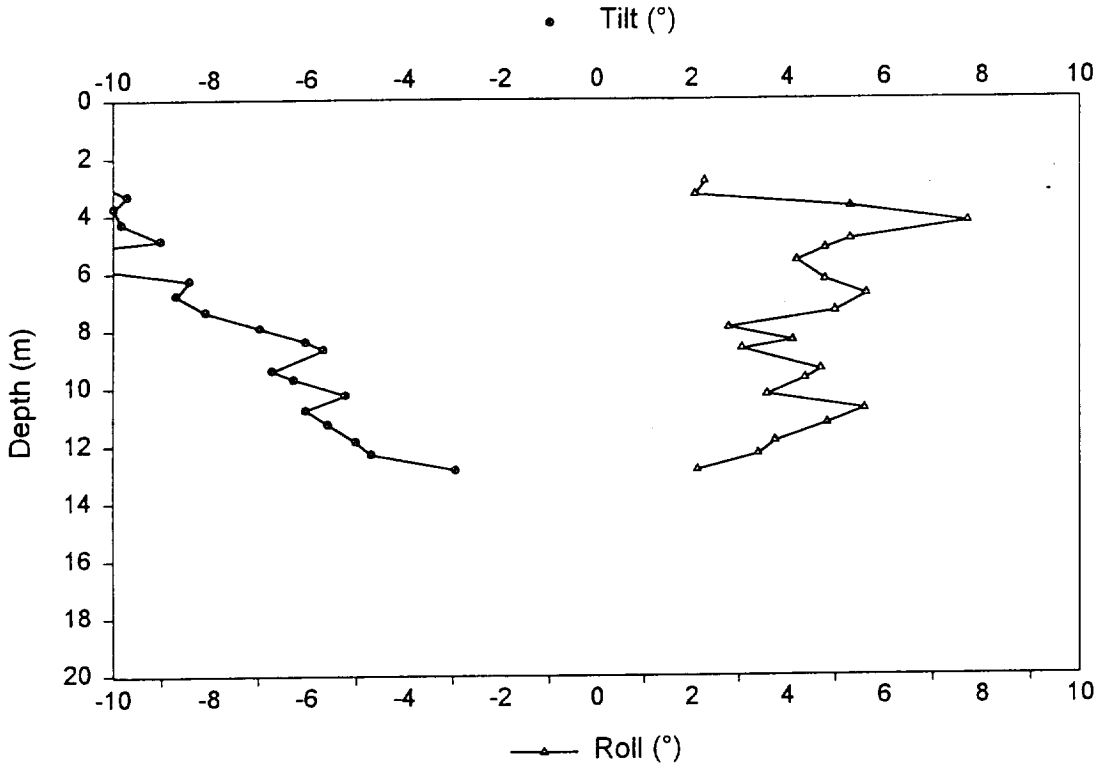


Figure A.5.b - Station E Upcast



Diffuse Attenuation Coefficient (kλ)

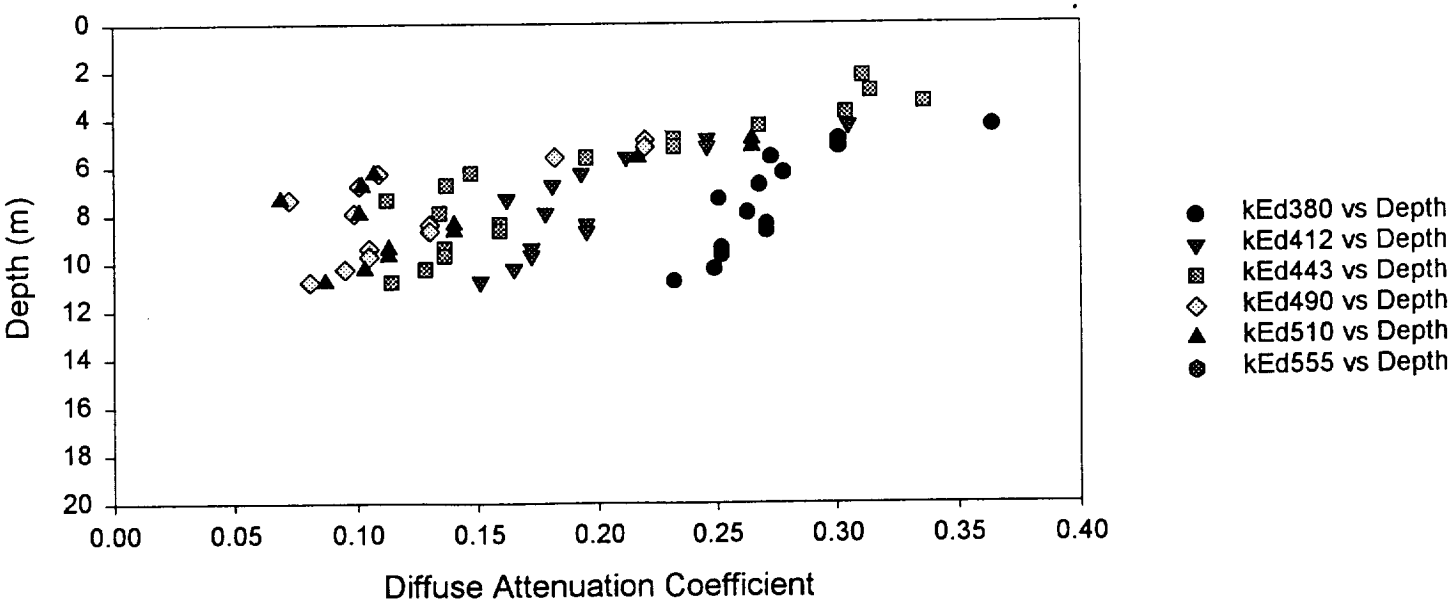
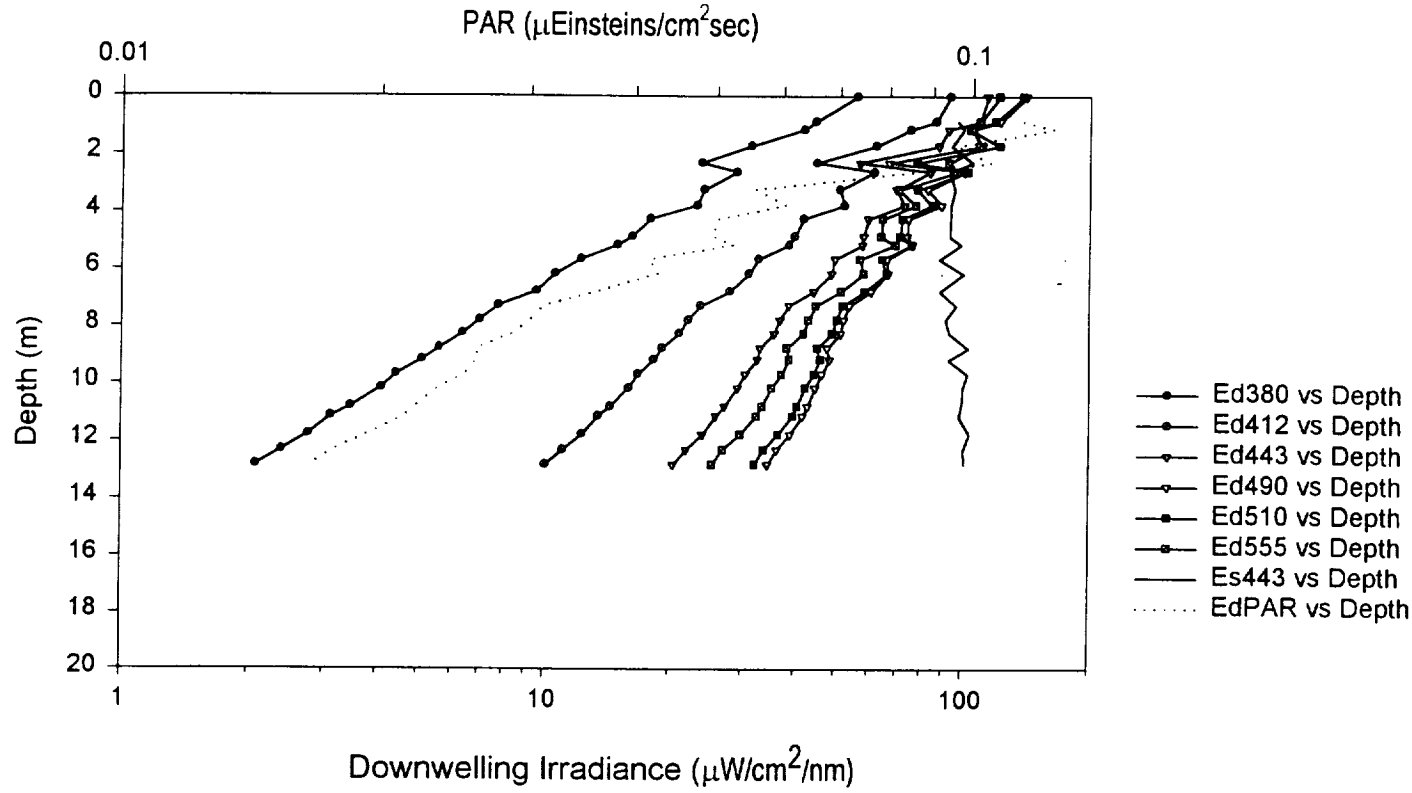


Figure A.6.a - Station E Upcast



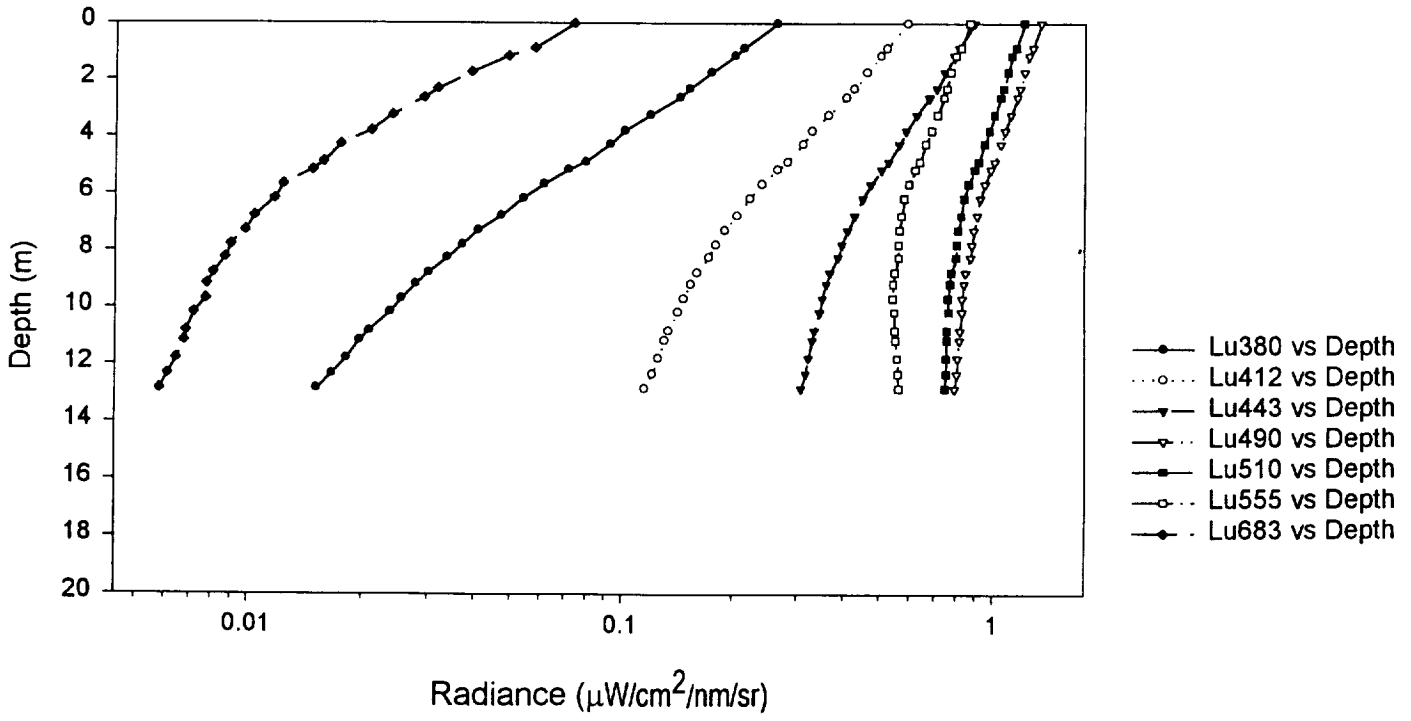
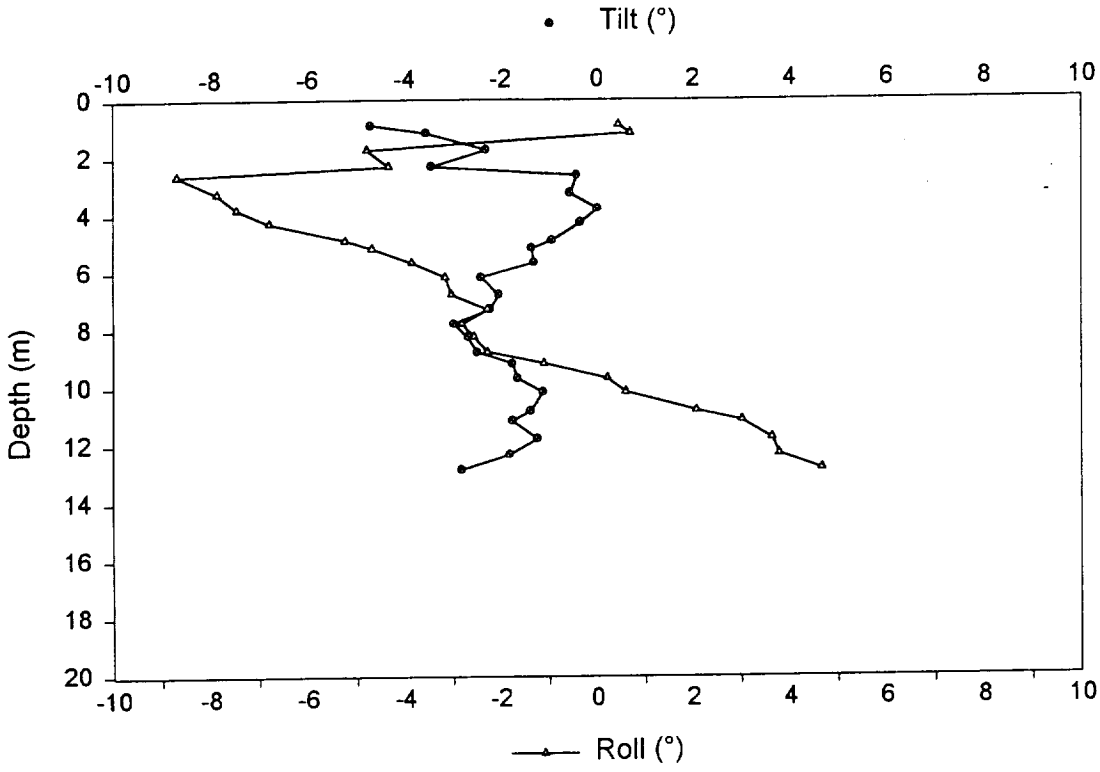


Figure A.6.b - Station E Upcast



Diffuse Attenuation Coefficient (kλ)

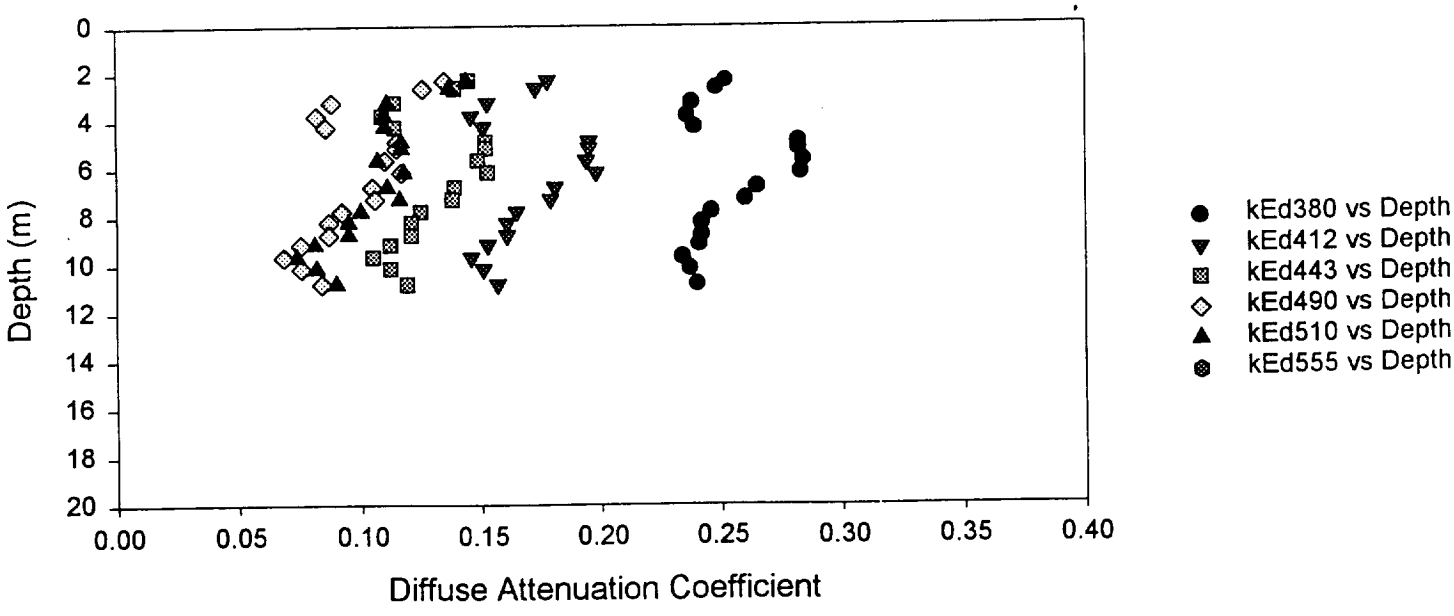
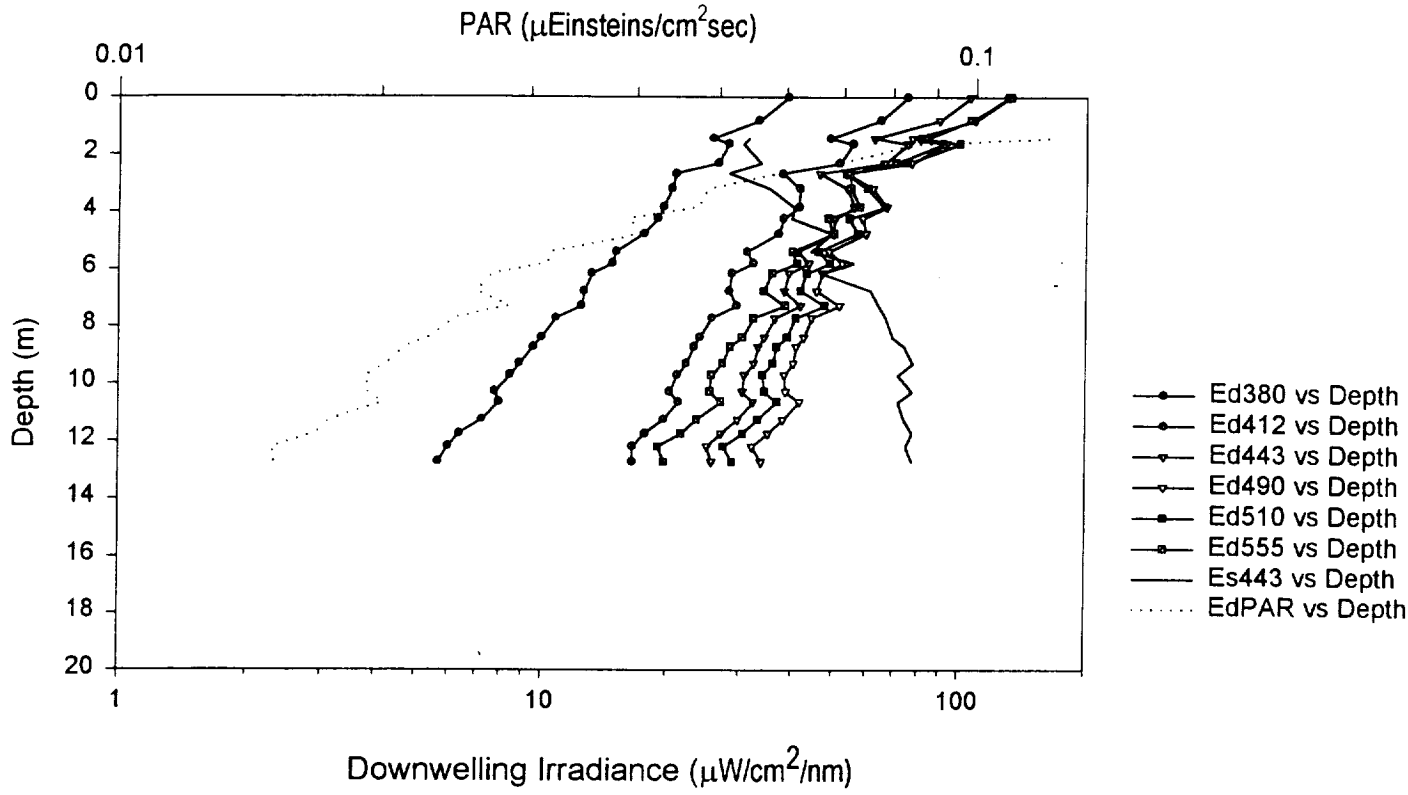


Figure A.7.a - Station F Downcast



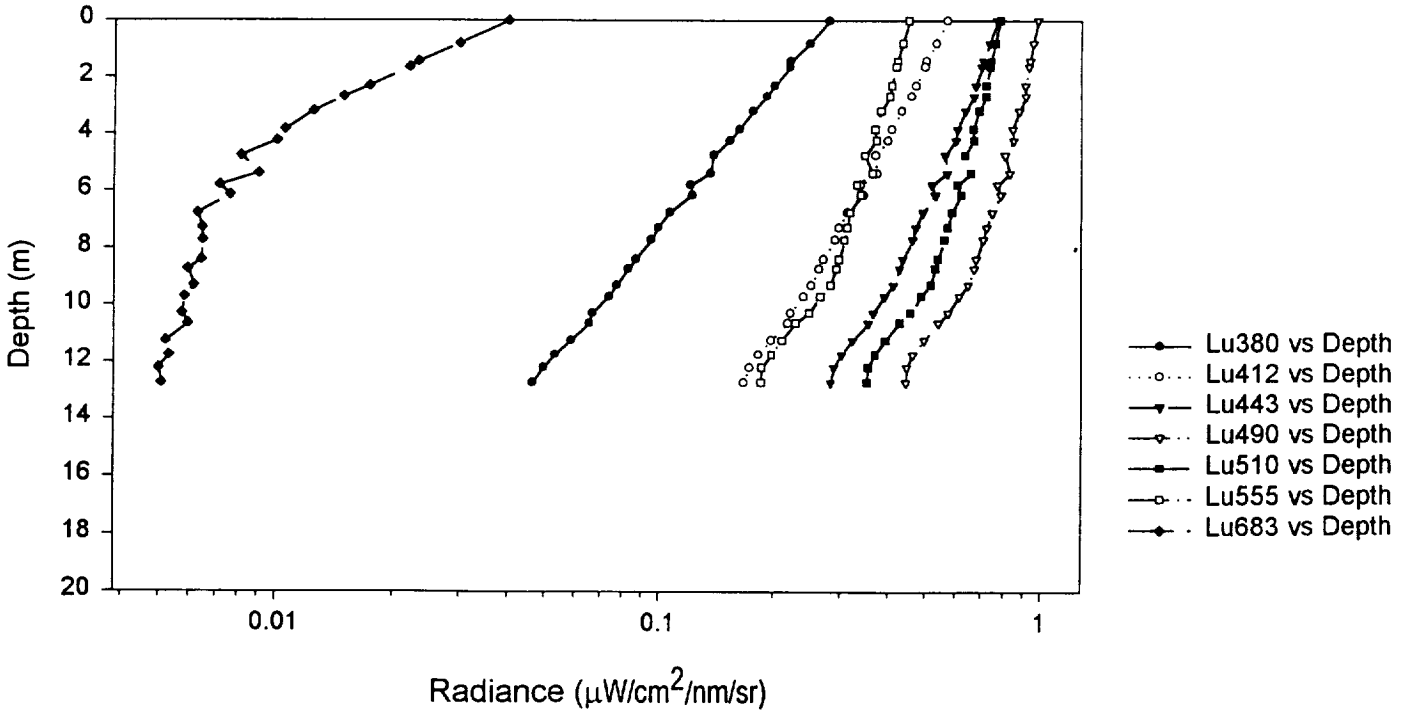
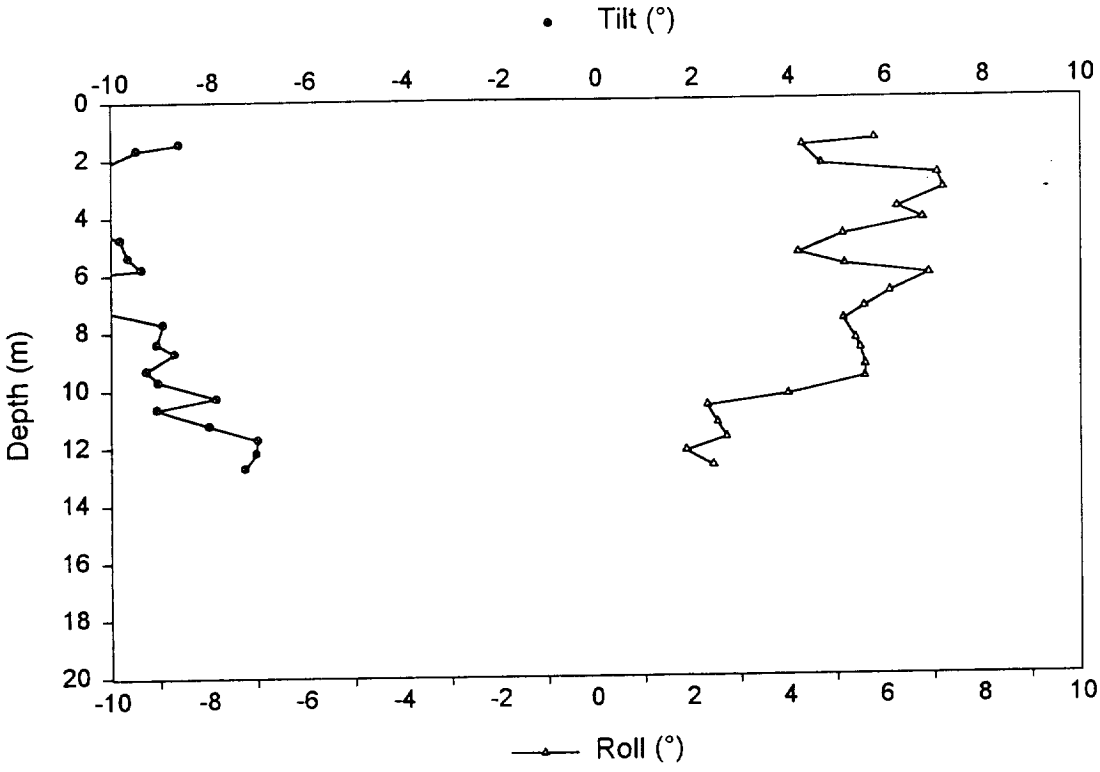


Figure A.7.b - Station F Downcast



Diffuse Attenuation Coefficient (kλ)

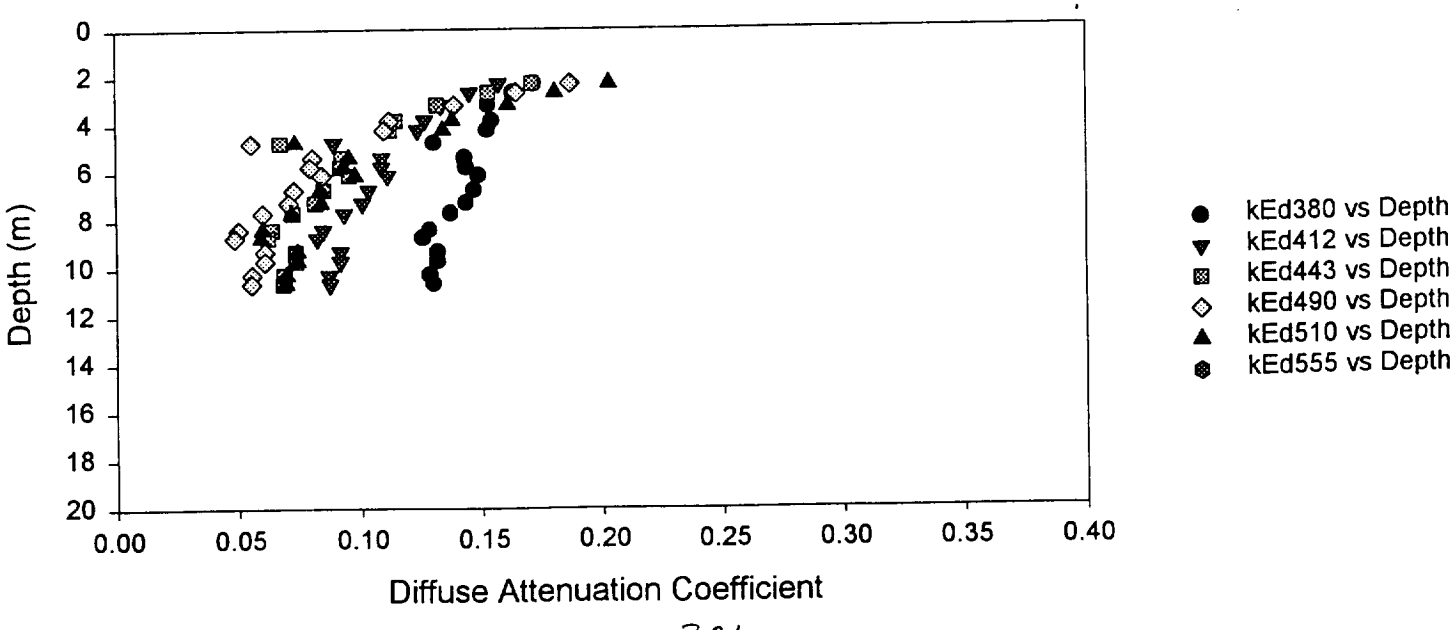
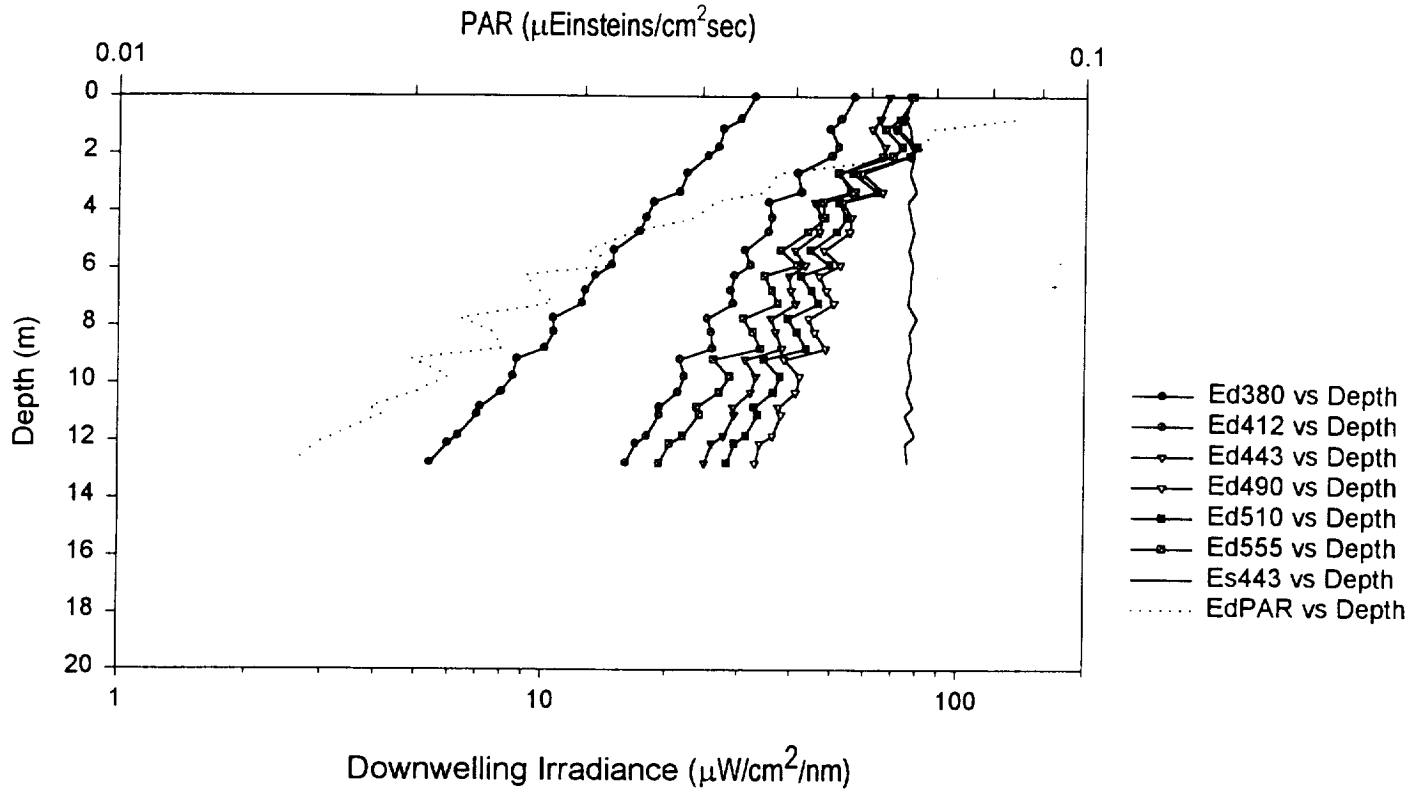


Figure A.8.a - Station F Upcast



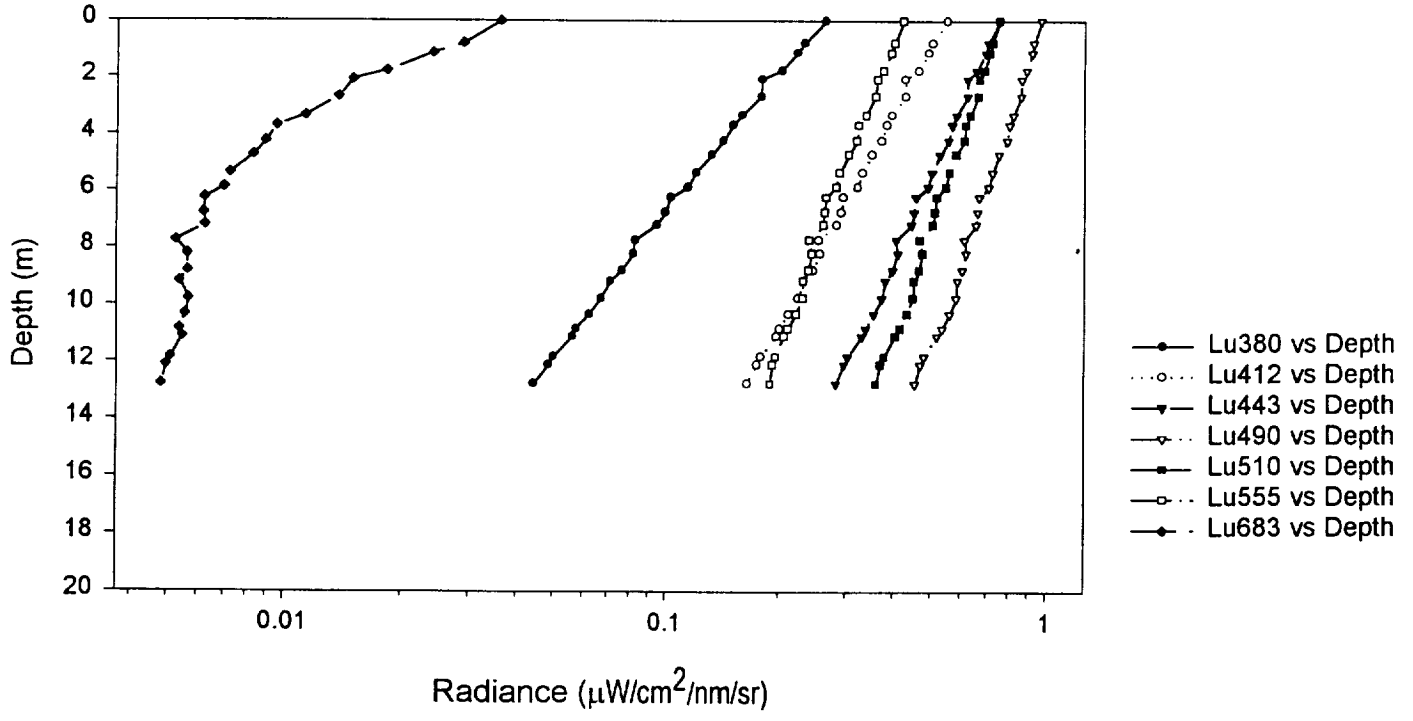
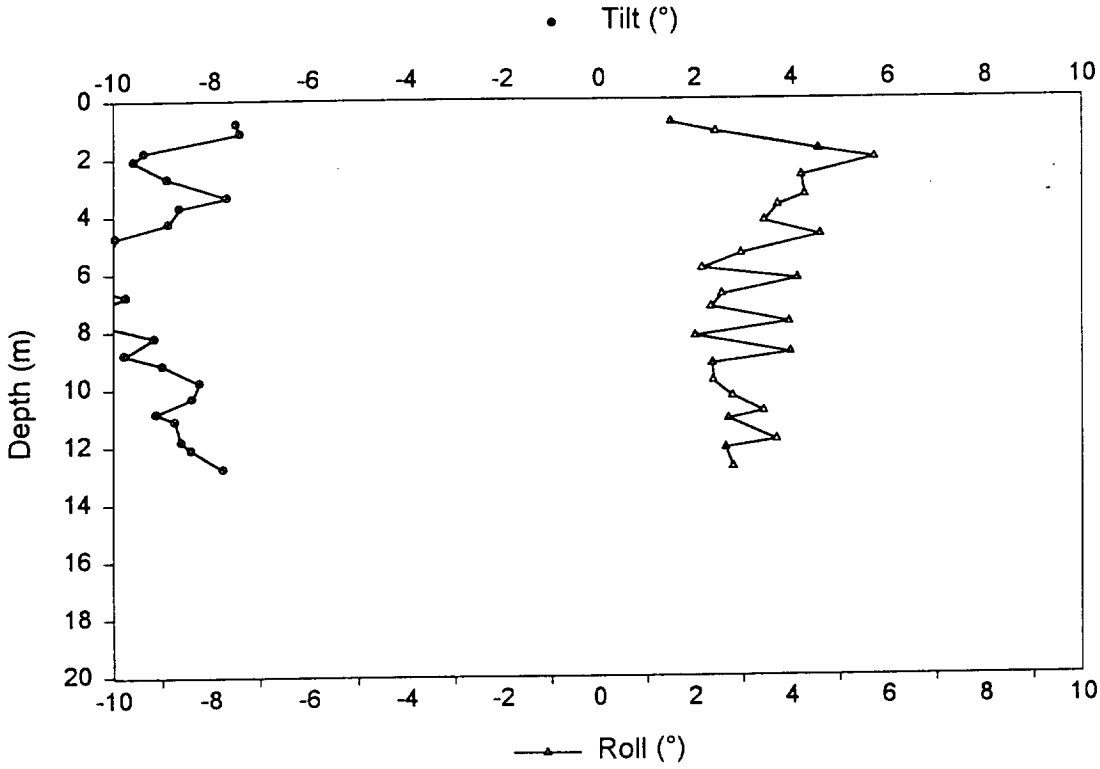


Figure A.8.b - Station F Upcast



Diffuse Attenuation Coefficient (kλ)

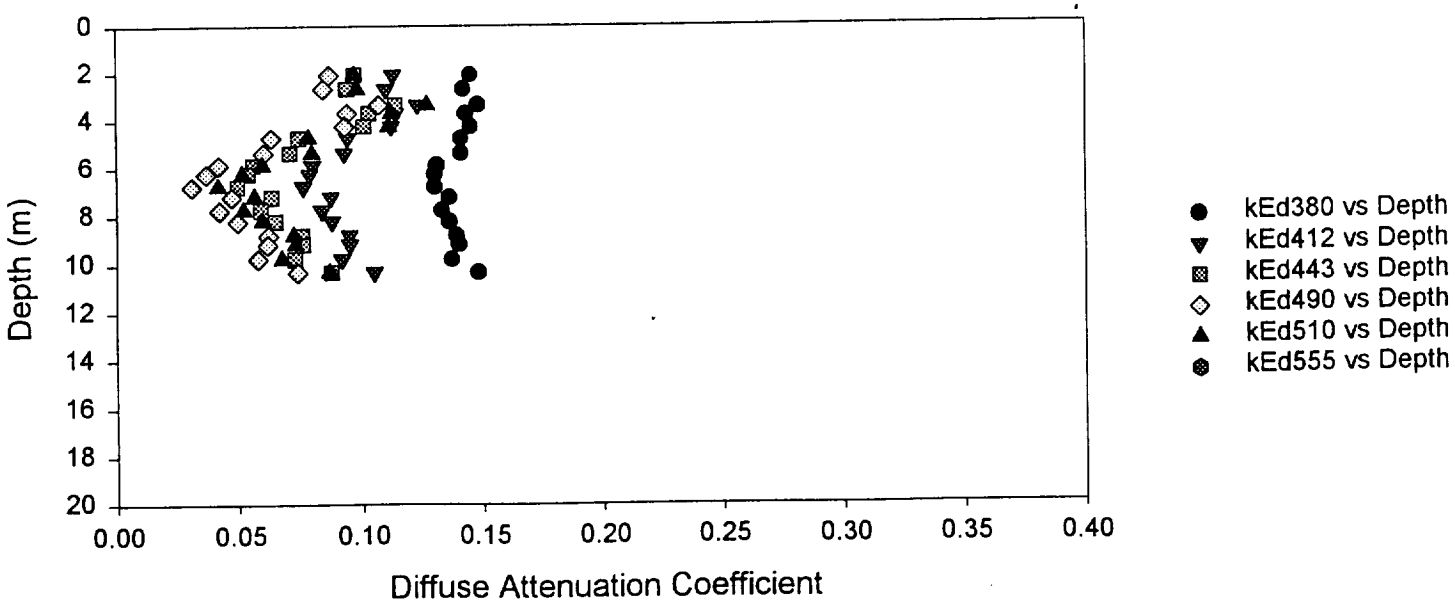
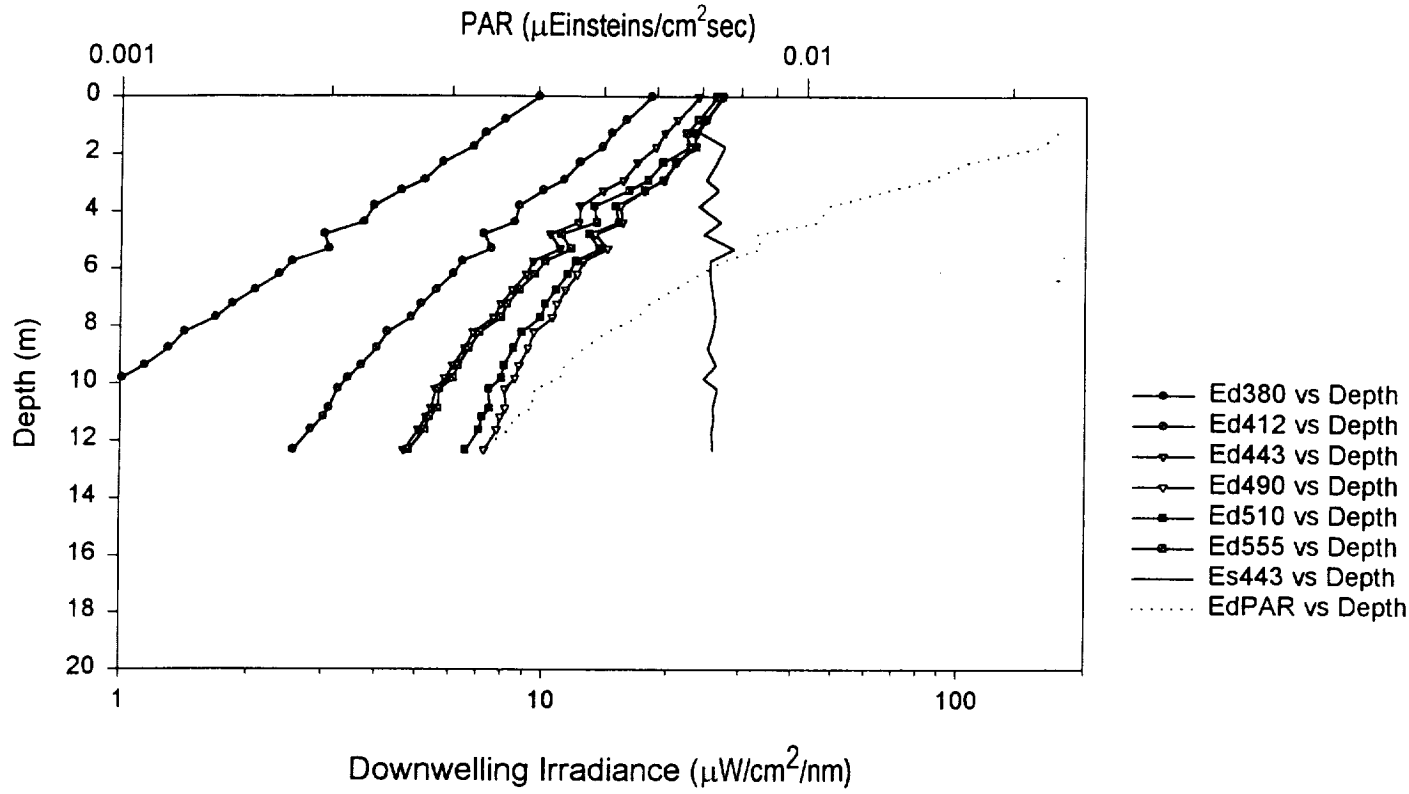


Figure A.9.a - Station G Downcast



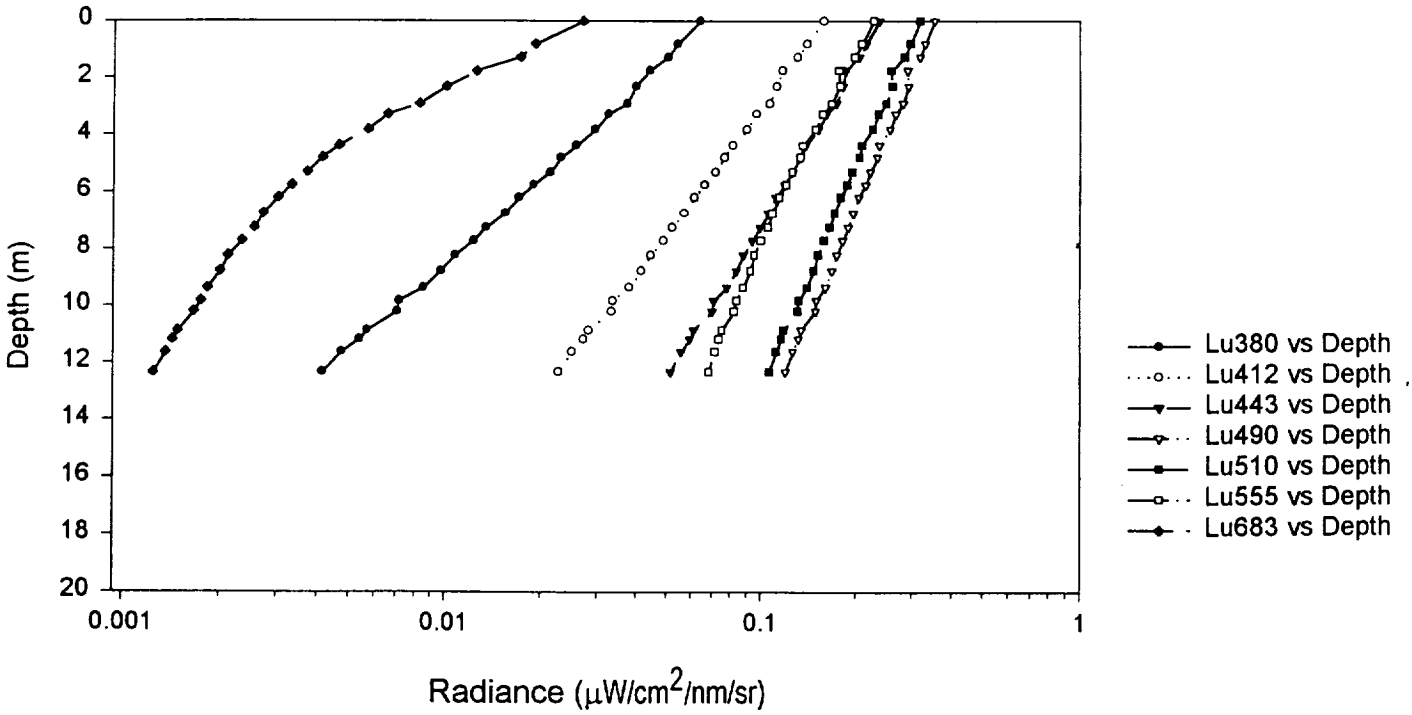
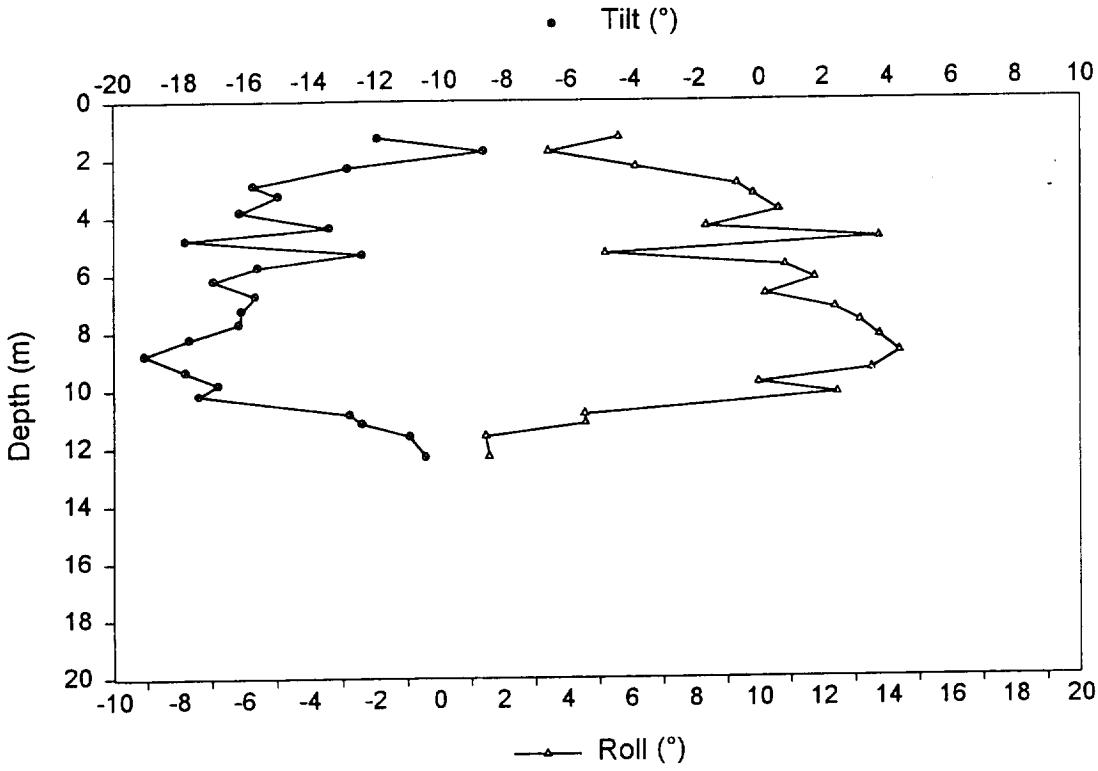


Figure A.9.b - Station G Downcast



Diffuse Attenuation Coefficient (kλ)

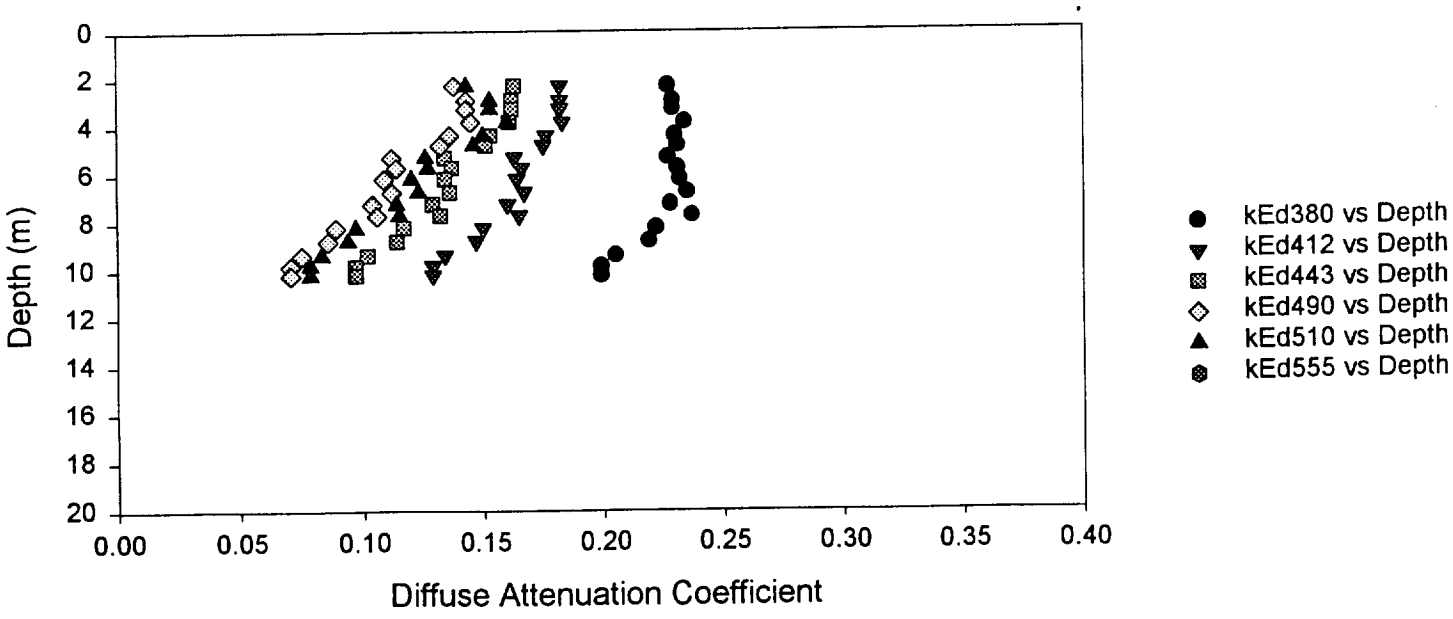
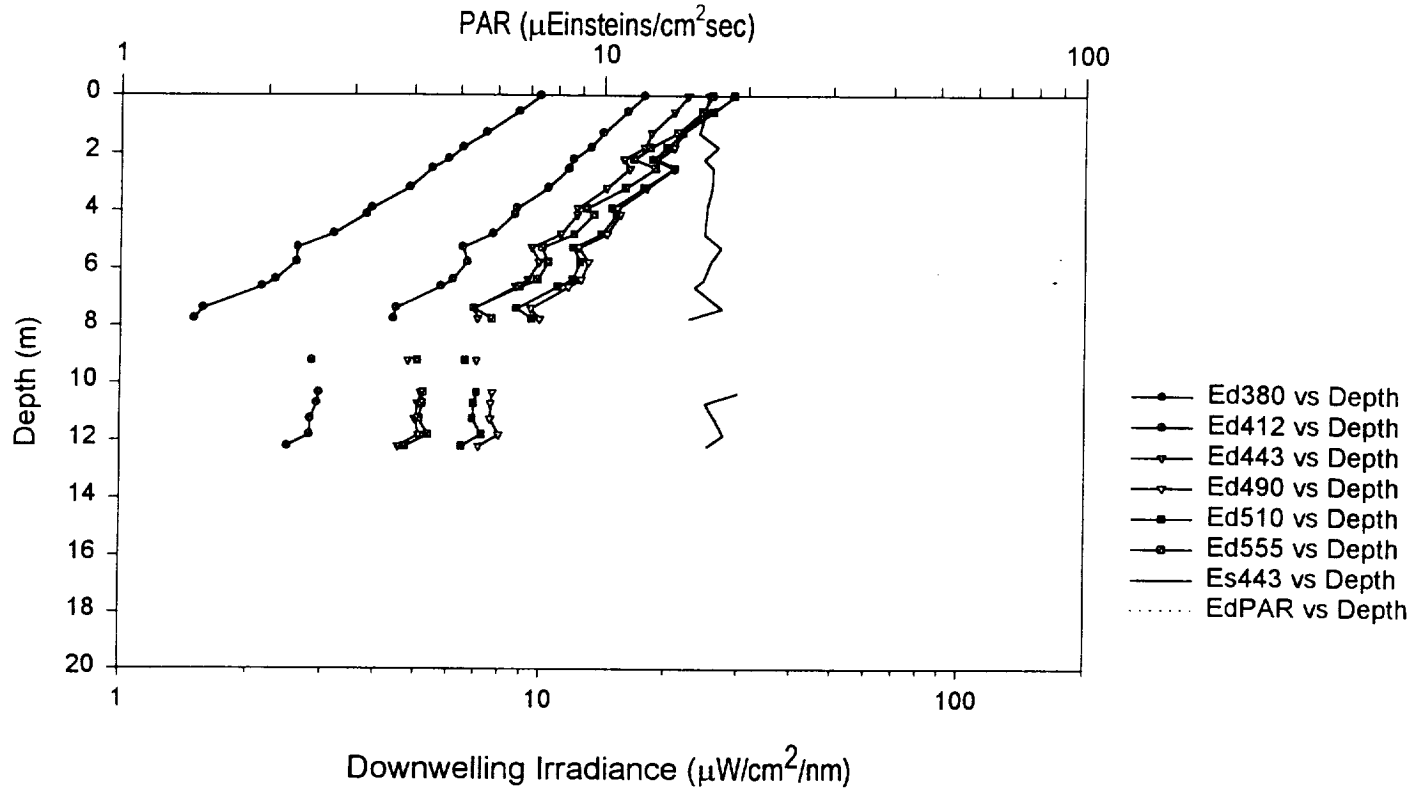


Figure A.10.a - Station G Upcast



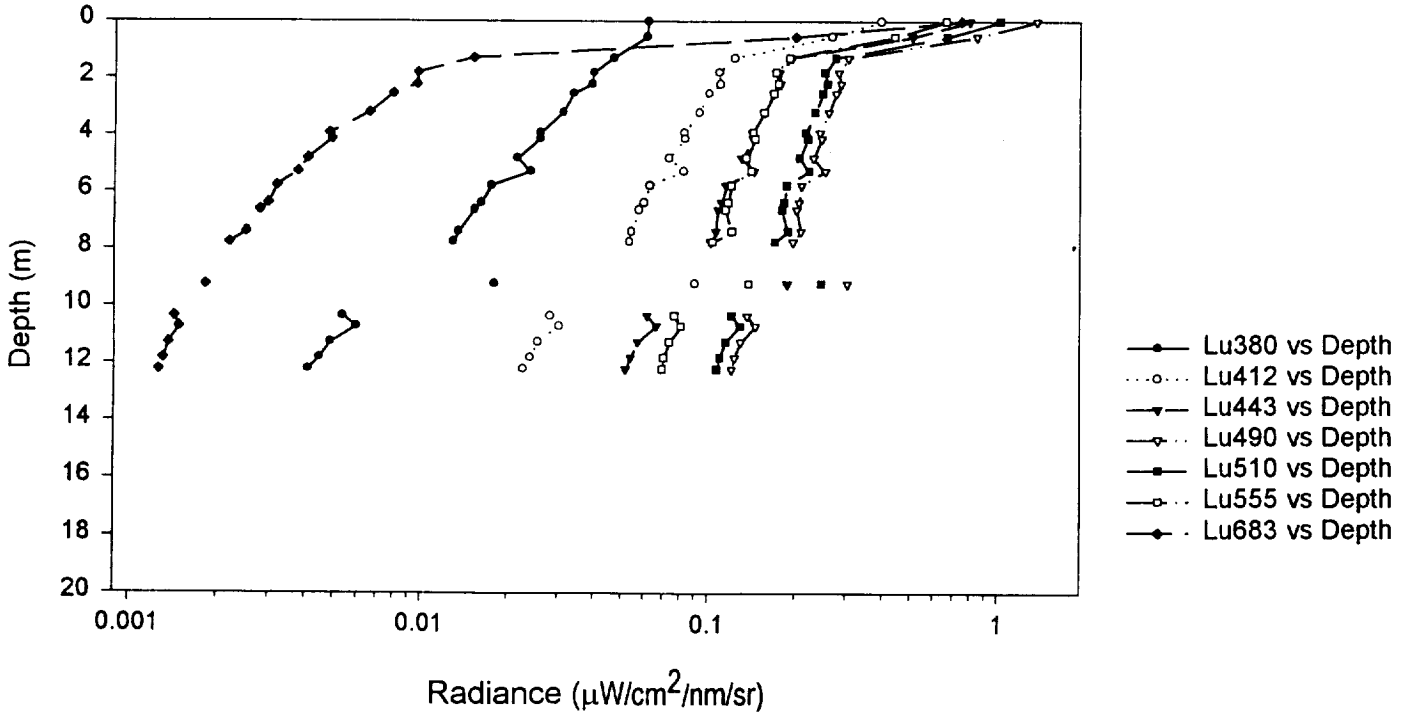
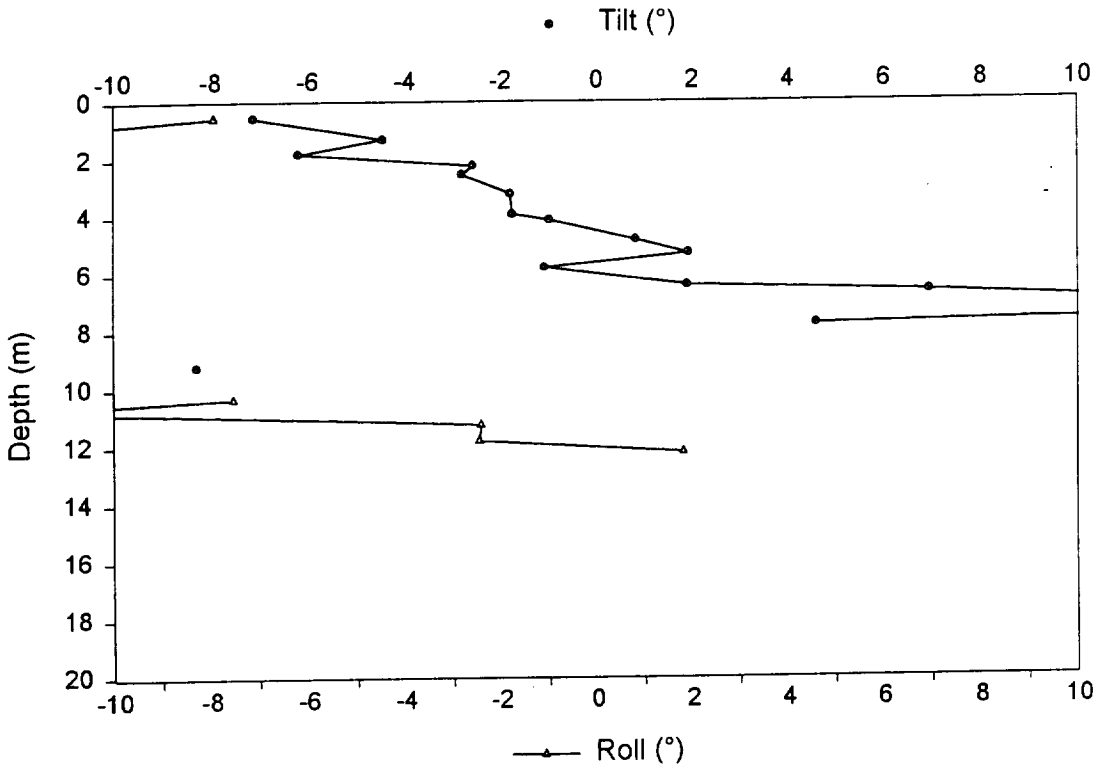


Figure A.10.b - Station G Upcast



Diffuse Attenuation Coefficient (kλ)

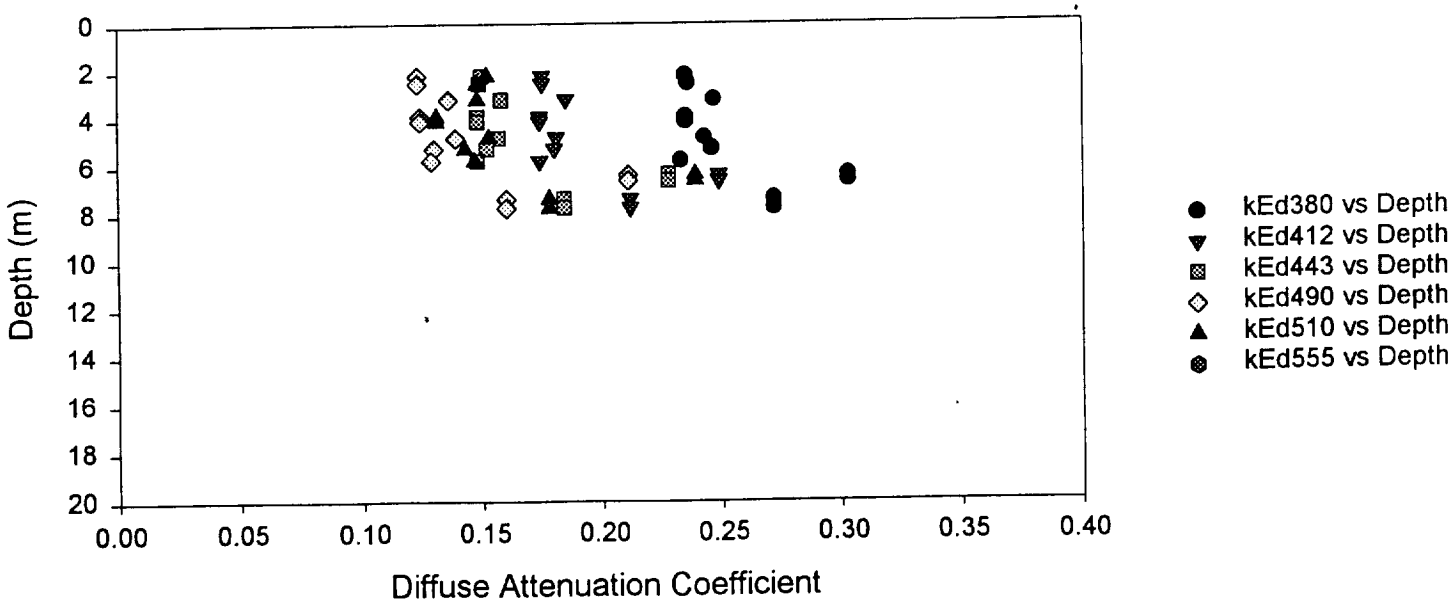
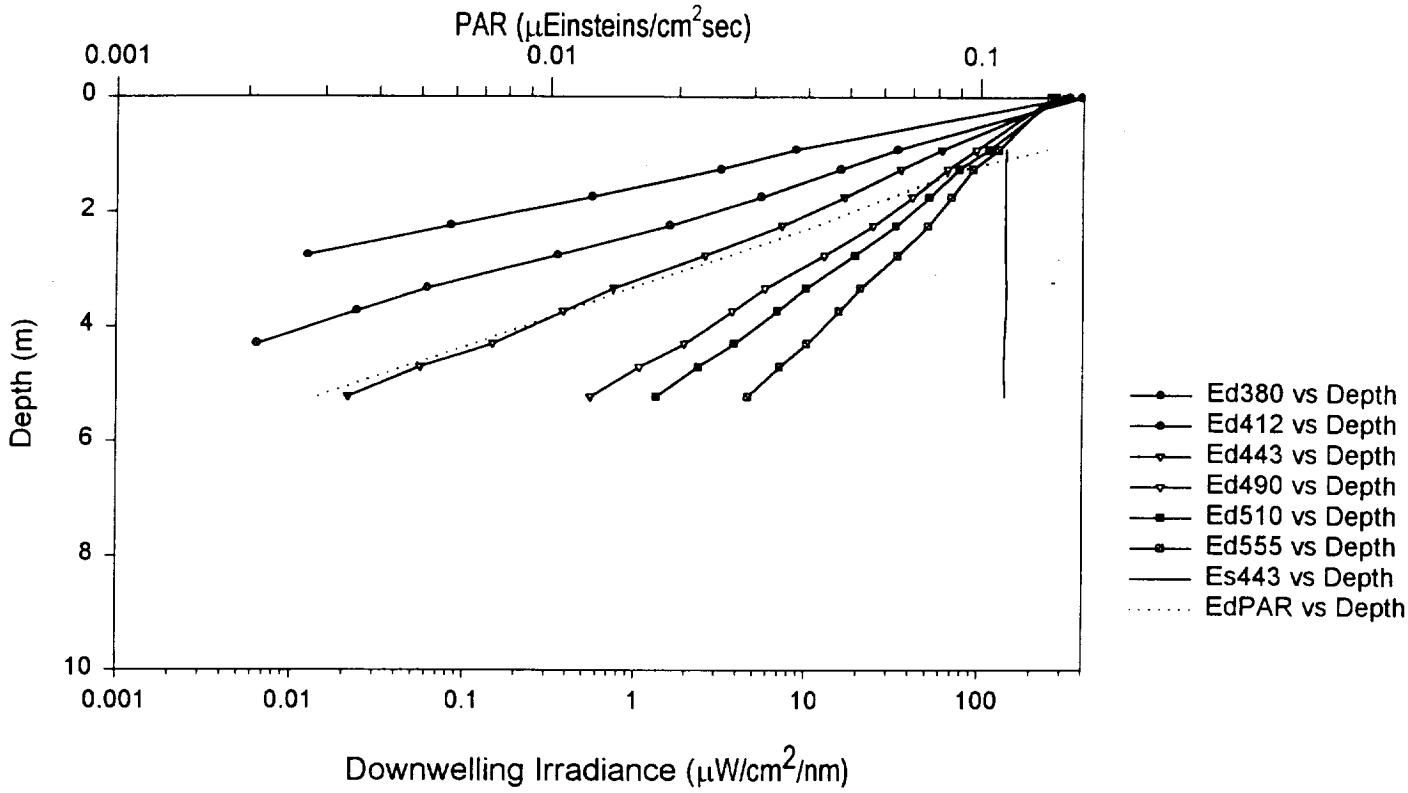


Figure A.11.a - Station 8A Downcast



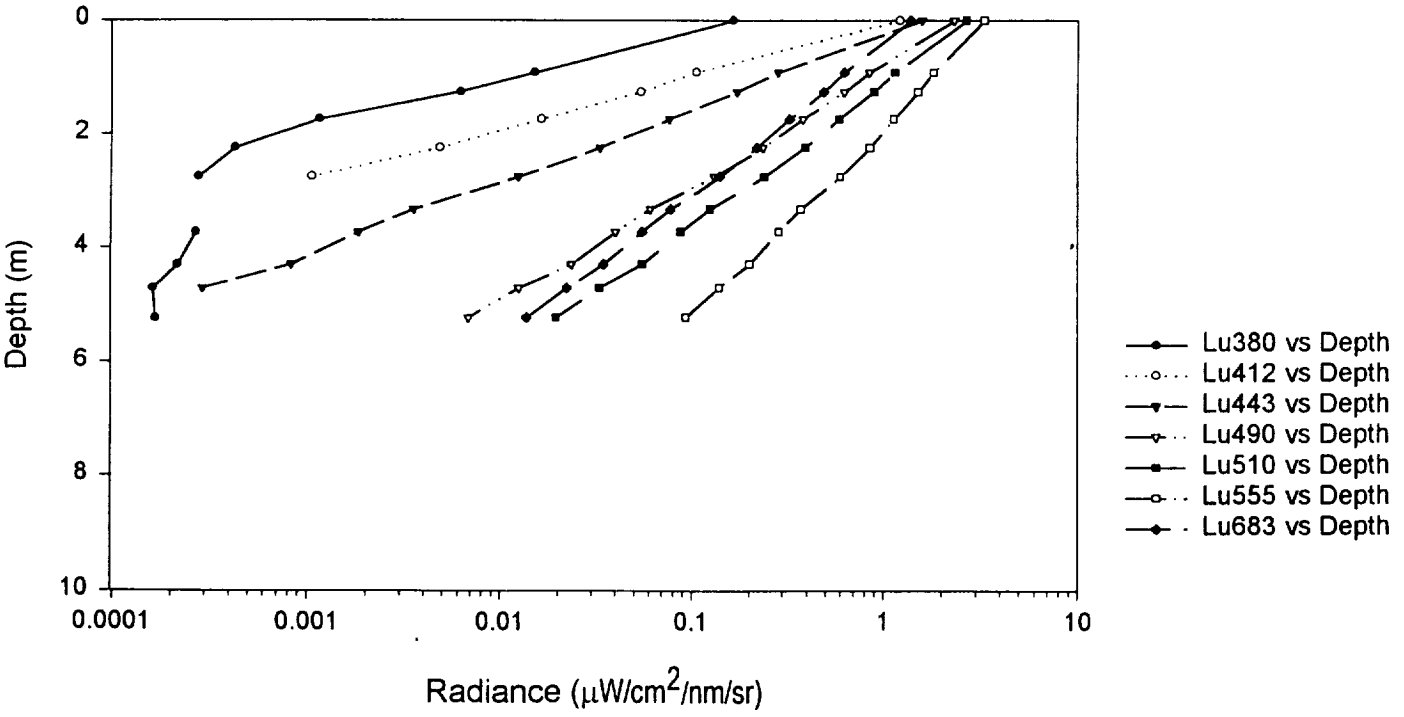
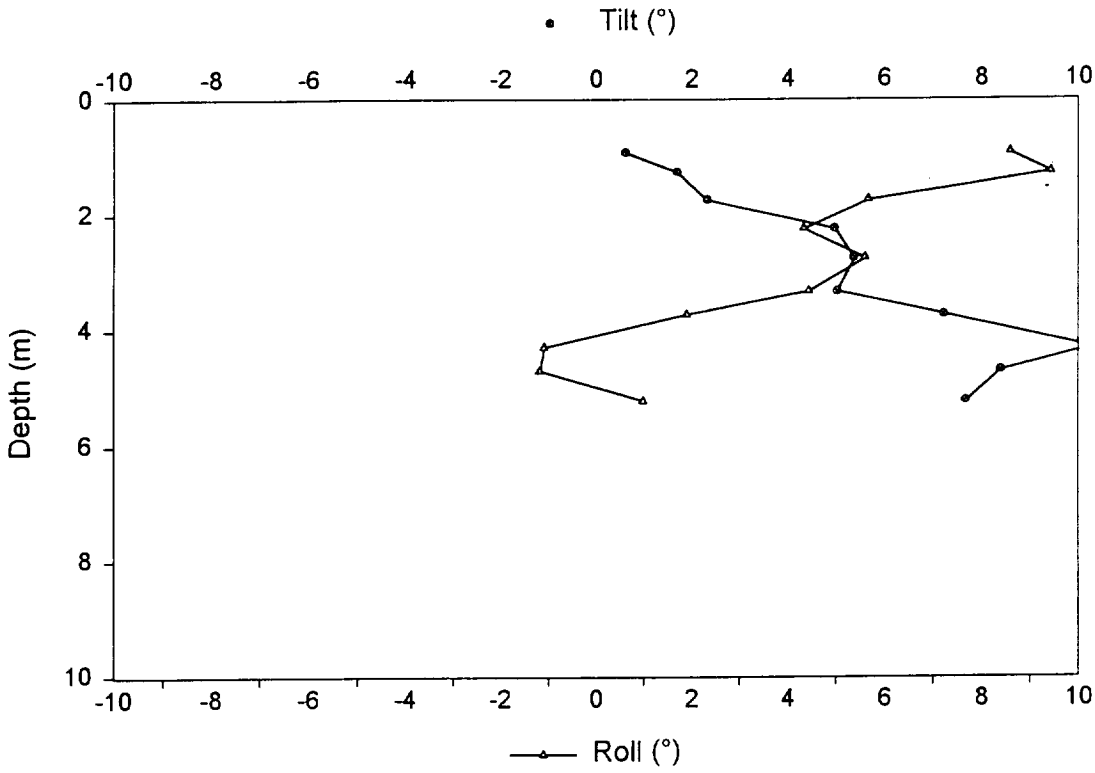


Figure A.11.b - Station 8A Downcast



Diffuse Attenuation Coefficient (kλ)

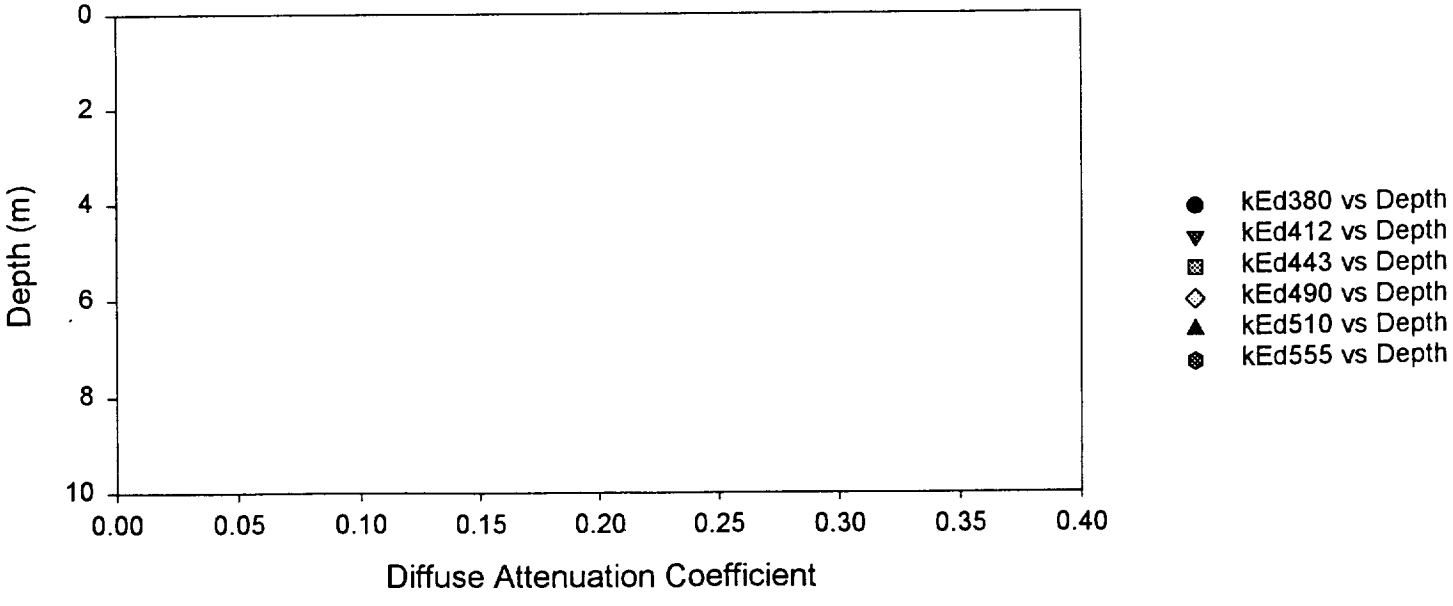
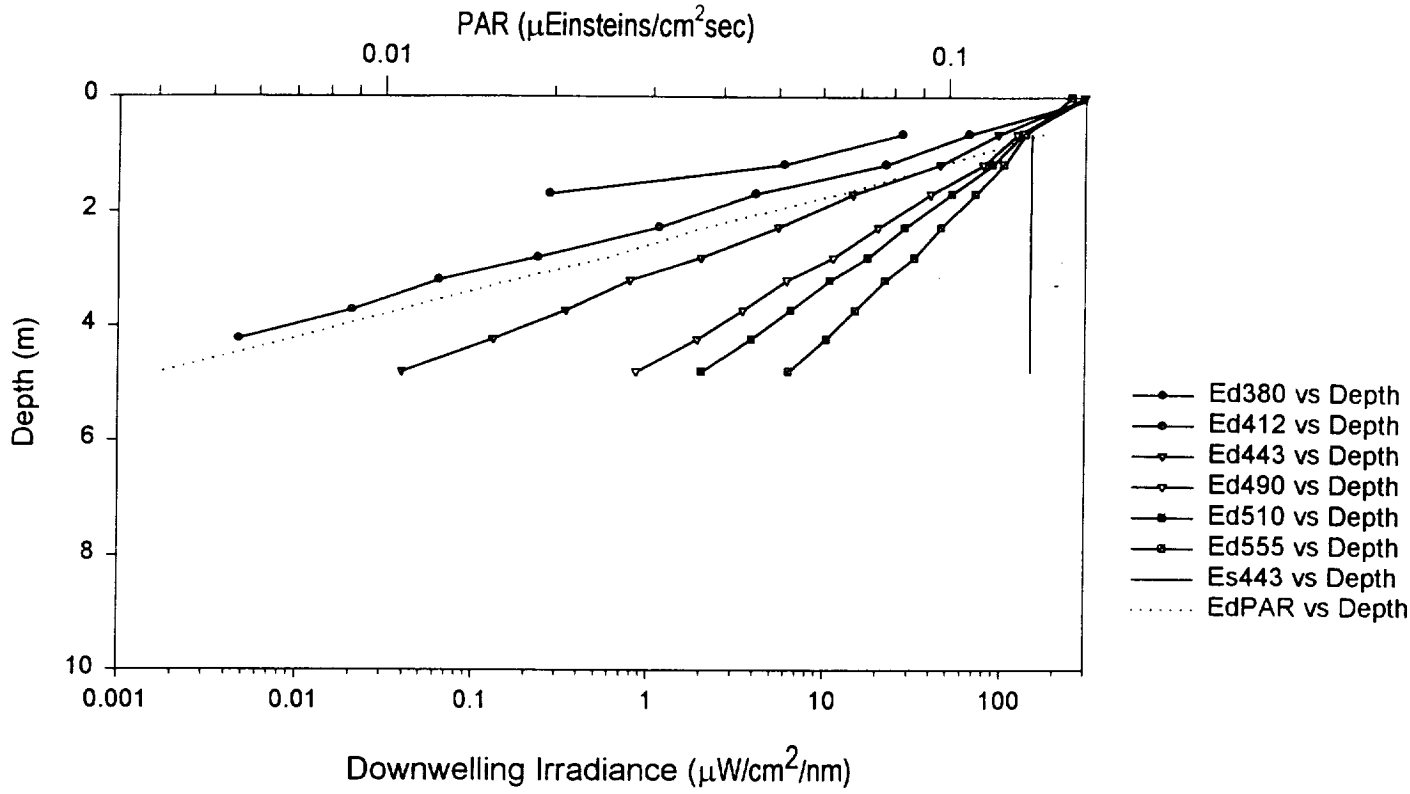


Figure A.12.a - Station 8A Upcast



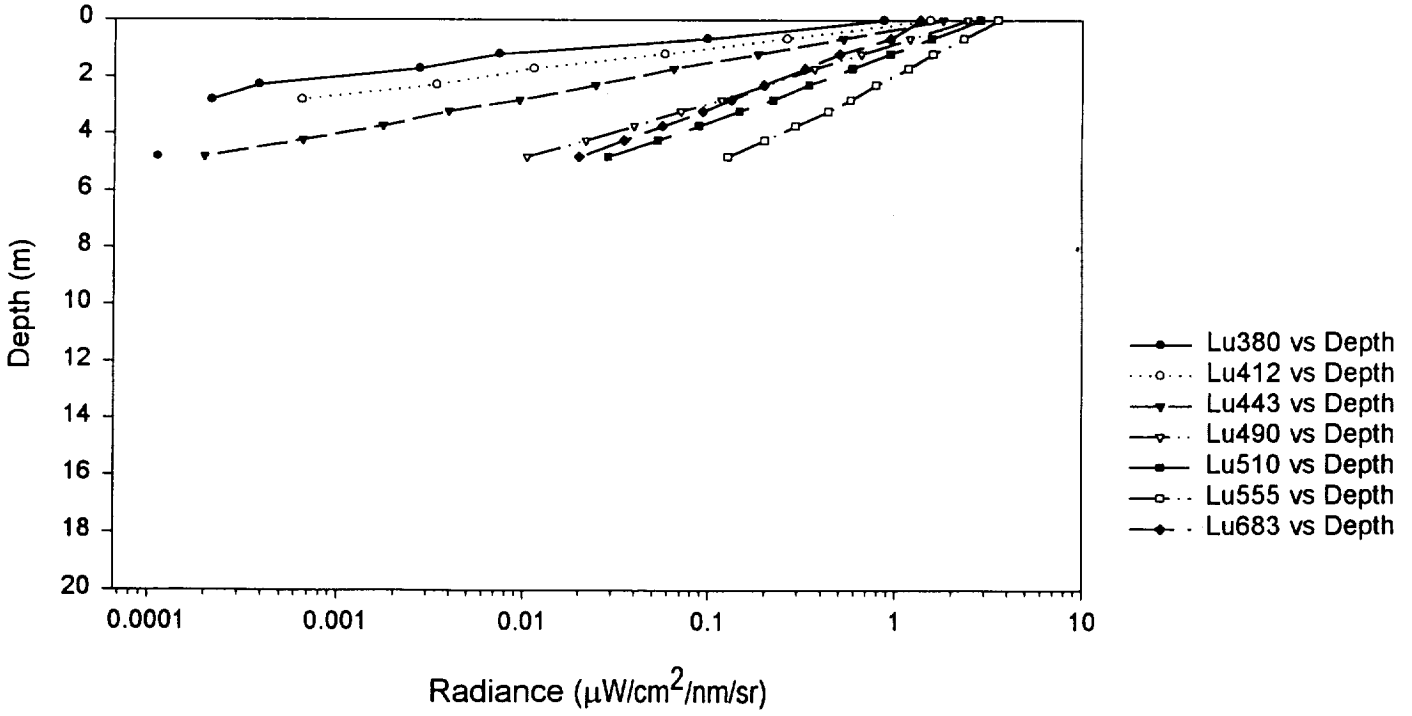
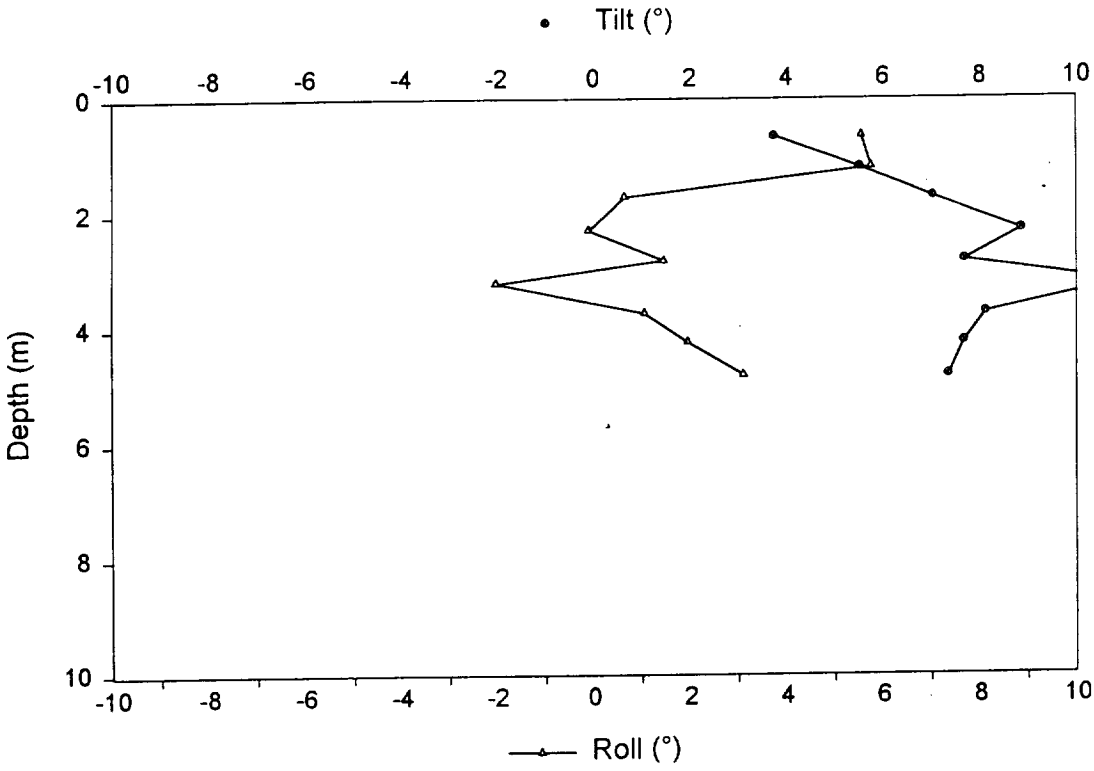


Figure A.12.b - Station 8A Upcast



Diffuse Attenuation Coefficient (kλ)

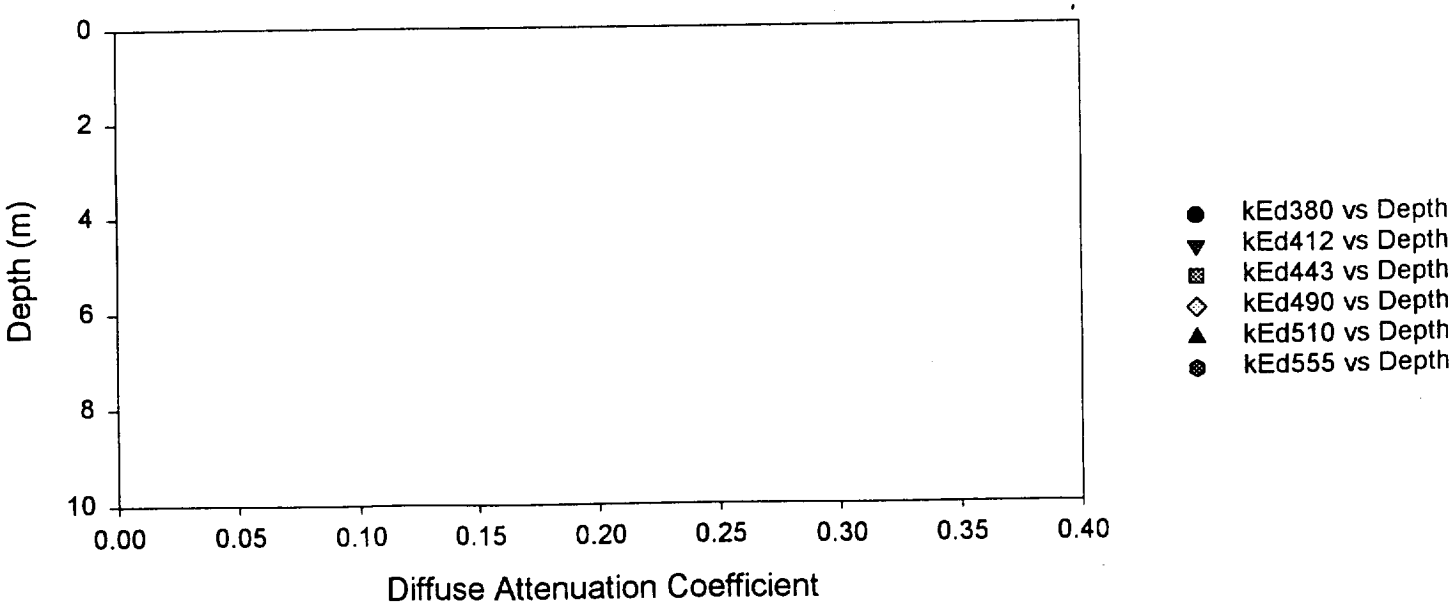
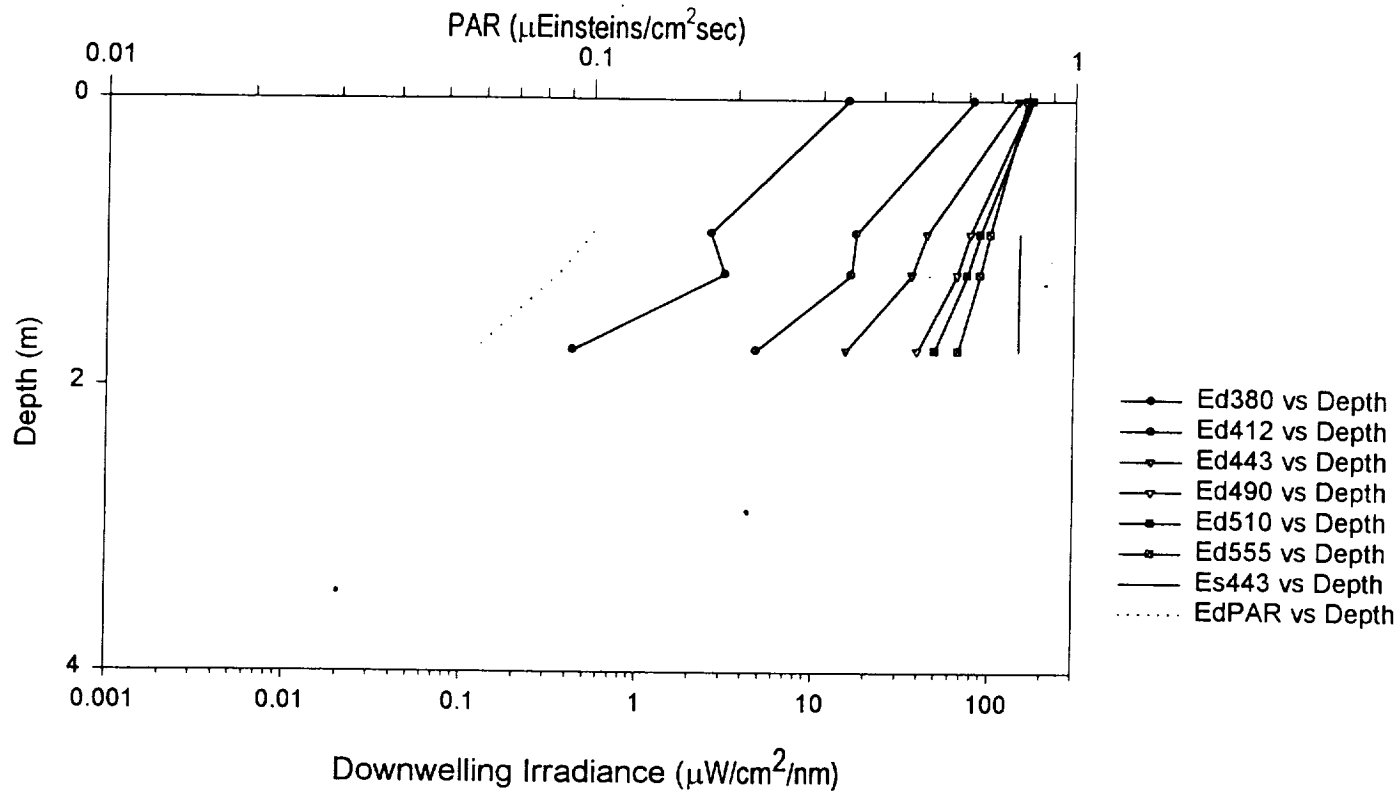


Figure A.13.a - Station 8C Downcast



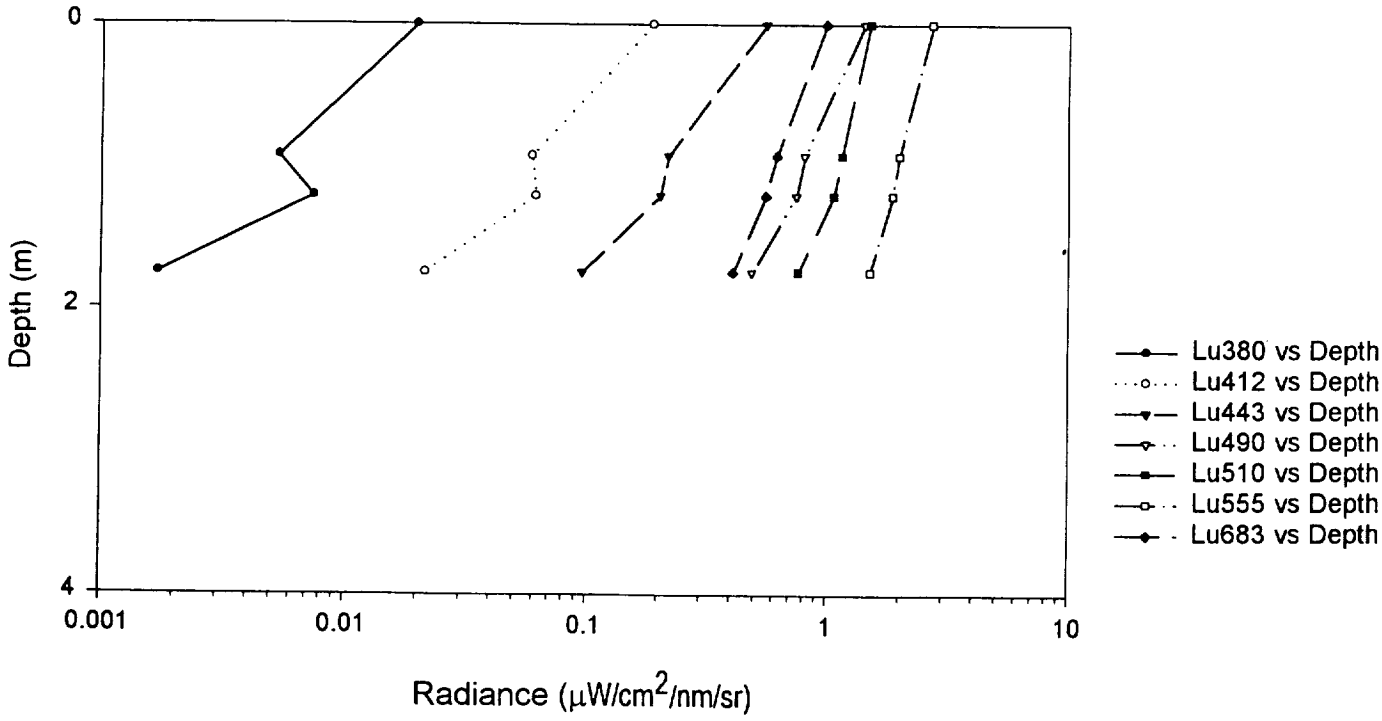
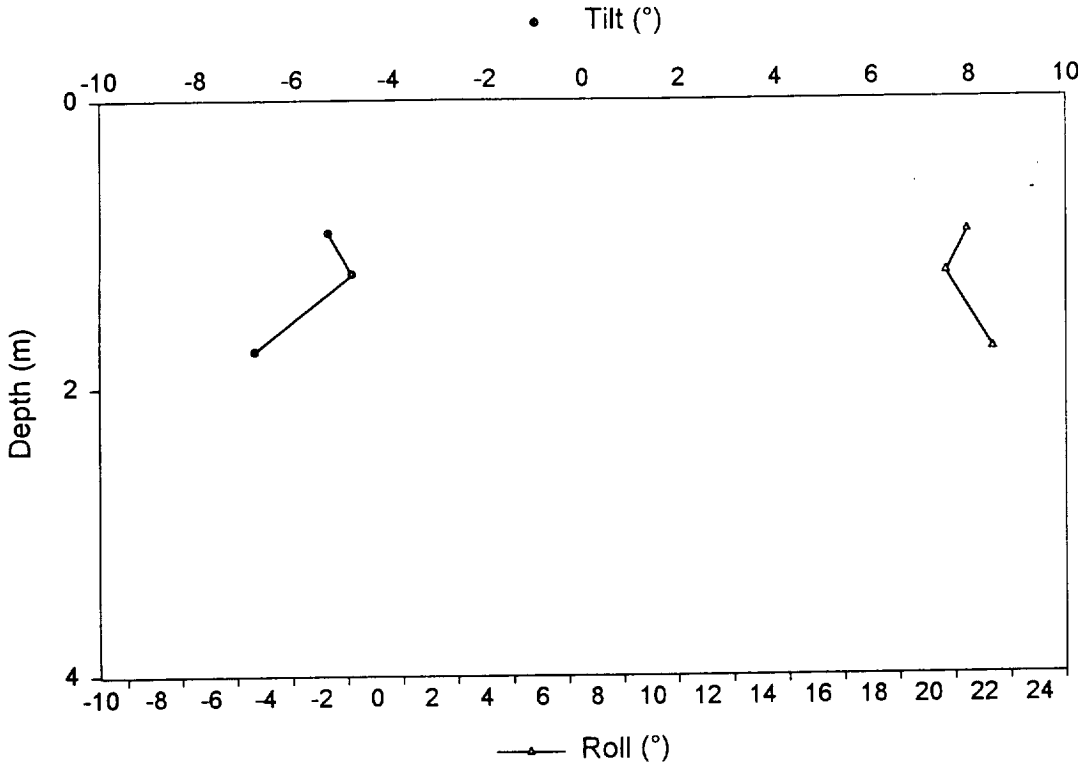


Figure A.13.b - Station 8C Downcast



Diffuse Attenuation Coefficient (kλ)

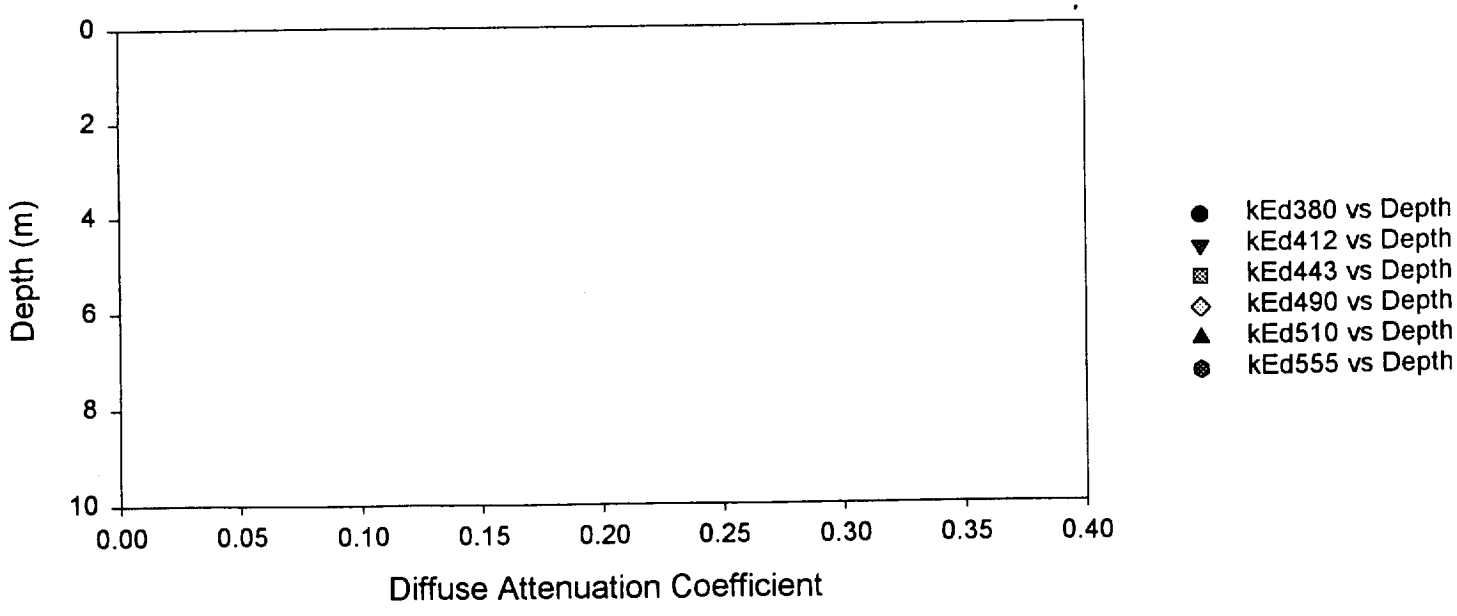
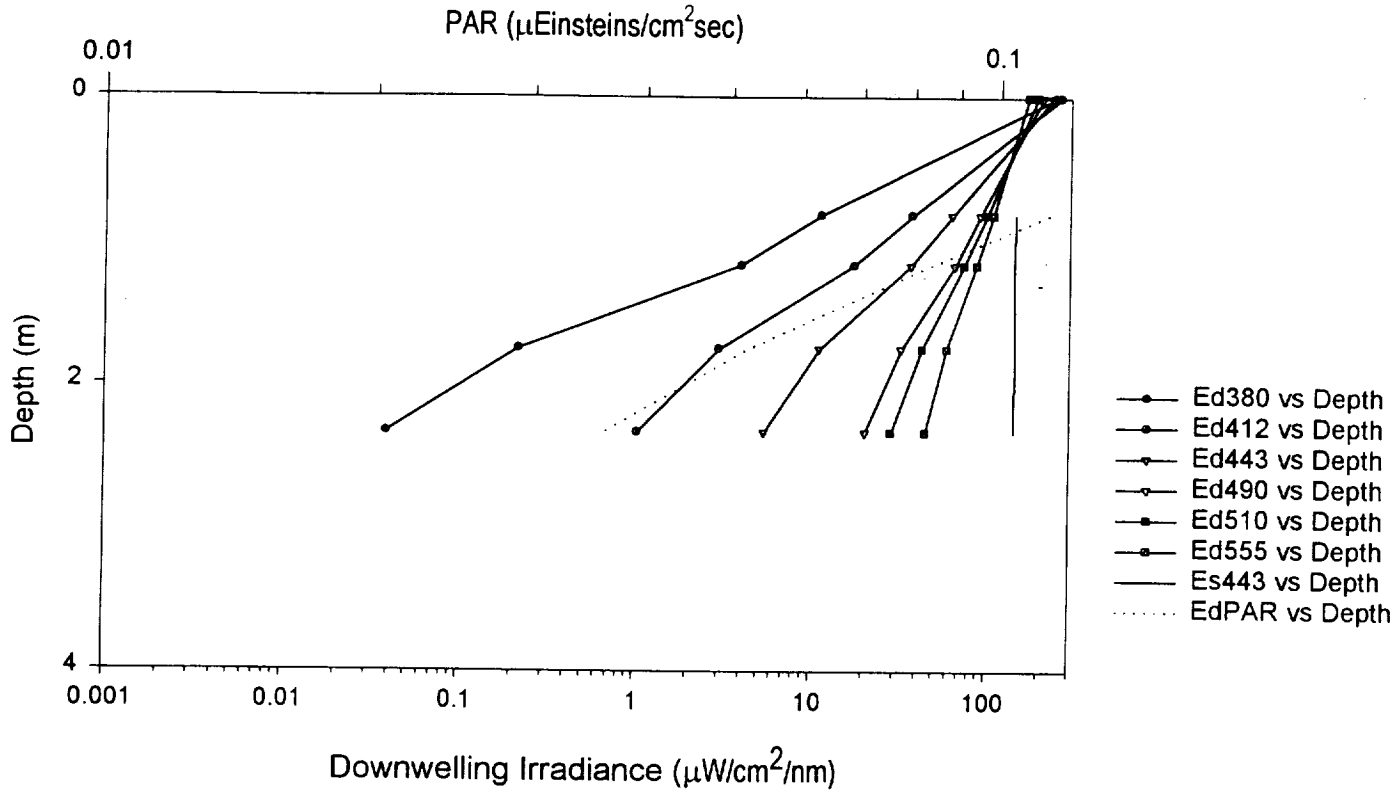


Figure A.14.a - Station 8C Upcast



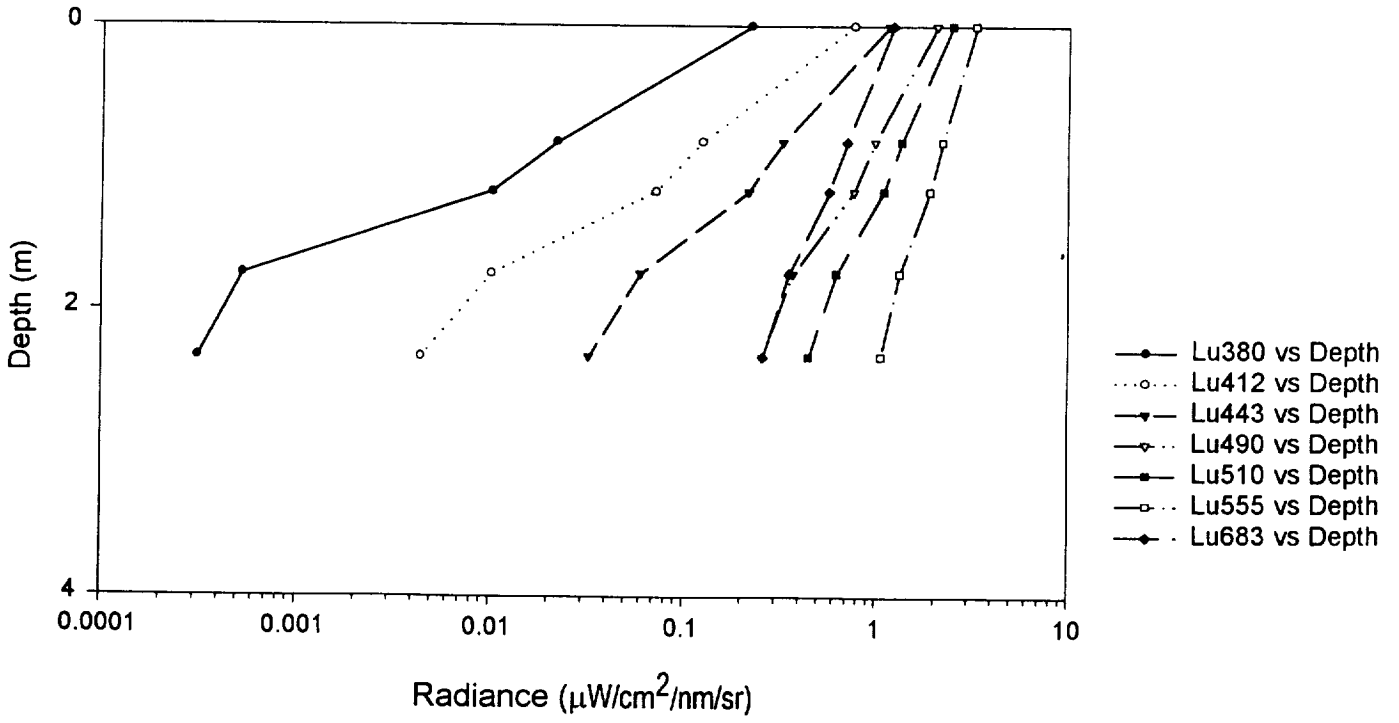
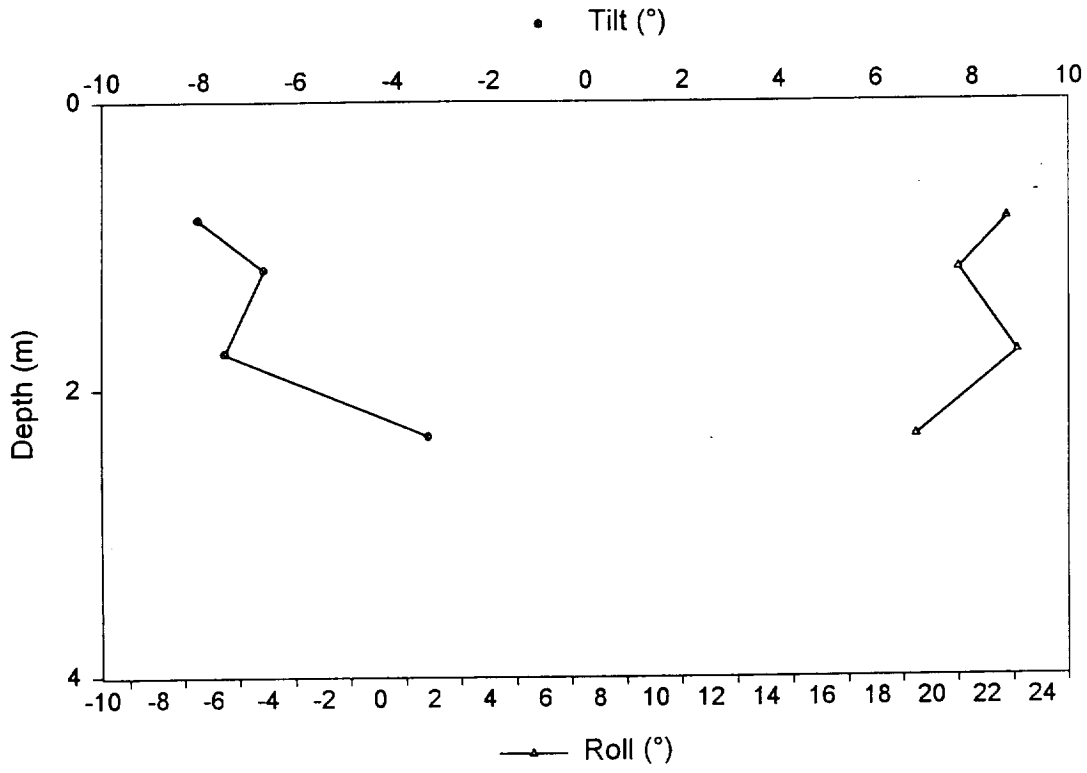


Figure A.12.b - Station 8A Upcast



Diffuse Attenuation Coefficient (kλ)

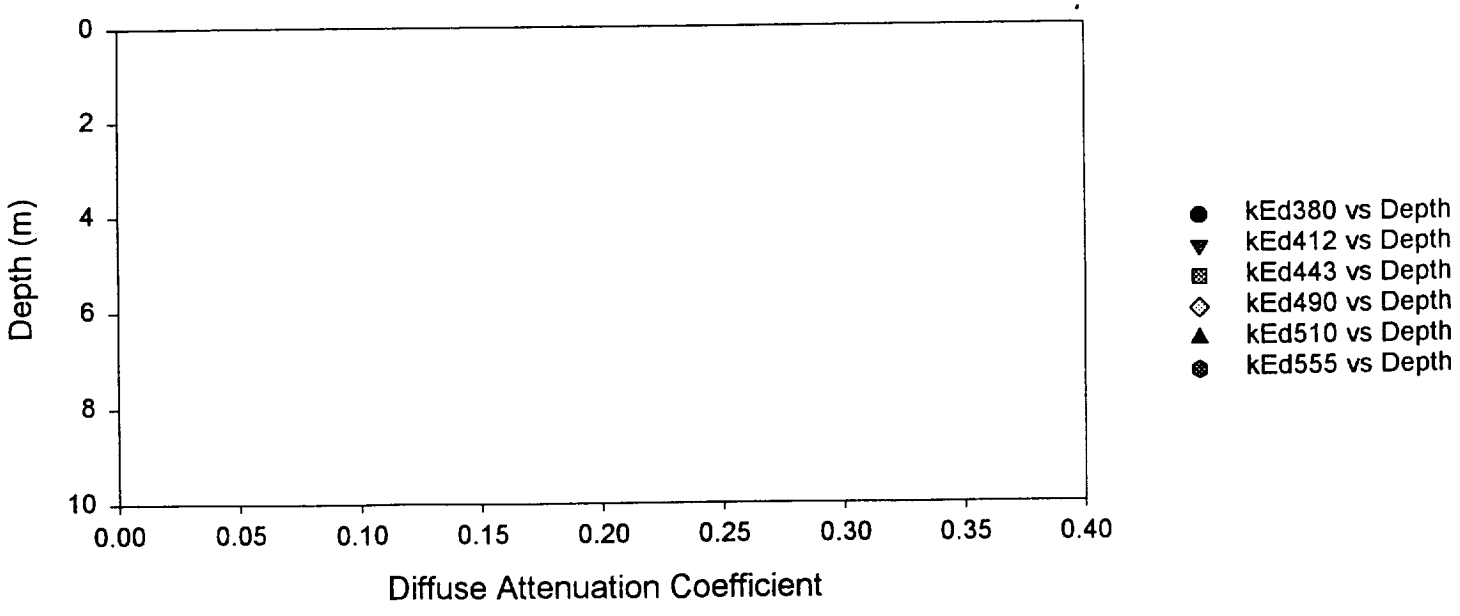
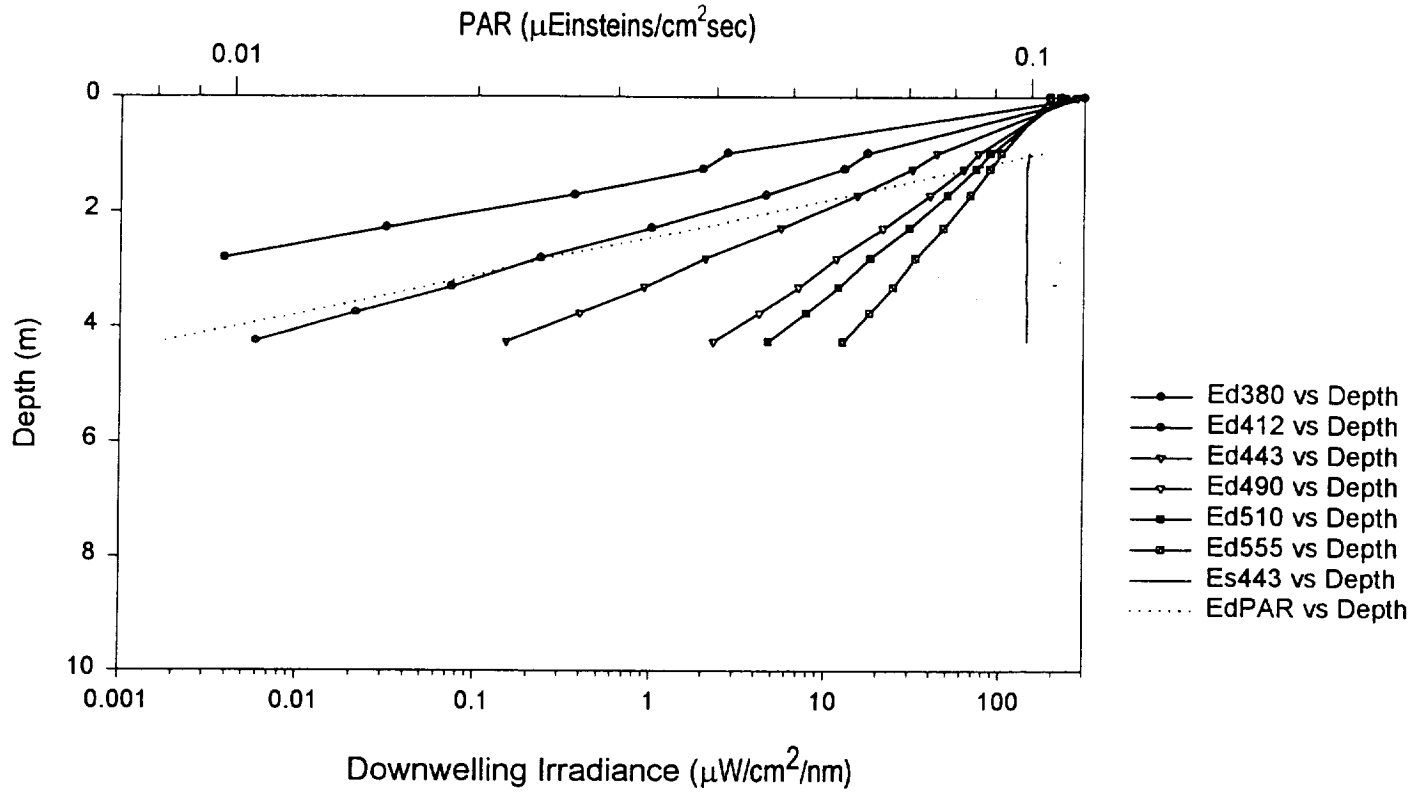


Figure A.15.a - Station 8E Downcast



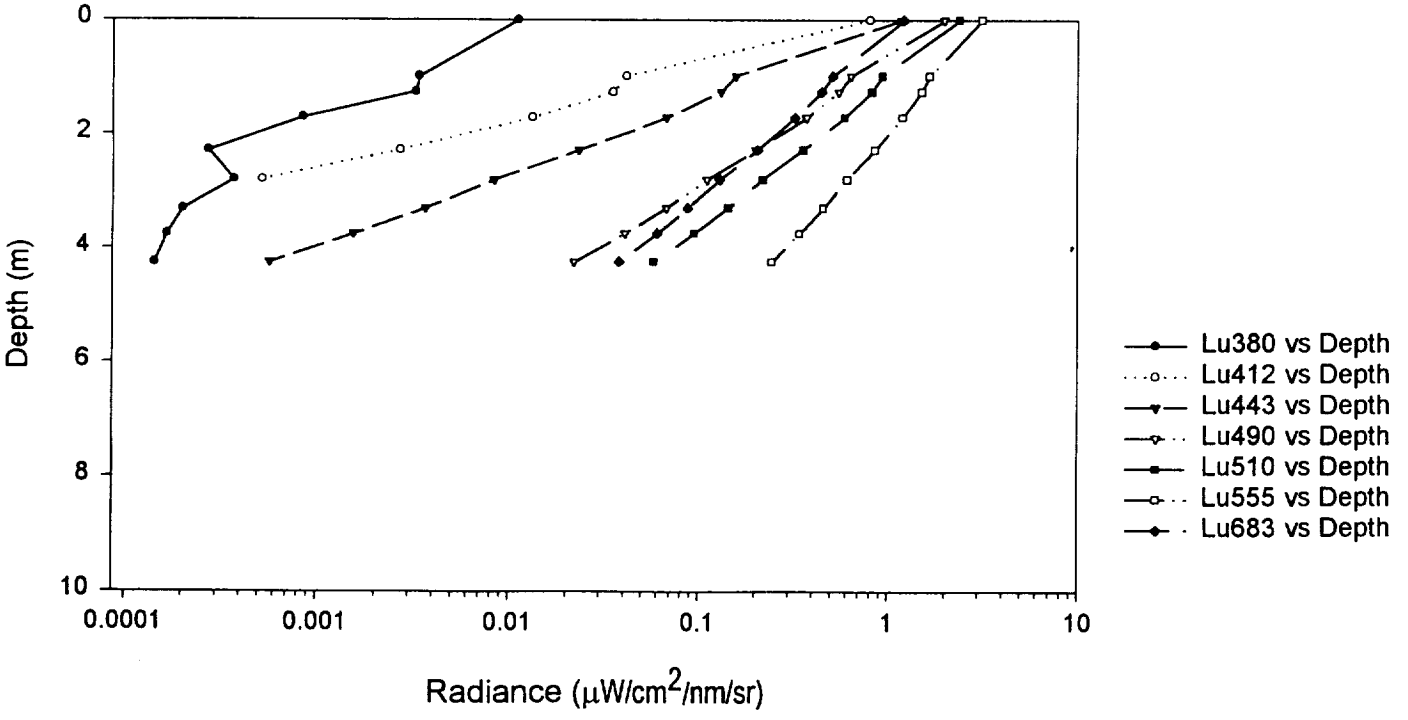
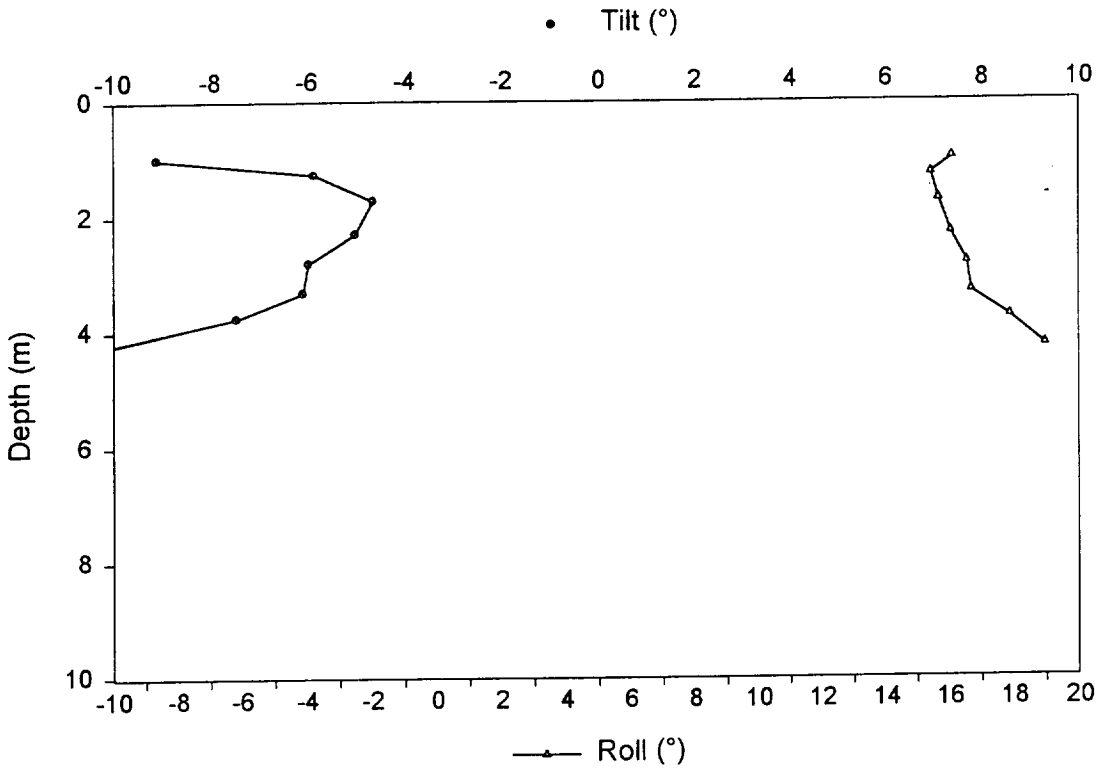


Figure A.15.b - Station 8E Downcast



Diffuse Attenuation Coefficient (kλ)

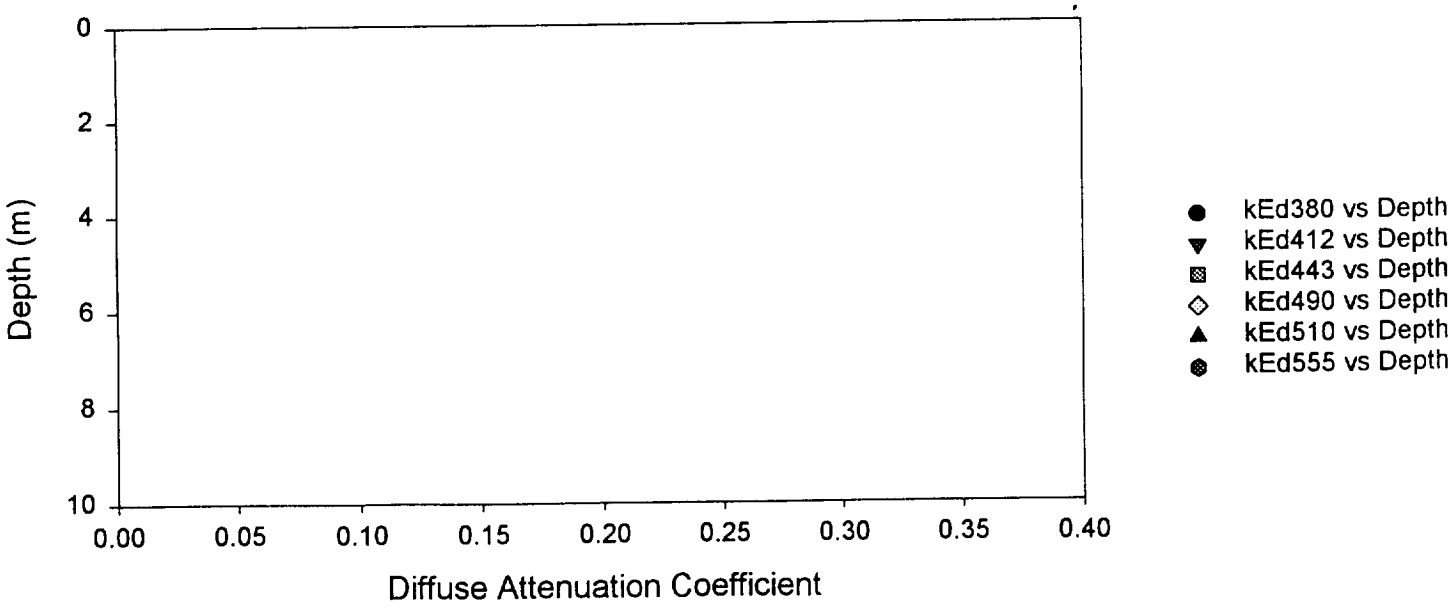
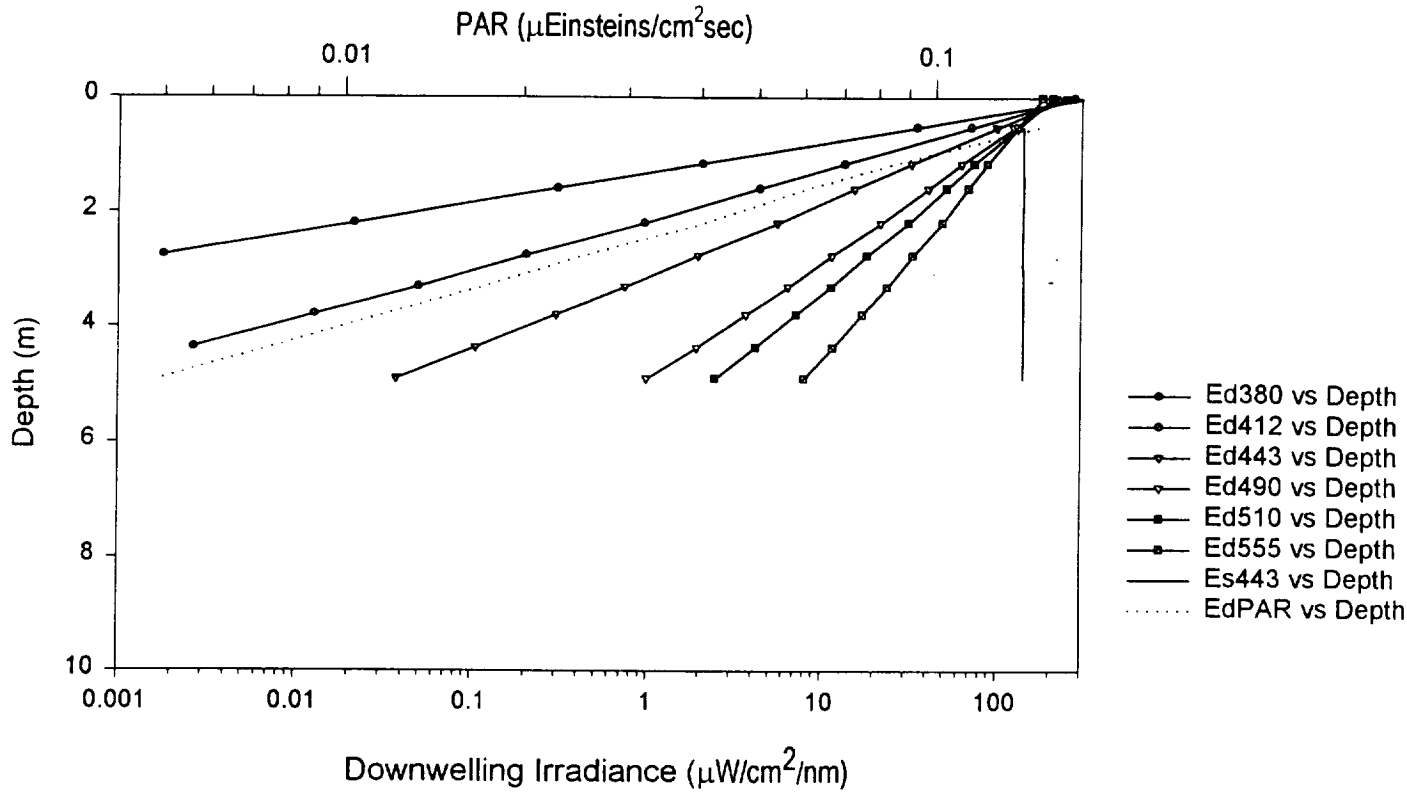


Figure A.16.a - Station 8E Upcast



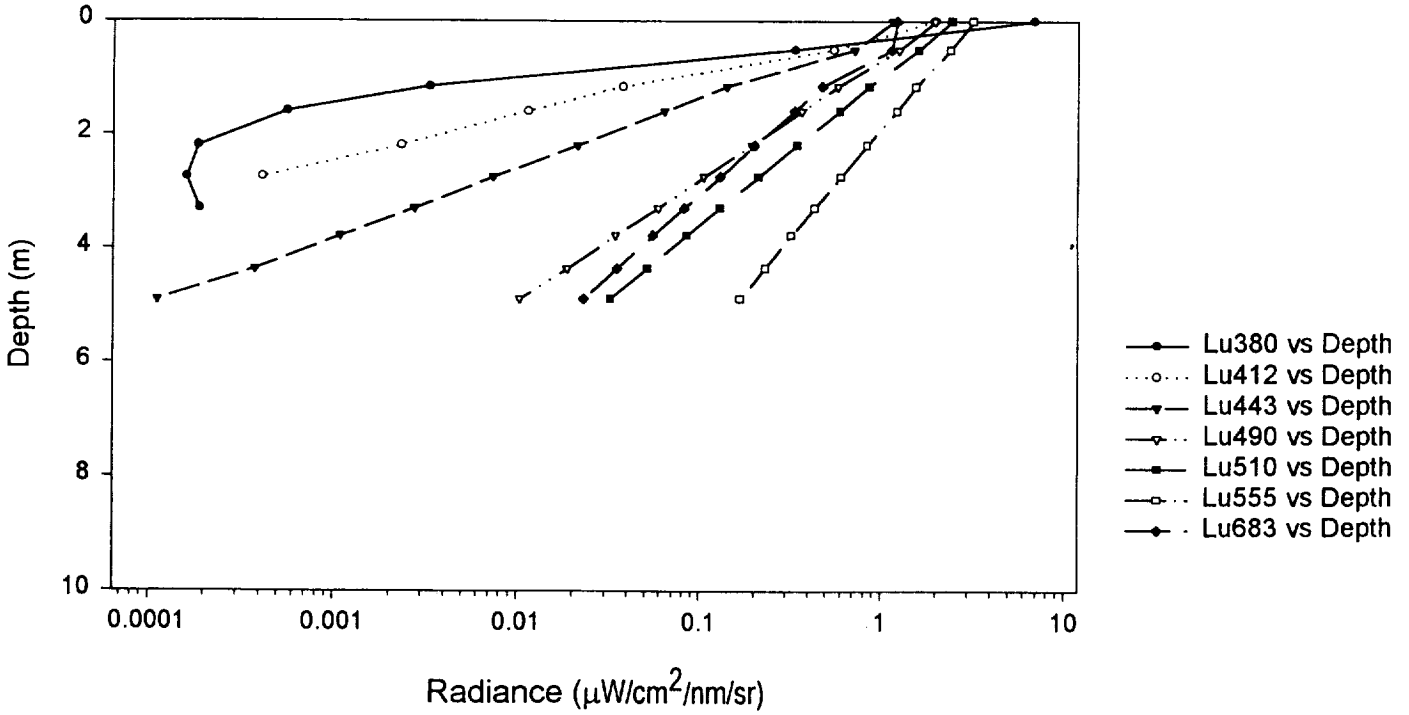
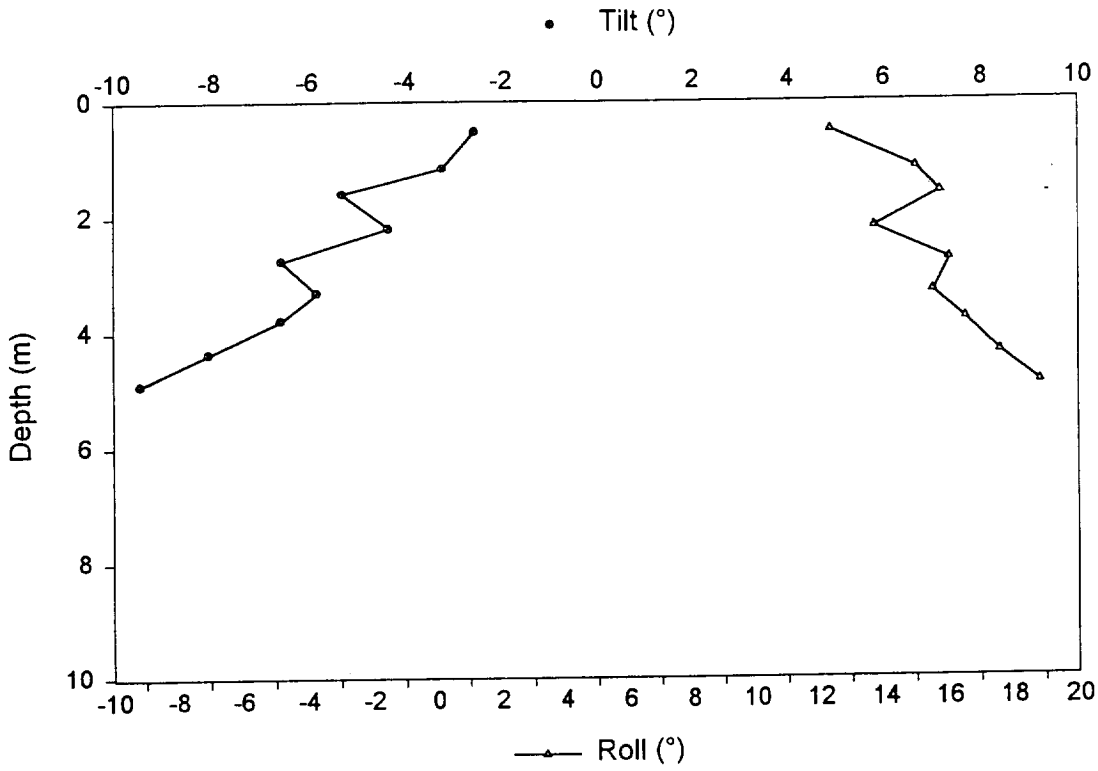


Figure A.16.b - Station 8E Upcast



Diffuse Attenuation Coefficient (kλ)

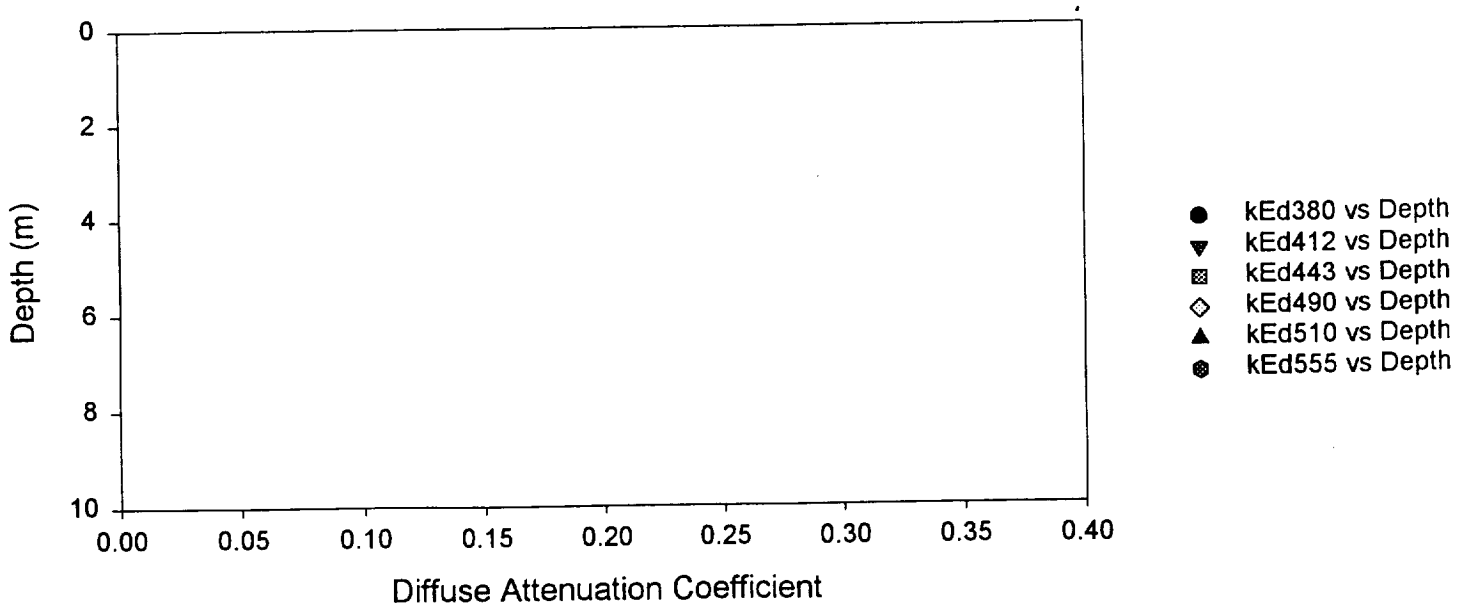
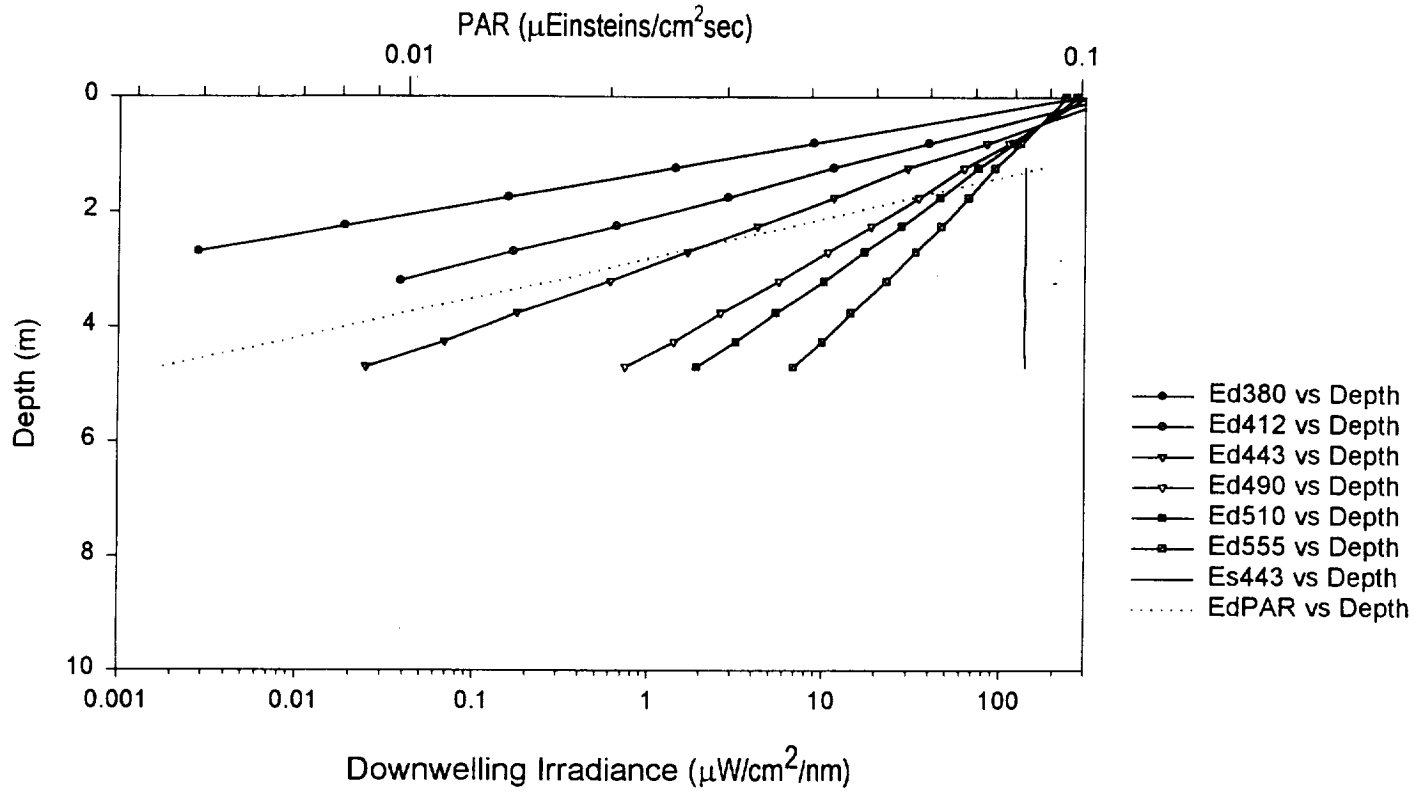


Figure A.17.a - Station 8G Downcast



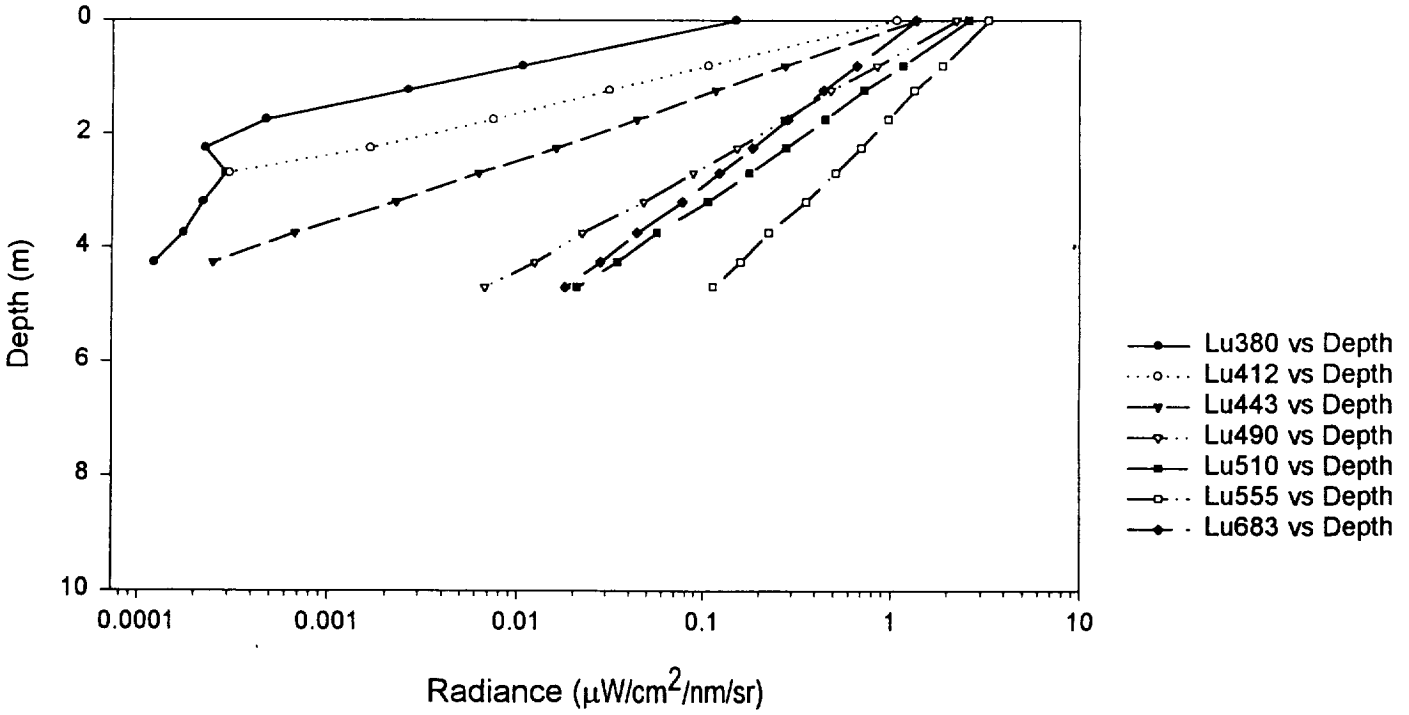
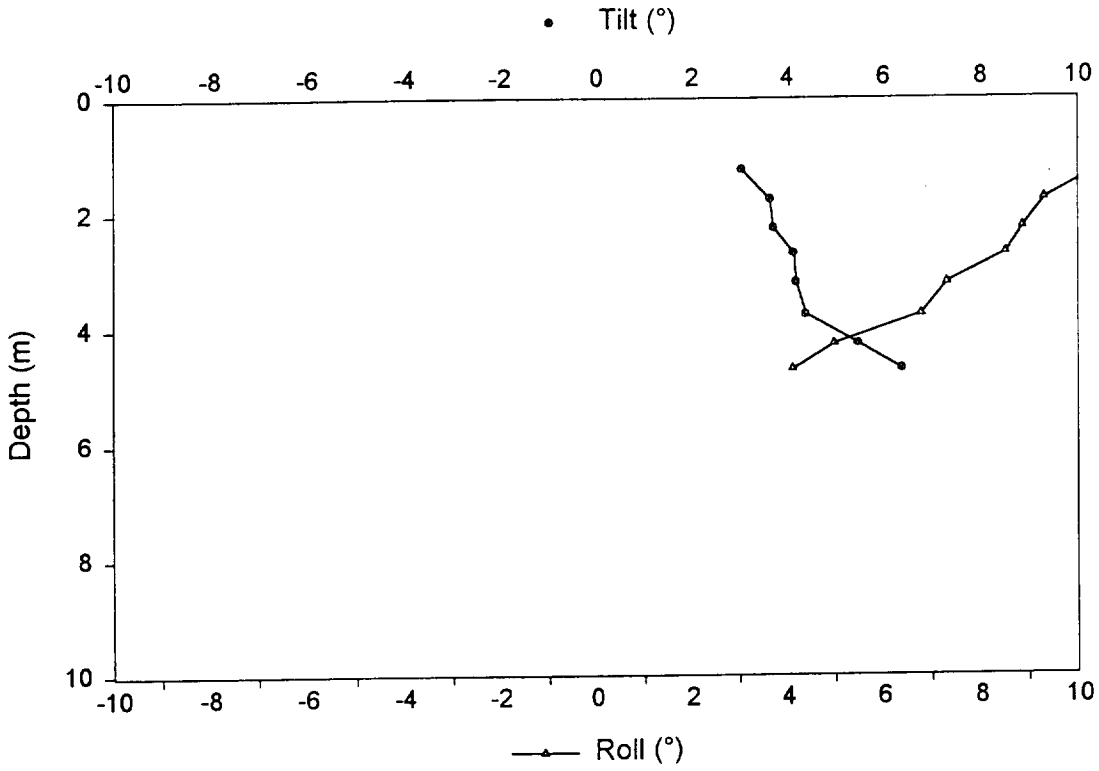


Figure A.17.b - Station 8G Downcast



Diffuse Attenuation Coefficient (kλ)

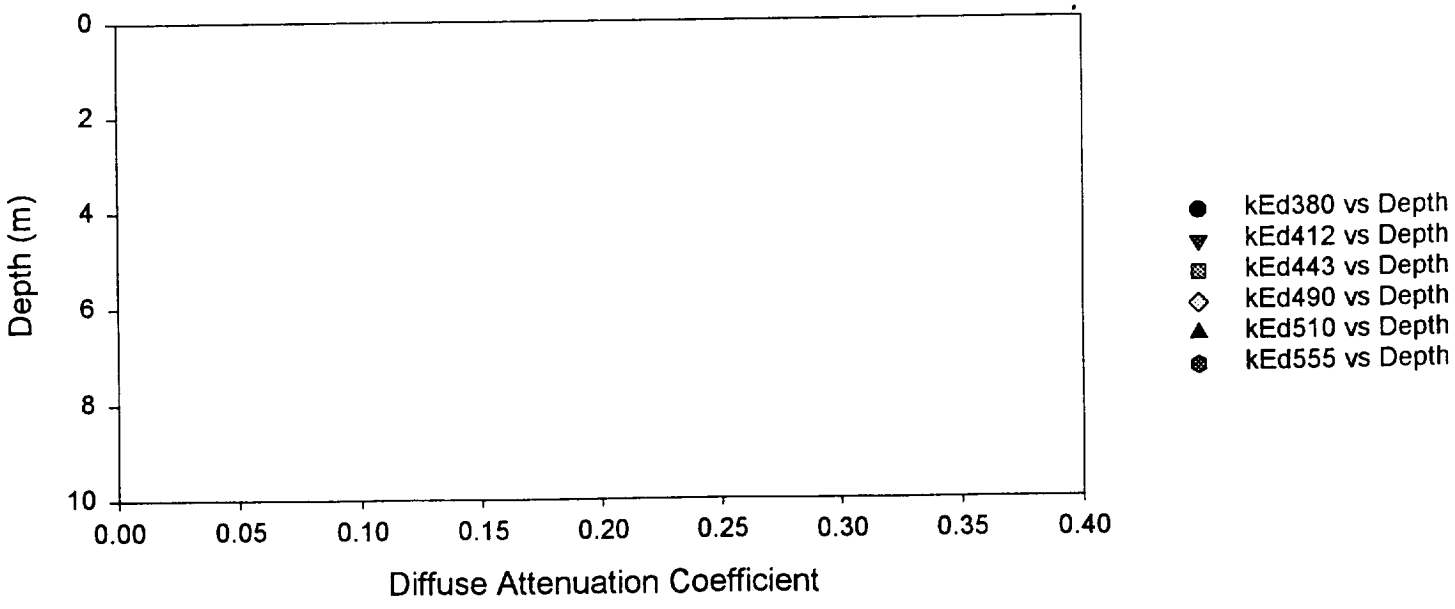
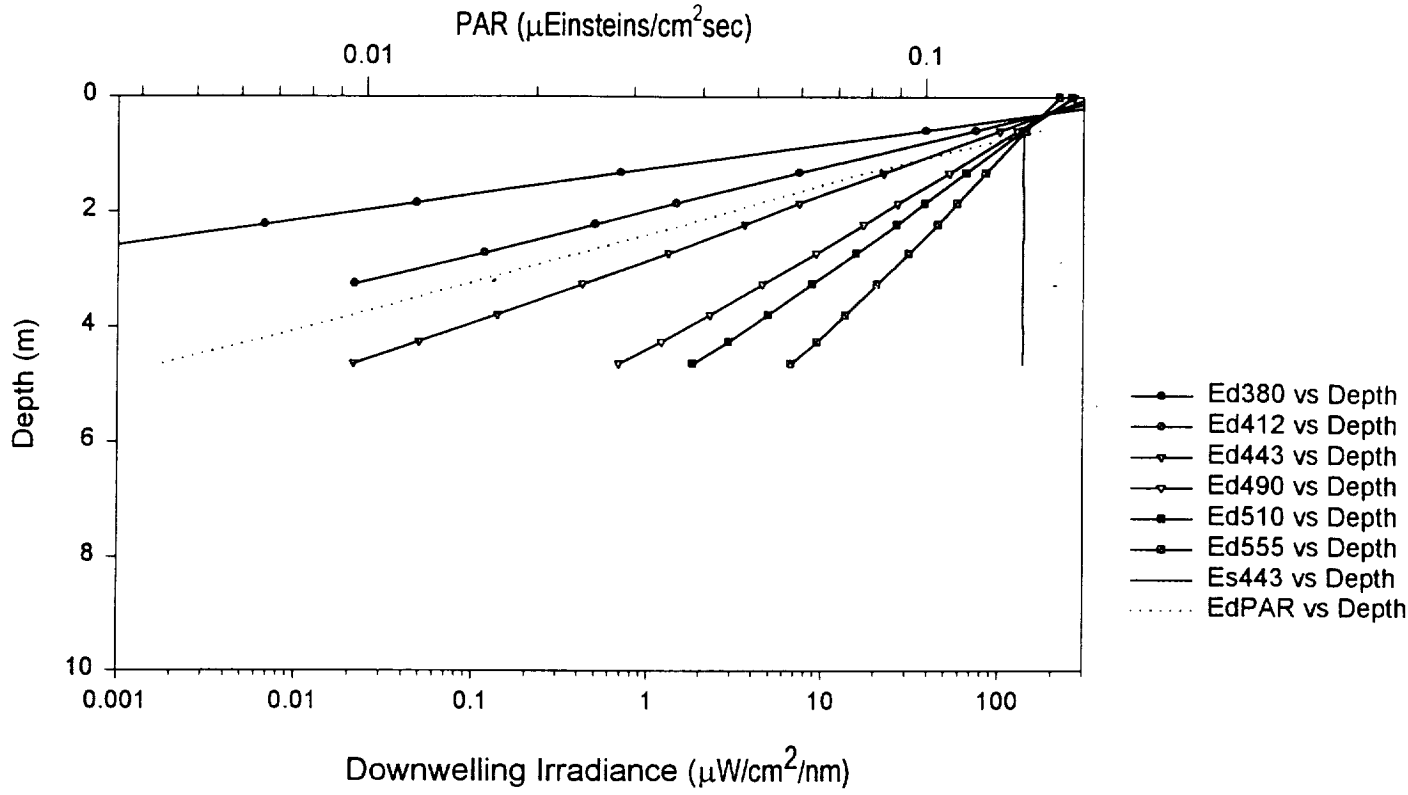


Figure A.18.a - Station 8G Upcast



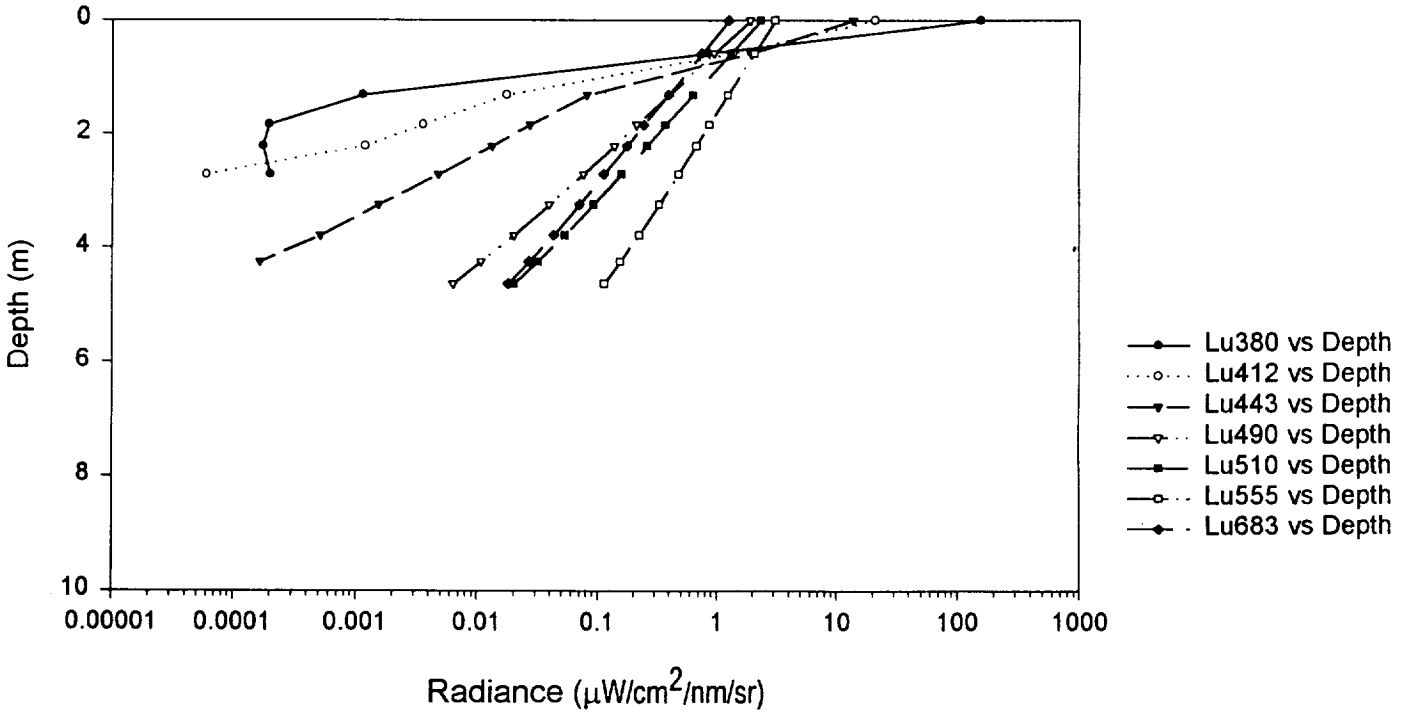
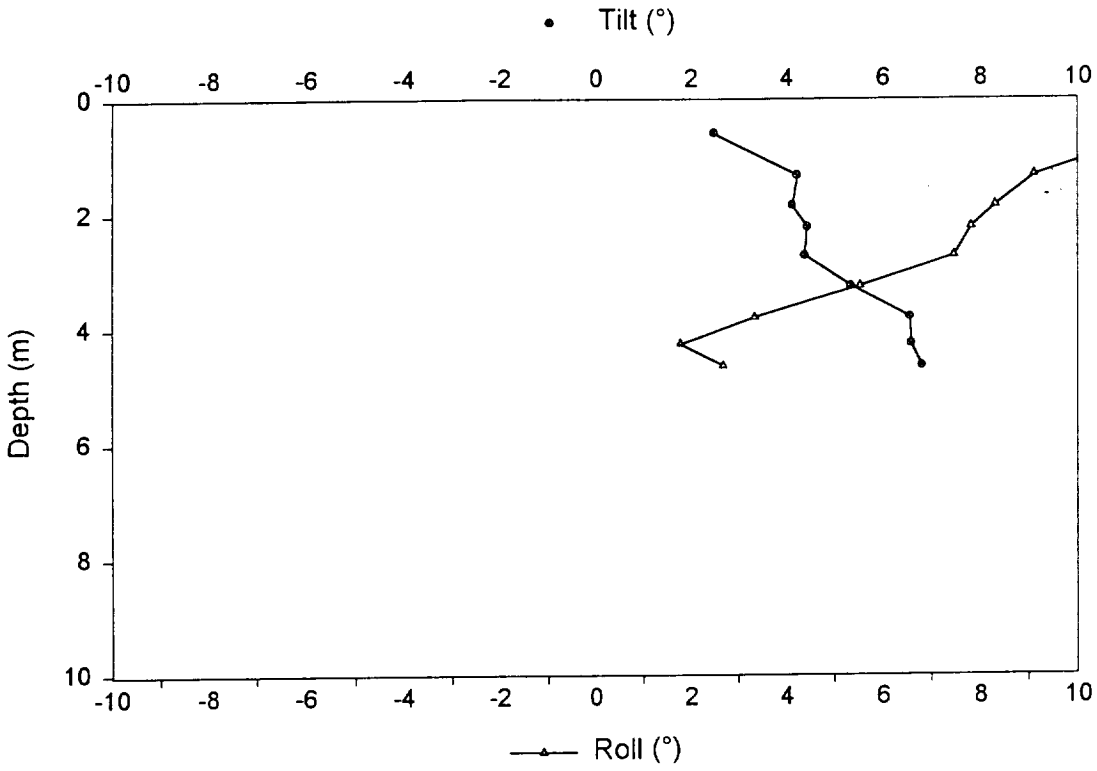
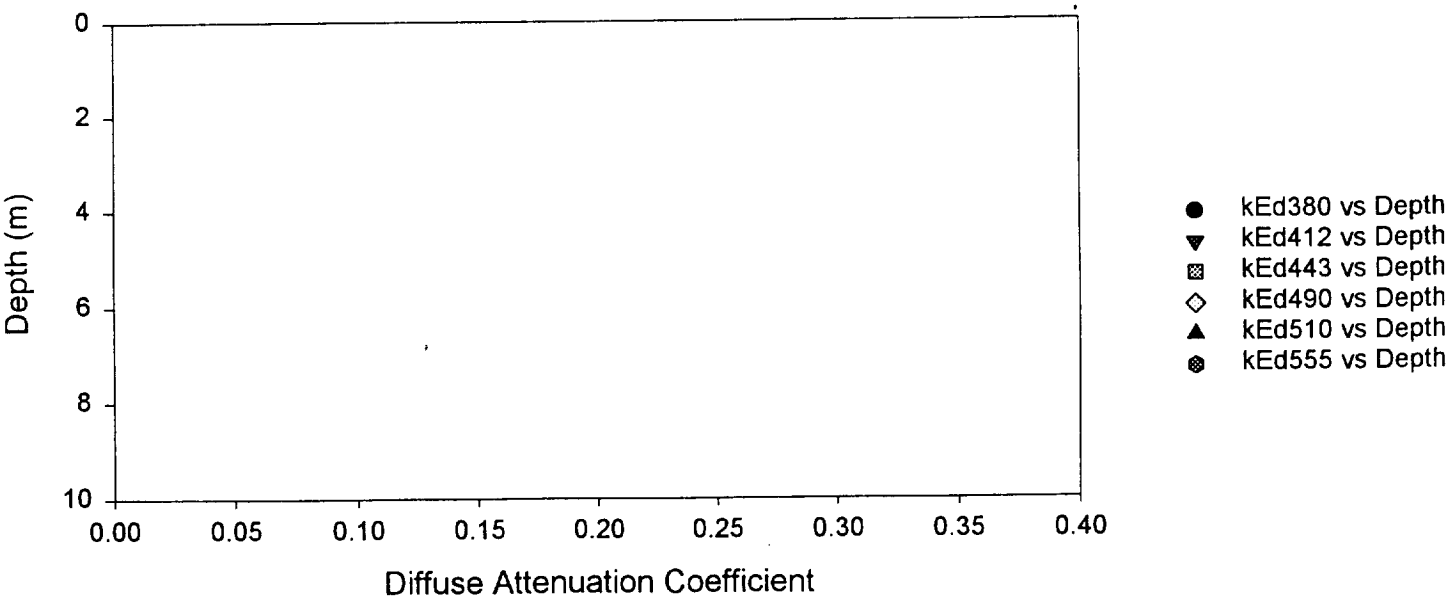


Figure A.18.b - Station 8G Upcast



Diffuse Attenuation Coefficient (kλ)



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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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

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

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

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

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

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

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

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

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

OPTIONAL CHANNELS

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

Notes:

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

Biospherical Instruments Inc.

EVALUATION FORM for PRR Spectroradiometer

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

Model Number: PRV-600S

Serial Number: 9643

Operator: JCE/LFG

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

Ch	Tag	λ (nm)	Lamp Irradiance	Immersion Coefficient	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Calibration Factor - Wet (V/µW)	Max E (Dry)	
DOWNWELLING IRRADIANCE CHANNELS						Irradiance Units: µW/cm²·nm, E = Irradiance				
1	0	380	1.486	0.671	0.000160	-0.019050	-0.012927	-0.008677	773.8	
2	0	412	2.559	0.677	0.000095	-0.081553	-0.031907	-0.021592	313.4	
3	0	443	3.906	0.682	0.000116	-0.126520	-0.032421	-0.022113	308.4	
4	0	490	6.483	0.690	0.000272	-0.218429	-0.033732	-0.023280	296.5	
5	0	510	7.683	0.694	0.000108	-0.250415	-0.032609	-0.022617	306.7	
6	0	555	10.536	0.701	0.000459	-0.345228	-0.032809	-0.023010	304.8	
7	0	PAR[4]	0.0152	0.686	0.000337	-0.200664	-13.196577	-9.050741	0.758	[4]
8	0	Gnd.[5]	0.000309	Volts						

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

DRY = (Light - Dark)/Lamp Output

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

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

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

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

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

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

	Irr. Array	Rad. Array
Scale Factor	1.057879	1.074227
Offset	0.000206	0.000278
Full Scale Voltage	9.4647	9.3090

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

OPTIONAL CHANNELS

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

Notes:

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

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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

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

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

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

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

9	0	TEMPERATURE[7, 9]	Temperature (°C) = (Voltage - Offset)/Scale
		Scale	0.1421
		Offset	0.0889
10	0	PRESSURE/DEPTH[2, 9]	Pressure/Depth (dbars or meters) = (a x Voltage²) + (b x Voltage) + c
		Scale Factor "a"	0.9383
		Scale Factor "b"	83.1773
		Offset "c"	26.9099

NOMINAL TO ACTUAL VOLTAGE CONVERSION FACTORS[3] (For use with external sensors, only, see manual)

	Irr. Array	Rad. Array	
Scale Factor	1.057679	1.074227	(Calibrated on 3-96)
Offset	0.000206	0.000278	
Full Scale Voltage	9.4647	9.3090	

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

OPTIONAL CHANNELS

Ch	Tag			
11	0	Transmissometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
12	0	Scalar PAR: QSP-200 S/N 4443[2]	quanta/(cm^2·sec) = (Voltage - Offset)/Scale	
		Scale Factor (Wet)	-1.020E-17	Volts/(quanta/cm^2·sec)
		Offset	0.0009	Volts
13	0	AXIS 1 ANGLE SENSOR - "TILT"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0418	(Calibrated on 3-96)
		Offset	2.6862	
14	0	AXIS 2 ANGLE SENSOR - "ROLL"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0416	(Calibrated on 3-96)
		Offset	2.6973	
15	0	Light Scattering Sensor[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
16	0	Fluorometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts

Notes:

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

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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.

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

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

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

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

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

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

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

FIRMWARE VERSIONS

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

OPTIONAL CHANNELS

Ch	Tag			
11	0	Transmissometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
12	0	Scalar PAR: QSP-200 S/N 4443	quanta/(cm^2·sec) = (Voltage - Offset)/Scale	
		Scale Factor (Wet)	-1.020E-17	Volts/(quanta/cm^2·sec)
		Offset	0.0009	Volts
13	0	AXIS 1 ANGLE SENSOR - "TILT"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0418	
		Offset	2.6862	
14	0	AXIS 2 ANGLE SENSOR - "ROLL"[2]	Degrees = (Voltage - Offset)/Scale	
		Scale Factor	0.0416	
		Offset	2.6973	
15	0	Light Scattering Sensor[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts
16	0	Fluorometer[1]	Output = (Voltage - Offset)/Scale	
		Scale Factor	1.0	Volts/Volt
		Offset	0.0	Volts

Notes:

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

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

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Calibration Date: 1/7/98 **Form:** 1/8/98
Model Number: PRV-600S
Serial Number: 9643
Operator: TMM/DAN
Standard Lamp: 94531 (01/02/97) for Irradiance, 94532 (10/11/95) for Radiance

Ch	Ta	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient (Type P6-2)	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/μW)	Calibration Factor - Wet (V/μW)	Max E (Dry)	
DOWNWELLING IRRADIANCE CHANNELS						Irradiance Units: μW/cm²·nm, E = Irradiance				
1	0	380	1.578	0.671	0.000216	-0.019687	-0.012617	-0.008469	792.6	
2	0	412	2.595	0.677	0.000144	-0.082185	-0.031725	-0.021469	315.2	
3	0	443	4.003	0.682	0.000186	-0.129799	-0.032473	-0.022149	307.9	
4	0	490	6.647	0.690	0.000293	-0.223611	-0.033683	-0.023246	296.9	
5	0	510	7.880	0.694	0.000160	-0.255997	-0.032509	-0.022547	307.6	
6	0	555	10.730	0.701	0.000481	-0.351498	-0.032802	-0.023005	304.9	
7	0	PAR[4]	0.01539	0.689	0.000366	-0.204294	-13.296675	-9.158271	0.752	[5]
8	0	Gnd.[5]	0.000315	Volts						

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

Ch	Ta	λ (nm)	Lamp Irradiance @ 50 cm	Immersion Coefficient (BK7 window)	Plaque Reflectivity S/N 20166	Radiance[6]	Calibration Voltage - Dark	Calibration Voltage - Blocked[3]	Calibration Voltage - Light	Calibration Factor - Wet (V/μW)	Max L (Wet)
UPWELLING RADIANCE CHANNELS						Radiance Units: μW/cm²·nm·sr, L = Radiance					
1	1	380	1.308	1.765	0.987	0.011	0.000199	0.000189	-0.002868	-0.154031	64.9
2	1	412	2.275	1.758	0.990	0.020	-0.000094	-0.000102	-0.017453	-0.503175	19.9
3	1	443	3.514	1.752	0.991	0.030	0.000239	0.000220	-0.048862	-0.923407	10.8
4	1	490	5.911	1.745	0.991	0.051	0.000197	0.000169	-0.090176	-1.014244	9.9
5	1	510	7.038	1.743	0.991	0.061	0.000331	0.000308	-0.133501	-1.262725	7.9
6	1	555	9.746	1.738	0.991	0.084	0.000171	0.000118	-0.260191	-1.779516	5.6
7	1	683	16.755	1.730	0.991	0.145	0.000091	0.000001	-0.383667	-1.533607	6.5
8	1	Gnd.[5]	0.000164	Volts							

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

9	0	TEMPERATURE[7]	Temperature (°C) = (Voltage - Offset)/Scale
		Scale	0.1419
		Offset	0.0919
10	0	PRESSURE/DEPTH[8]	Pressure/Depth (dbars or meters) = (a x Voltage²) + (b x Voltage) + c
		Scale Factor "a"	0.9298
		Scale Factor "b"	83.3548
		Offset "c"	26.8924

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

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

FIRMWARE VERSION(S)

	Tag 0	Tag 1
Underwater ROM	2765B	2043A

Notes:

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: 1/7/98 **Form:** 1/8/98
Model Number: PRV-600S
Serial Number: 9643
Operator: TMM/DAN

OPTIONAL CHANNELS

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

Notes:
1) These sensors are not calibrated at BSI. When applicable, see the manufacturers' specifications.
2) These channels/sensors were not evaluated during this service period.

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

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

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

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

	Irr. Array
Scale	1.061494
Offset	0.000049
Full Scale Voltage	9.4207

FIRMWARE VERSION

	Tag 2
Surface ROM	2106B

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

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

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

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

	Irr. Array
Scale	1.061494
Offset	0.000049
Full Scale Voltage	9.4207

FIRMWARE VERSION

	Tag 2
Surface ROM	2106B

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

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)

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

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

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

	Irr. Array
Scale	1.061494
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).

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

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

Ch	Tag	λ (nm)	Lamp Output	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Max E (Dry)	
SURFACE IRRADIANCE CHANNELS					Irradiance Units: µW/cm²-nm, E = Irradiance			
1	2	380	1.578	0.000240	-0.049332	-0.031424	318.2	
2	2	412	2.595	-0.000879	-0.084205	-0.032110	311.4	
3	2	443	4.003	-0.000021	-0.135255	-0.033785	296.0	
4	2	490	6.647	-0.000256	-0.219210	-0.032938	303.6	
5	2	510	7.880	-0.000241	-0.257444	-0.032641	306.4	
6	2	555	10.730	0.000203	-0.346664	-0.032328	309.4	
7	2	PAR[4]	0.0154	0.000069	-0.162024	-10.531115	0.950	4)
8	2	Gnd.[3]	0.000101	Volts				

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

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

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

FIRMWARE VERSION

	Tag 2
Surface ROM	2106B

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

DO NOT DESTROY
Biospherical Instruments Inc.
CALIBRATION DATA

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE for PRR Spectroradiometer

Calibration Date: ~~2/10/97~~ 1/7/98 use **Form:** 1/8/98
Model Number: PRV-610
Serial Number: 9644
Operator: TMM/DAN
Standard Lamp: 95431 (01/02/97)

Ch	Tag	λ (nm)	Lamp Output	Calibration Voltage - Dark[3]	Calibration Voltage - Light	Calibration Factor - Dry (V/µW)	Max E (Dry)
SURFACE IRRADIANCE CHANNELS					Irradiance Units: µW/cm^2-nm, E = Irradiance		
1	2	380	1.578	0.000250	-0.050046	-0.031883	313.6
2	2	412	2.595	-0.000869	-0.084474	-0.032217	310.4
3	2	443	4.003	-0.000011	-0.136253	-0.034036	293.8
4	2	490	6.647	-0.000248	-0.221013	-0.033211	301.1
5	2	510	7.880	-0.000220	-0.259113	-0.032856	304.4
6	2	555	10.730	0.000225	-0.348584	-0.032507	307.6
7	2	PAR[4]	0.0154	0.000105	-0.161913	-10.526242	0.950 [4]
8	2	Gnd.[5]	0.000105	Volts			

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

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

	Irr. Array
Scale	1.061494
Offset	0.000049
Full Scale Voltage	9.4207

FIRMWARE VERSION

	Tag 2
Surface ROM	2106B

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