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

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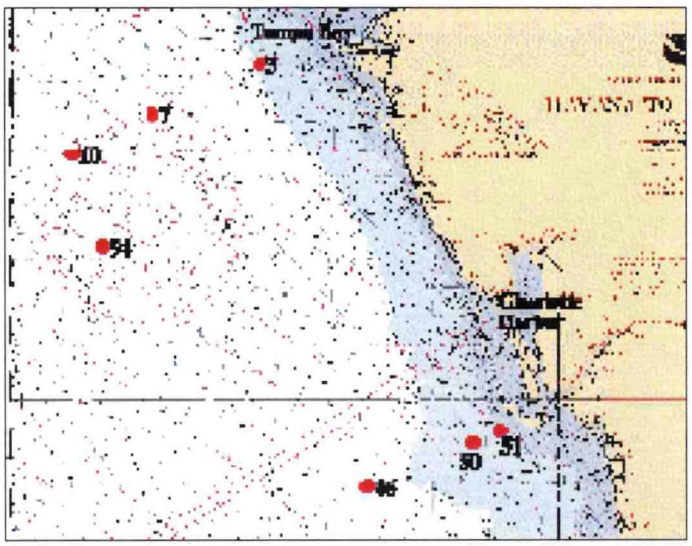
NOAA NOS Cruise APR00FWS: West Florida Shelf Cruise



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University of Maryland
University of South Florida


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

CSC Technical Report: NOAA/CSC/20018-PUB

NOAA Cruise APR00FWS: West Florida Shelf Cruise

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Abstract

A total of seven stations were occupied between April 4 and 6, 2000, on the Florida West Shelf for the purpose of validating algorithms for the calculation of chlorophyll *a* concentrations. Data for calculation were obtained from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on board the SeaStar spacecraft. Algorithms that utilize optical measurements of downwelling irradiance and upwelling radiance to calculate chlorophyll concentration were compared to traditional methods of measurement.

A range of chlorophyll concentrations was measured during this cruise. High chlorophyll concentrations were present in the narrow inshore area near Charlotte Harbor, and stations farther north and offshore had low concentrations. The two instrument systems and four algorithms produced estimates similar to the chlorophyll concentrations measured using fluorometry. In addition, the concentrations measured by the SeaWiFS satellite on coincident days were similar to the measured concentration, indicating that atmospheric correction problems were minimal.

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Acknowledgments

This cruise was conducted in collaboration with the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Florida project, led by Dr. Karen Steidinger of the Florida Marine Research Institute. The cooperation and assistance provided by Dr. Cynthia Heil, chief scientist, is greatly appreciated. We thank the Captain and the crew of the Research Vessel *SunCoaster* for assistance provided.

I. Introduction

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

II. Objectives

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

III. Methods

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

A. Sampling Platform

The Research Vessel *SunCoaster*, belonging to the Florida Marine Research Institute, was used on this cruise.

B. Sampling Locations

A total of 7 stations were occupied between April 4 and 6, 2000 (Figure 1).

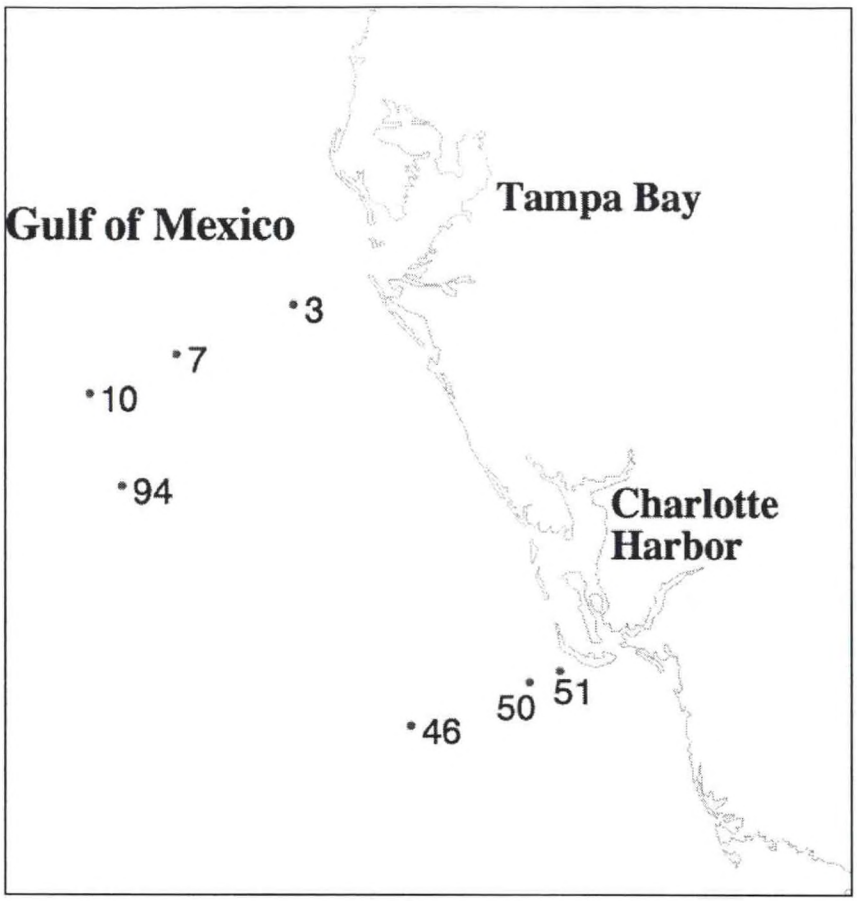

Figure 1. Station locations

C. Sample Collection Methods Summary

Surface samples were acquired by bucket at all station locations for fluorometric determination of chlorophyll concentration, High Performance Liquid Chromatography (HPLC) determination of photosynthetic pigments, and absorption of light by particulate matter (Table 1). A Biospherical Instruments, Inc., PRR-600s was used at these stations to provide a profile of the ocean optical and hydrographic properties. A PRR-610 was used to measure the above-water spectral downwelling irradiance at the same wavelengths as the PRR-600s. A Satlantic SeaWiFS Multi-channel Surface Radiometer (SMSR), a surface tethered buoy that measures above-water spectral downwelling irradiance and *in-situ* spectral upwelling radiance 75 centimeters below the surface, was used at all stations. A Satlantic SeaWiFS Profiling Multi-channel Radiometer (SPMR) was used at some stations to measure *in-situ* profiles of downwelling irradiance and upwelling radiance over 13 channels. *In-situ* profiles of spectral absorption attenuation coefficients were made using a WetLabs, Inc., AC9, and backscattering coefficients were measured using a HOBI Labs Hydroscat-6. Atmospheric aerosol optical thickness and above-surface water-leaving radiance were measured using a Microtops II Sun Photometer and a SIMBAD on clear days. A SeaBird CTD was used to obtain *in-situ* profiles of temperature, conductivity, salinity, fluorescence, and beam transmission. The

instruments used at each station are listed in Table 1. A salinothermograph system attached to the ship's flow-through system was used to create maps of surface temperature, salinity, and fluorescence.

Table 1. Station locations, samples collected, and instruments used

Station	Date	Time GMT	Latitude (decimal degrees)	Longitude (decimal degrees)	Water Depth (m)	Samples Collected and Instruments Used
3	4/4/00	18:00	27.4546	-82.9599	15	1,2,4,8
51	4/5/00	17:00	26.4097	-82.1855	8	1,2,4,8,8a,13,14,15
50	4/5/00	18:10	26.3776	-82.2716	11	1,2,4,8,8a,13,14,15
46	4/5/00	21:50	26.2523	-82.6161	25	1,2,4,8,8a,13
95	4/6/00	14:30	26.9386	-83.4558	51	1,2,4,8,8a,13
10	4/6/00	18:05	27.2008	-83.5541	48	1,2,4,8,8a,13,14,15
7	4/6/00	21:20	27.3133	-83.3002	40	1,2,4,8,8a,13,14,15

Key to Samples Collected and Instrumentation Used:

1: Fluorometric Chlorophyll
2: HPLC Pigments
4: Particulate Absorption
8: SMSR/SPMR
8a: Profiling Reflectance Radiometer (PRR)
13: Hydroscat-6
14: SIMBAD
15: Microtops

D. Optical Sampling Instruments and Methodology

The PRR-600s (Serial No. 9643) is a spectroradiometer manufactured by Biospherical Instruments, Inc., that measures seven channels of downwelling irradiance, seven channels of upwelling radiance, depth, tilt, roll, and temperature. A surface unit 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 full width at half maximum), centered at the indicated wavelengths. Channel 7 on the irradiance sensor is a broadband detector that measures Photosynthetically Available Radiation (PAR) between 400 and 700 nanometers (Table 2). The irradiance and radiance sensors of the PRR-600s are separate units, mounted such that the collectors are on the same horizontal plane. The PRR-610 surface unit was strapped onto the superstructure of the vessel, close to the davit used to lower the PRR-600s.

Table 2. Center wavelengths (nm) for the PRR system

Channel No.	PRR-600s Downwelling Light Sensor	PRR-600s Upwelling Light Sensor	PRR-610
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

The SeaWiFS Profiling Multi-channel Radiometer (SPMR; Serial No. 024) and the SeaWiFS Multi-channel Surface Radiometer (SMSR; Serial No. 024) are multispectral radiometers manufactured by Satlantic Inc. The SPMR is a free-falling instrument that measures 13 wavelengths of downwelling irradiance, 12 wavelengths of upwelling radiance (Table 3), depth, temperature, conductivity, salinity, tilt, and roll. The SMSR is a surface-tethered buoy that measures 13 wavelengths of above-water downwelling irradiance and 13 wavelengths of upwelling radiance at 75 centimeters below the surface. It was floated away from the side of the vessel to avoid ship shadow effects in the calculation of water-leaving radiance, and data were collected for 5 to 10 minutes. Both instruments are designed for use away from the ship to avoid perturbations of the *in-situ* light field by ship shadow.

Table 3. Center wavelengths (nm) for the SMSR/SPMR system

Channel No.	SPMR Downwelling Irradiance	SPMR Upwelling Radiance	SMSR Downwelling Irradiance	SMSR Upwelling Radiance
1	339.3	--	339.2	339.9
2	379.8	379.8	380.1	380.1
3	412.4	411.2	411.2	412.4
4	443.2	443.3	442.0	442.8
5	489.6	490.3	490.4	489.9
6	509.4	510.4	510.5	509.7
7	520.8	519.2	519.3	519.9
8	554.9	554.3	554.9	554.4
9	565.5	565.1	564.9	565.3
10	619.1	619.1	619.2	619.3
11	665.3	665.6	665.4	664.4
12	669.7	670.0	670.1	669.8
13	683.9	683.8	682.2	682.7

E. Bucket Samples

Discrete surface water samples were obtained using a bucket at the same time as the PRR cast. Chlorophyll biomass was determined using a Turner Designs fluorometer (Parsons et al. 1984). Phytoplankton pigment concentrations were determined by HPLC as described in Tester et al. (1995).

F. Optical Data Processing

All of the optical profiles were graphed and examined. Profiles that showed evidence of surface perturbations such as ship shadow, effects of passing clouds, etc., were not used in further analysis. 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 subsurface. 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 were replaced by -9.9×10^{35}. The data were then quality controlled using flags for data with tilt and roll angles greater than 10 degrees, and records in which the surface incident irradiance was not uniform. The temperature channel was de-spiked 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-meter bins. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface, and spectral attenuation coefficients were calculated for the optical channels over a five-point moving window. The diffuse attenuation coefficient, K, for each channel (E_d and L_u) was calculated as the slope of a linear regression of depth against the natural logarithm of the upwelling radiance or downwelling irradiance. The downwelling irradiance, $E_d(0^-)$, and the upwelling radiance, $L_u(0^-)$, at the null depth just below the surface were calculated from the intercept of the linear regression. The downwelling irradiance was extrapolated to above the water using a 96 percent transmission factor, that is, $E_d(0^+)=0.96*E_d(0^-)$ (O'Reilly et al. 1998).

The raw SMSR/SPMR data were converted to calibrated values, binned, and averaged using Proview software provided by Satlantic Inc. For the SMSR, normalized water-leaving radiance was calculated from the measured above-surface downwelling irradiance and the radiance at 0.75 meters below the surface. The radiance measured at 0.75 meters was propagated just below the surface using the attenuation coefficient (K) calculated as per Morel (1988). Briefly, the approximate chlorophyll concentration at that location was calculated using the 443/555-band ratio. The K at 490 nanometers for that chlorophyll concentration was calculated using the relationship of Austin and Petzold (1984) and then transferred to the other wavelengths using the relationships detailed in Morel (1988). The normalized water-leaving radiance was then calculated using Equation 1 below. At stations where the SPMR was used, the normalized water-leaving radiance was calculated using three different techniques. The first is as detailed above, using only the SMSR data. In the second technique, the SPMR data were binned to 0.5-meter bins and K was calculated using data from the top 10 meters. This K was then used to propagate the L_s measured 0.75 meters below the surface by the SMSR to the null depth. In the third technique, upwelling attenuation and downwelling attenuation coefficients were calculated from the SPMR and then used to propagate E_d and L_u measured by the SPMR through the surface.

The normalized water-leaving radiance (nL_w) was calculated from the upwelling radiance just below the surface ($L_u(0^-)$), and above-surface downwelling irradiance (E_s), as

$$nLw = 0.544 * F_0 * \frac{L_u(0^-)}{E_s} \qquad (1)$$

where F_0 is the mean extraterrestrial solar irradiance (Neckel and Labs 1984), and the factor 0.544 accounts for transmission and the index of refraction of radiance across the air-water interface. The remote sensing reflectance (R_{rs}) at a particular wavelength (λ) was calculated as the ratio of nL_w to E_s.

The July 2000 reprocessing of the SeaWiFS OC4 algorithm (OC4v4) (O'Reilly et al. 2000) was used to calculate the satellite estimates of chlorophyll *a* (C) as

$$C = 10^{\left(0.336 - 3.067X + 1.930X^2 + 0.649X^3 - 1.532X^4\right)} \tag{2}$$

where

$$X = \log_{10}\left(\frac{R_{rs}(443)}{R_{rs}(555)} > \frac{R_{rs}(490)}{R_{rs}(555)} > \frac{R_{rs}(510)}{R_{rs}(555)}\right). \tag{3}$$

In addition, chlorophyll estimates were made using the September 1998 algorithm (OC2v2) (O'Reilly et al. 1998) as

$$C = -0.0929 + 10^{\left(0.2974 - 2.2429X + 0.8358X^2 - 0.0077X^3\right)} \tag{4}$$

where

$$X = \log_{10}\frac{R_{rs}(490)}{R_{rs}(555)}. \tag{5}$$

and the algorithm used for the Coastal Zone Color Scanner (CZCS) (Gordon and Clark 1983) where

$$C = 10^{(0.053 - 1.71X)}, \tag{6}$$

where

$$X = \log_{10}\frac{R_{rs}(443)}{R_{rs}(550)} \tag{7}$$

if C is less than 1.5 μgl^{-1} or

$$C = 10^{(0.522 - 2.44X)} \tag{8}$$

with

$$X = \log_{10}\frac{R_{rs}(520)}{R_{rs}(550)} \tag{9}$$

if C is greater than 1.5 μgl^{-1}.

G. Image Processing

The April 5 and April 6, 2000, images from the OrbImage/NASA Sea-viewing Wide Field of view Sensor (SeaWiFS) ocean color satellite were retrieved from the NASA Goddard Data Archive Center in Level 1a format. They were processed using the SeaWiFS Data Analysis System (SeaDAS) version 4 to Level 2, using the local values for climatology and atmospheric conditions, and the Siegel 765 and 865 nanometer multiple scattering atmospheric correction algorithm with near infrared iterations (Siegel

et al. submitted). Chlorophyll concentration was calculated using OC4v4 (see Equations 2 and 3).

IV. Results

A. Meteorological Observations

To aid in the assessment of data quality, careful recordings of sky and sea states were made (Table 4). The conditions were favorable for the last two days of the cruise; however, the first day was overcast with rough seas.

Table 4. Meteorological observations for each station

Date	Station	Sky State	Sea State
04/04/00	3	100% Overcast	1.5 m waves
04/05/00	51	Clear	1 m swell, 30 cm waves, whitecaps
04/05/00	50	Clear	1 m swell, 30 cm waves, whitecaps
04/05/00	46	Clear	1 m swell, 30 cm waves, whitecaps
04/06/00	94	Patchy cirrus, moving during cast	60 cm swell
04/06/00	10	Clear - 5% at horizon	30 cm swell
04/06/00	7	Clear	30 cm swell

B. Bucket Samples

Chlorophyll *a* concentrations ranged widely from 0.187 to 2.611 µg/l. Chlorophyll *a* concentrations tended to be higher in the nearshore areas, and were higher on the southern transect near Charlotte Harbor (stations 46, 50, and 51) than on the northern transect. Fucoxanthin concentrations generally were high, indicating that diatoms were a prominent phytoplankton type in these waters.

Table 5. Pigment concentrations (µg l^{-1}) at each station

Station	Fluor chl *a*	Chl *a*	Phaeo	Chl *b*	Chl *c*	Diadin	Fuco	Perid	Zeax	19'-But	19'-Hex
3	0.791	0.452	0.014	0.022	0.069	0.029	0.098	0.000	0.143	0.006	0.018
7	0.270	0.195	0.005	0.013	0.026	0.011	0.021	0.008	0.071	0.006	0.010
10	0.187	0.125	0.001	0.006	0.014	0.008	0.011	0.004	0.061	0.003	0.006
46	0.485	0.369	0.005	0.025	0.047	0.015	0.038	0.014	0.111	0.006	0.022
50	1.803	1.424	0.048	0.089	0.231	0.089	0.422	0.039	0.106	0.008	0.023
51	2.611	2.172	0.060	0.144	0.361	0.073	0.636	0.033	0.196	0.013	0.051
94	0.214	0.164	0.003	0.013	0.021	0.010	0.013	0.006	0.055	0.004	0.008

Table 6. HPLC pigment abbreviations and indicators

Pigment	Abbreviation	Phytoplankton Group
Chlorophyll *a*	Chl *a*	All

Pigment	Abbreviation	Phytoplankton Group
Chlorophyll *b*	Chl *b*	Chlorophytes, Prochlorophytes
Chlorophyll *c*	Chl *c*	Protists
Diadinoxanthin	Diad	Diatoms
Fucoxanthin	Fucox	Diatoms, others
Peridinin	Perid	Dinoflagellates
Phaeophytin	Phaeophytin	Degraded chlorophyll
Zeaxanthin	Zeax	Cyanobacteria, Rhodophytes
19'-Butanoyloxyfucoxanthin	19-But	Prymnesiophytes
19'-Hexanoyloxyfucoxanthin	19-Hex	Haptophytes

C. Optical data

Data from the PRR and the SPMR systems show similar patterns for reflectance spectra. The three northern stations (7, 10, and 94) had lower chlorophyll concentrations and exhibit low reflectance spectra with the highest reflectance values in the blue regions of the spectrum. The two southern stations (50 and 51) exhibit higher reflectances in general, with the highest values in the green regions of the spectrum (Figure 2 and Figure 3). These stations were sampled in waters with high chlorophyll concentrations and high colored dissolved organic matter absorption (data not shown). Both instrument systems provided similar reflectance spectra; although differences were observed for normalized water-leaving radiances (Appendix A).

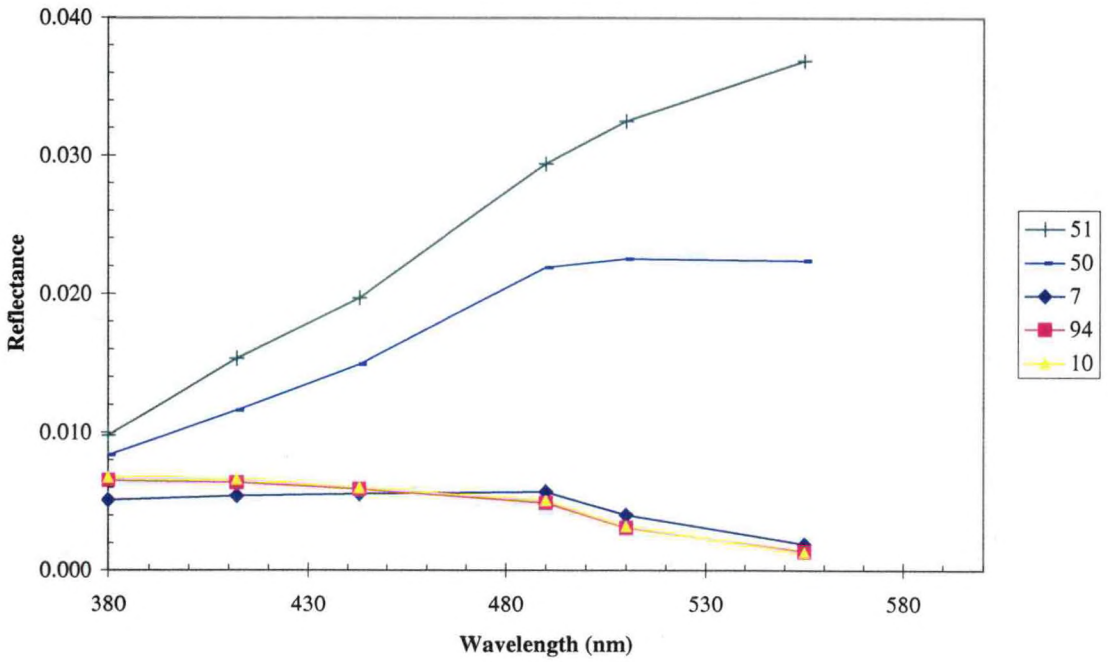

Figure 2. Remote-sensing reflectance spectra for each station measured using the PRR system

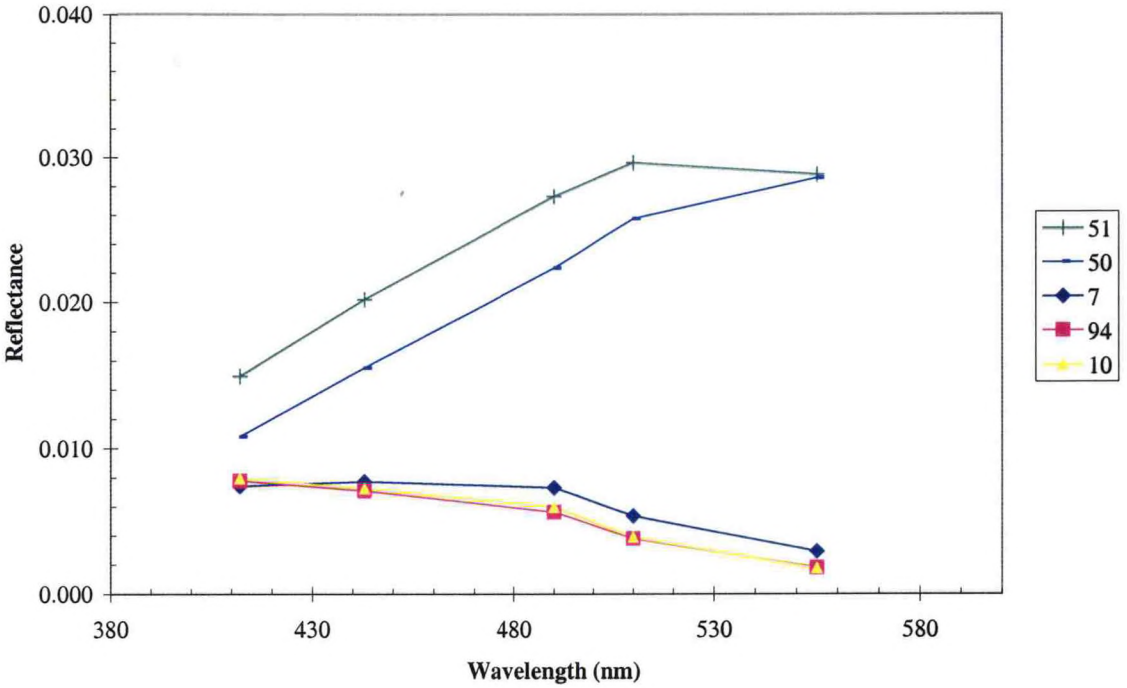

Figure 3. Remote-sensing spectra for each station measured using the SPMR system

D. Algorithm Evaluation

The values for all measured radiance and irradiance for each instrument system are shown in Table 7. These values were used in Equations 1 through 9 to derive chlorophyll concentrations using the three different algorithms. The chlorophyll concentrations derived from each algorithm are displayed against fluorometrically measured chlorophyll *a* in Figure 4. The SPMR tended to yield slightly higher concentrations than the PRR. The CZCS algorithm provided higher pigment concentrations than the SeaWiFS algorithms, and the OC4v4 algorithm tended to provide higher concentrations than OC2v2; however, these trends are not statistically significant. In all cases the algorithms underestimated low chlorophyll *a* concentrations (0.1 to 0.4 $\mu g l^{-1}$) and overestimated higher concentrations (1 to 3 $\mu g l^{-1}$).

Table 7. Irradiance and radiance values with estimated chlorophyll concentrations

Station	**prr51**	**Spmr51**	**Prr50**	**spmr50**	**prr94**	**spmr94**
Date	4/5/00	4/5/00	4/5/00	4/5/00	4/6/00	4/6/00
Time GMT	17:00	17:00	18:10	18:10	14:30	14:30
Latitude	26.410	26.410	26.378	26.378	26.939	26.939
Longitude	-82.185	-82.185	-82.272	-82.272	-83.456	-83.456
ChlF ug/l	2.611	2.611	1.803	1.803	0.214	0.214
PRR File	p000405a2	sta50avg	p000405b2	51 avg	p000406a2	94 avg
Ed0-380	88.323		101.717		55.096	
Ed0-412	142.050		162.423		90.820	
Ed0-443	164.894		189.515		108.886	
Ed0-490	174.061		200.614		116.249	
Ed0-510	172.337		201.315		116.986	
Ed0-555	164.303		193.109		112.637	
Lu0-380	1.191		1.309		0.687	
Lu0-412	2.849	3.475	2.822	2.615	1.073	1.192
Lu0-443	4.228	5.207	4.225	4.170	1.178	1.240
Lu0-490	6.572	7.929	6.644	6.810	1.066	1.120
Lu0-510	7.152	8.493	6.911	7.719	0.697	0.754
Lu0-555	7.743	7.627	6.719	7.958	0.304	0.318
Lu0-683	1.822	1.390	0.764	2.313	0.016	0.034
Es0+380	65.467		84.071		56.550	
Es0+412	100.152	126.293	130.847	131.839	90.350	83.565
Es0+443	115.750	139.870	152.692	146.195	107.024	95.257
Es0+490	120.605	157.465	163.571	165.412	116.575	108.894
Es0+510	118.759	155.247	165.433	162.627	119.375	109.010
Es0+555	113.290	143.273	161.761	150.867	117.384	99.921
nLw380	0.928		0.795		0.620	
nLw412	2.624	2.538	1.989	1.830	1.095	1.315
nLw443	3.737	3.808	2.830	2.918	1.126	1.332
nLw490	5.699	5.267	4.248	4.306	0.956	1.076
nLw510	6.126	5.565	4.249	4.828	0.594	0.704
nLw555	6.842	5.330	4.159	5.281	0.259	0.318
Rrs380	0.010		0.008		0.007	
Rrs412	0.015	0.015	0.012	0.011	0.006	0.008
Rrs443	0.020	0.020	0.015	0.015	0.006	0.007
Rrs490	0.029	0.027	0.022	0.022	0.005	0.006
Rrs510	0.033	0.030	0.023	0.026	0.003	0.004
Rrs555	0.037	0.029	0.022	0.028	0.001	0.002
ChlaOC2v2	3.266	2.157	1.993	3.443	0.115	0.142
ChlaOC4v4	3.469	2.138	2.282	3.240	0.133	0.140
CZCSPigOC2	4.274	2.846	2.634	4.500	0.161	0.198
ChlaF	2.611	2.611	1.803	1.803	0.214	0.214

Station	prr10	spmr10	prr7	spmr7
Date	4/6/00	4/6/00	4/6/00	4/6/00
Time GMT	18:05	18:05	21:20	21:20
Latitude	27.201	27.201	27.313	27.313
Longitude	-83.554	-83.554	-83.300	-83.300
ChlF ug/l	0.187	0.187	0.270	0.270
PRR File	p000406b2	10 avg	p000406c2	sta7 avg
Ed0-380	75.504	91.194	32.374	32.388
Ed0-412	122.113	149.332	55.162	57.386
Ed0-443	147.782	155.434	67.291	61.486
Ed0-490	159.521	177.555	73.553	72.594
Ed0-510	164.589	170.792	73.695	66.371
Ed0-555	158.236	151.057	71.045	54.061
Lu0-380	1.024		0.351	
Lu0-412	1.592	1.739	0.628	0.828
Lu0-443	1.676	1.753	0.771	0.975
Lu0-490	1.498	1.656	0.856	1.099
Lu0-510	0.949	1.037	0.615	0.783
Lu0-555	0.382	0.416	0.295	0.382
Lu0-683	0.016	0.037	0.013	0.042
Es0+380	81.760		36.776	
Es0+412	129.271	119.852	62.186	61.037
Es0+443	150.543	132.443	74.281	68.797
Es0+490	158.690	152.227	80.459	82.331
Es0+510	159.511	146.278	81.726	79.896
Es0+555	156.599	134.950	81.843	72.443
nLw380	0.639		0.488	
nLw412	1.136	1.338	0.932	1.251
nLw443	1.139	1.354	1.062	1.449
nLw490	0.987	1.138	1.113	1.397
nLw510	0.605	0.721	0.766	0.997
nLw555	0.244	0.309	0.361	0.528
Rrs380	0.007		0.005	
Rrs412	0.007	0.008	0.006	0.007
Rrs443	0.006	0.007	0.006	0.008
Rrs490	0.005	0.006	0.006	0.007
Rrs510	0.003	0.004	0.004	0.005
Rrs555	0.001	0.002	0.002	0.003
ChlaOC2v2	0.092	0.115	0.174	0.244
ChlaOC4v4	0.120	0.131	0.220	0.254
CZCSPigOC2	0.129	0.161	0.241	0.337
ChlF	0.187	0.187	0.270	0.270

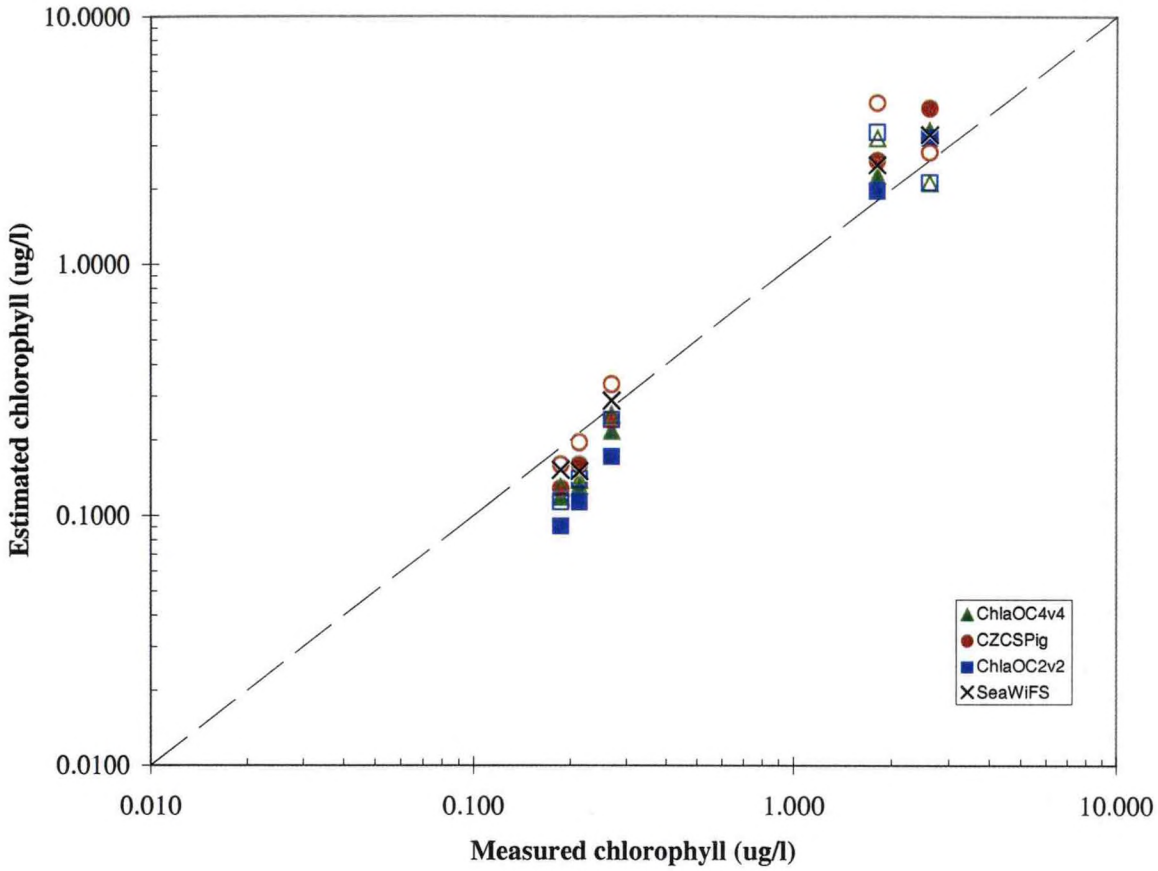

Figure 4. Estimated chlorophyll compared to measured chlorophyll for three algorithms (see legend) and two instruments (PRR, filled symbols; SPMR, open symbols; one-to-one line, dashed line). Cross designates chlorophyll from SeaWiFS satellite using OC4v4 algorithm on day of collection.

Imagery on April 5 and 6 show clear days with a range of chlorophyll concentrations across the shelf (Figure 5 and Figure 6). Comparison of the concentrations estimated from the imagery and from *in-situ* measurements indicates that the values are similar (Figure 4); therefore, the atmospheric correction algorithm used (Siegel et al. submitted) was effective for this situation.

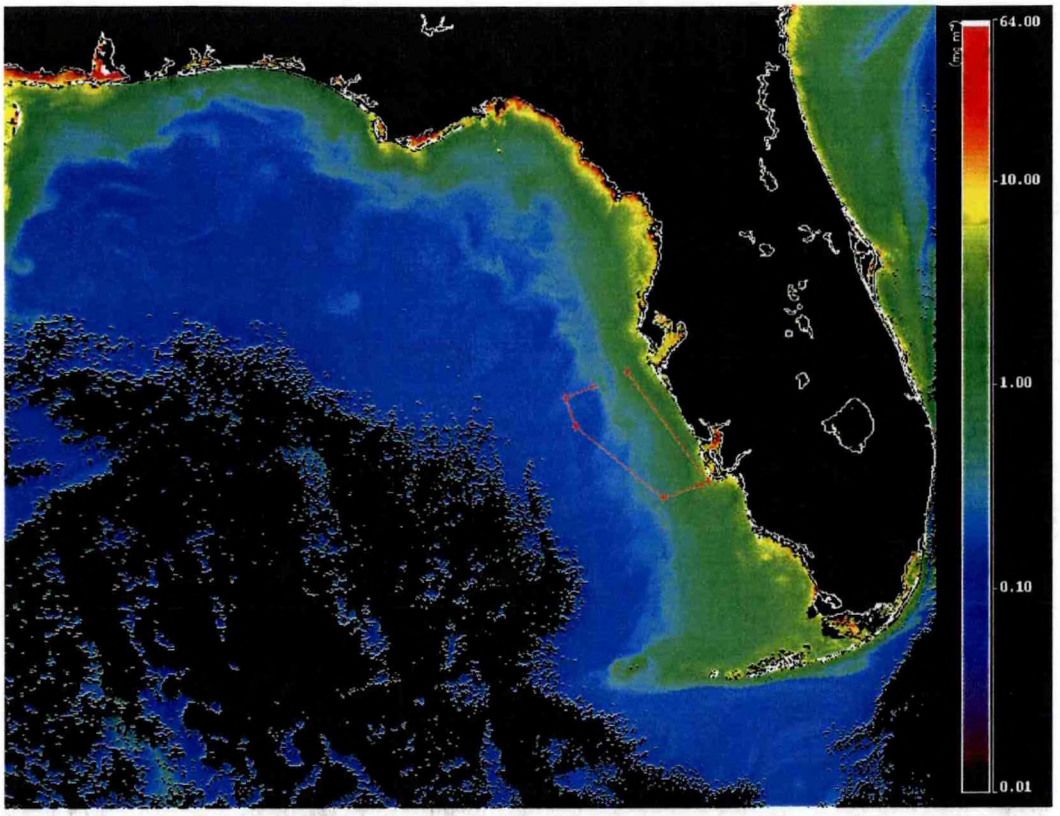

Figure 5. SeaWiFS image from April 5, 2000. Cruise track is shown in red.

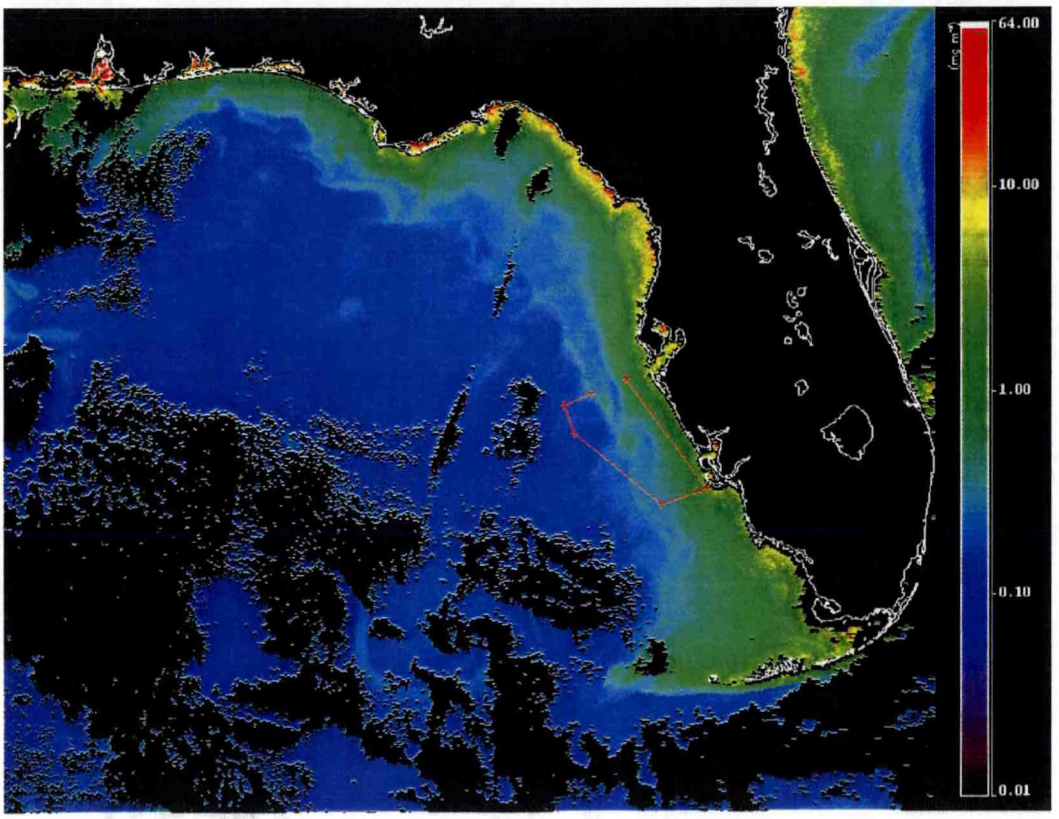

Figure 6. SeaWiFS image from April 6, 2000. Cruise track shown in red.

V. Summary

Data collected on the West Florida Shelf in April 2000 indicated high chlorophyll and colored dissolved organic matter concentrations in a narrow area off of Charlotte Harbor. Stations farther north and offshore, but still on the shelf, had low concentrations. The two instrument systems used on this cruise yielded similar results for irradiances, radiances, and ultimately, chlorophyll concentrations. Four algorithms were tested to derive pigment concentrations, and each produced a value similar to that measured on water samples using traditional flurometric methods. In addition, the concentrations measured by the SeaWiFS satellite on concurrent days were similar to the measured concentration, indicating that atmospheric correction problems were minimal.

VI. References

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O'Reilly, J. E. and 21 others. 2000. Ocean color chlorophyll *a* algorithms for SeaWiFS, OC2 and OC4: Version 4. SeaWiFS Postlaunch Calibration and Validation Analyses, part 3. NASA SeaWiFS technical report series. pp. 8-22.

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

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

Phinney, D. A. and C. S. Yentsch. 1991. On the contribution of particles to blue light attenuation in the sea. *J. Plankton Res.* **13** suppl.: 143-152.

Siegel, D. A., M. Wang, S. Maritorena, and W. Robinson (submitted). Atmospheric correction of satellite ocean color imagery: the black pixel assumption. *Applied Optics.*

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.

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

VII. Metadata

Identification Information:

Citation:

Citation Information:

Originator: Ajit Subramaniam, Earth System Science Interdisciplinary Center, University of Maryland
Originator: Mary Culver, NOAA Coastal Services Center
Originator: Mark Geesey, Grice Marine Laboratory, University of Charleston
Publication Date: 2000
Title: NOAA CSC/CRS Cruise APR00FWS: West Florida Shelf Cruise
Geospatial Data Presentation Form: profile
Series Information:
Series Name: CSC Technical Report
Issue Identification: NOAA/CSC/20018-PUB
Publication Information:
Publication Place: Charleston, South Carolina
Publisher: NOAA Coastal Services Center
Online Linkage: http://www.csc.noaa.gov/crs/cruises/apr00fws/index.html

Description:

Abstract: The Coastal Services Center's (CSC) Coastal Remote Sensing (CRS) Program is involved with programs to validate satellite algorithms for ocean properties. CRS is involved with the effort to validate ocean color algorithms to derive chlorophyll concentrations from the NASA ocean color satellite, Sea-viewing Wide Field-of-view Sensor (SeaWiFS). This program is funded in part through a NASA Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) contract awarded to CRS and the Ocean Color Program at the NOAA NESDIS Office of Research and Applications. The development and validation of satellite algorithms requires ground truthing to ensure accuracy. For optically derived products, a ship-based program is often the most sensible method to develop new satellite-based ocean products. In addition to information provided by CSC's instruments, the CRS team often works with other partners who provide complementary data and ship time.

Purpose: The objective of this cruise was to obtain bio-optical data from on the West Florida Continental Shelf.

Time Period of Content:

Time Period Information:
Range of Dates/Times:
Beginning Date: 20000404
Ending Date: 20000406
Currentness Reference: September 2000

Status:

Progress: Complete
Maintenance and Update Frequency: Unknown

Spatial Domain:

Bounding Coordinates:

West Bounding Coordinate: -83.5541
East Bounding Coordinate: -82.1855
North Bounding Coordinate: 27.4546
South Bounding Coordinate: 26.2523

Keywords:

Theme:

Theme Keyword Thesaurus: None
Theme Keyword: oceanography
Theme Keyword: bio-optical
Theme Keyword: turbidity
Theme Keyword: water clarity
Theme Keyword: algal blooms
Theme Keyword: coastal water optics
Theme Keyword: case II algorithms
Theme Keyword: light attenuation
Theme Keyword: reflectance difference
Theme Keyword: in-situ optical profiling
Theme Keyword: ocean color satellites
Theme Keyword: coastal ocean algorithm development
Theme Keyword: downwelling irradiance
Theme Keyword: upwelling radiance
Theme Keyword: chlorophyll
Theme Keyword: particulate absorption
Theme Keyword: colored dissolved organic matter
Theme Keyword: spectral attenuation
Theme Keyword: spectral absorption
Theme Keyword: fluorescence

Place:

Place Keyword Thesaurus: None
Place Keyword: Gulf of Mexico
Place Keyword: Florida
Place Keyword: United States

Temporal:

Temporal Keyword Thesaurus: None
Temporal Keyword: Spring
Temporal Keyword: April 2000

Access Constraints: None

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

Point of Contact:

Contact Information:

Contact Organization: NOAA Coastal Services Center
Contact Address:

Address Type: mailing and physical address
Address: 2234 South Hobson Avenue
City: Charleston
State or Province: South Carolina
Postal Code: 29405-2413
Country: USA
Contact Voice Telephone: (843) 740-1200
Contact Facsimile Telephone: (843) 740-1224
Contact Electronic Mail Address: csc@noaa.gov
Hours of Service: 8AM-5PM, M-F

Data Set Credit: Master and crew of Research Vessel

Data Quality Information:

Attribute Accuracy:

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

Logical Consistency Report: The PRR data was processed using the Bermuda Bio-Optics Project (BBOP) processing software. A least common denominator (LCD) file was created from the binary data files, the cast card files, the calibration files, and cruise notes. The LCD file header contains the metadata for the cast and includes information on the parameters sampled, parameters derived, filters used, and the statistical results of the regression used to extrapolate light to the subsurface. 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 were replaced by -9.9×10^{35}. Then the data were quality controlled using flags for data with tilt and roll angles greater than 10° (flag value greater than 0 in the "aq-1Tilt-1Roll" field), and records where the surface incident irradiance was not uniform (flag value greater than 0 in the "kq-1ed412" field). The temperature, transmissometer, and fluorometer data were despiked, in two passes, with a difference threshold. A moving average was calculated for these channels. The data were separated into upcast and downcast profiles and then binned to 0.5-meter bins. Spectral attenuation coefficients were calculated for the optical channels over a five point moving window. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface using data from the top 3 meters.

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

Lineage:

Methodology:

Methodology Type: Shipboard deployments and data collection

Methodology Identifier:

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

Methodology Description: The Profiling Reflectance Radiometer (PRR) cage was deployed off the stern of the boat, to measure *in-situ* spectral downwelling irradiance, spectral upwelling radiance, temperature, chlorophyll fluorescence, light scattering, quantum scalar irradiance, and beam attenuation. Following the PRR cast, a Hydro-Optics, Biology, and Instrumentation Laboratories, Inc. (HOBI Labs) Hydroscat-6 spectral backscattering sensor was lowered by hand. *In-situ* temperature, salinity, and density were also measured at some stations with a Conductivity-Temperature-Depth (CTD) instrument. Water samples for chlorophyll biomass, HPLC-determined photosynthetic pigments, and particulate and dissolved absorption were obtained from the surface using a bucket.

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

Methodology Identifier:

Methodology Keyword Thesaurus: None
Methodology Keyword: chlorophyll
Methodology Keyword: fluorescence
Methodology Keyword: fluorometer
Methodology Keyword: extraction

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

Methodology Citation:

Citation Information:
Originator: T.R. Parsons
Originator: Y. Maita
Originator: C.M. Lalli
Publication Date: 1984
Title: A manual for Chemical and Biological Methods for Seawater Analysis
Publication Information:
Publication Place: New York, New York, USA
Publisher: Pergamon Press

Methodology Type: HPLC calibration and analysis of phytoplankton pigments

Methodology Identifier:

Methodology Keyword Thesaurus: None
Methodology Keyword: photosynthetic pigments
Methodology Keyword: high performance liquid chromatography
Methodology Keyword: chlorophylls
Methodology Keyword: carotenoids
Methodology Keyword: chemotaxonomy

Methodology Description: The concentration of purified photosynthetic pigments was measured using a spectrophotometer. In a series of runs, known amounts (generally 1 to 100 nanograms) were injected into the HPLC to establish the retention time and define a calibration curve for each pigment. Aboard ship, a measured volume of seawater was filtered onto a Whatman GF/F filter which was stored in liquid nitrogen. In the lab the filter was ground and extracted with 1.5 milliliters of 90 percent acetone, placed in the freezer overnight to extract. After centrifugation, 0.5 milliters of the supernatant was diluted with 0.25 milliliters water. 0.5 milliliters was injected into the HPLC to quantify the pigments present.

Methodology Citation:

Citation Information:
Originator: S.W. Wright
Originator: S.W. Jeffrey
Originator: R.F.C. Mantoura
Originator: C.A. Llewellyn
Originator: T. Bjornland
Originator: D. Repeta
Originator: N. Welschmeyer
Publication Date: 1991
Title: Improved HPLC method for the analysis of chlorophylls and carotenoids from marine phytoplankton
Series Information:
Series Name: Marine Ecology Progress Series
Issue Identification: Volume 77: 183-196

Methodology Type: Absorption measurement of suspended particulate matter

Methodology Identifier:

Methodology Keyword Thesaurus: None
Methodology Keyword: suspended particulate matter
Methodology Keyword: absorption spectrum
Methodology Keyword: particulate absorption

Methodology Description: A measured volume of seawater was filtered through a Whatman GF/F filter. The absorbance spectrum between 350 and 750 nanometers was measured using a dual-beam spectrophotometer equipped with a scattered-transmittance accessory, an end-on photomultiplier tube [PMT] with sample compartment and diffusing plate immediately in front of the PMT window in accordance with the SeaWiFS protocol. Beta correction for this specific instrument was determined using suspended versus filtered samples for cultured phytoplankton, and had a polynomial formulation. The filter was placed back on

the filtration rig and soaked in methanol heated to 45 degrees C for 15 minutes to extract photosynthetic pigments. The methanol was pulled through the filter and the filter was rinsed with filtered seawater. The absorbance spectrum between 350 and 750 nanometers was measured again.

Methodology Citation:

Citation Information:
Originator: D.A. Phinney
Originator: C.S. Yentsch
Publication Date: 1991
Title: On the contribution of particles to blue light attenuation in the sea
Series Information:
Series Name: Journal of Plankton Research
Issue Identification: Volume 13, supplement: 143-152

Citation Information:
Originator: J.L. Mueller
Originator: R.W. Austin
Publication Date: 1995
Title: Ocean optics protocols for SeaWiFS validation, Revision 1
Series Information:
Series Name: SeaWiFS Technical Report Series
Issue Identification: Volume 25, 66 pp.

Citation Information:
Originator: J.R. Nelson
Originator: S. Guarda
Publication Date: 1995
Title: Particulate and dissolved spectral absorption on the continental shelf of the southeastern United States
Series Information:
Series Name: Journal of Geophysical Research
Issue Identification: Volume 100 (C5): 8715-8732

Citation Information:
Originator: B.G. Mitchell
Publication Date: 1990
Title: Algorithms for determining the absorption coefficient of aquatic particulates using the quantitative filter technique (QFT)
Series Information:
Series Name: Ocean Optics
Issue Identification: X
Publication Information:
Publication Place: Orlando, Florida, USA
Publisher: SPIE

Citation Information:
Originator: J.S. Cleveland
Originator: A.D. Weidermann
Publication Date: 1993
Title: Quantifying absorption by aquatic particles: A multiple scattering

correcting for glass fiber filters
Series Information:
Series Name: Limnology and Oceanography
Issue Identification: Volume 38(6): 1321-1327

Process Step:
Process Description: Calibration of the Biospherical PRV-600s PRR Spectroradiometer
Process Date: 19990325
Process Contact:
Contact Information:
Contact Organization Primary:
Contact Organization: Biospherical Instruments, Inc.
Contact Address:
Address Type: mailing and physical address
Address: 5340 Riley Street
City: San Diego
State or Province: California
Postal Code: 92110-2621
Country: USA
Contact Voice Telephone: (619) 686-1888

Process Step:
Process Description: Calibration of the Biospherical PRV610 PRR Spectroradiometer
Process Date: 19990325
Process Contact:
Contact Information:
Contact Organization Primary:
Contact Organization: Biospherical Instruments, Inc.
Contact Address:
Address Type: mailing and physical address
Address: 5340 Riley Street
City: San Diego
State or Province: California
Postal Code: 92110-2621
Country: USA
Contact Voice Telephone: (619) 686-1888

Process Step:
Process Description: Calibration of the Hydroscat6 in situ Backscattering Sensor
Process Date: 19970527
Process Contact:
Contact Information:
Contact Organization Primary:
Contact Organization: HOBI Labs
Contact Address:
Address Type: mailing and physical address
Address: 55 Penny Lane, Suite 104

City: Watsonville
State or Province: California
Postal Code: 95076-6017
Country: USA
Contact Voice Telephone: (408) 768-0680

Process Step:
Process Description: Calibration of the Microtops II Sun Photometer
Process Date: 19980129
Process Contact:
Contact Information:
Contact Organization Primary:
Contact Organization: NASA
Contact Address:
Address Type: mailing and physical address
Address:
City:
State or Province:
Postal Code:
Country: USA
Contact Voice Telephone:

Process Step:
Process Description: Calibration of Satlantic SPMR (SeaWiFS Profiling Multichannel Radiometer)
Process Date: 19980310
Process Contact:
Contact Information:
Contact Organization Primary:
Contact Organization: Satlantic, Inc.
Contact Address:
Address Type: mailing and physical address
Address: 3295 Barrington Street
City: Halifax
State or Province: Nova Scotia
Postal Code: B3K 5X8
Country: Canada
Contact Voice Telephone: (902) 492-4780

Spatial Data Organization Information:
Indirect Spatial Reference: USA
Distribution Information:
Distributor:
Contact Information:
Contact Organization Primary:
Contact Organization: NOAA Coastal Services Center
Contact Address:
Address Type: mailing and physical address

Address: 2234 South Hobson Avenue
City: Charleston
State or Province: South Carolina
Postal Code: 29405-2413
Country: USA
Contact Voice Telephone: (843) 740-1200
Contact Facsimile Telephone: (843) 740-1224
Contact Electronic Mail Address: csc@noaa.gov
Hours of Service: 8AM-5PM, M-F

Resource Description: APR00FWS Cruise Report

Distribution Liability: None

Custom Order Process: Contact the distributor for a paper copy of the technical report, or the data can be accessed on-line at http://www.csc.noaa.gov/crs/cruises/apr00fws/index.html.

Metadata Reference Information:

Metadata Date: 20000601

Metadata Review Date: 20000601

Metadata Contact:

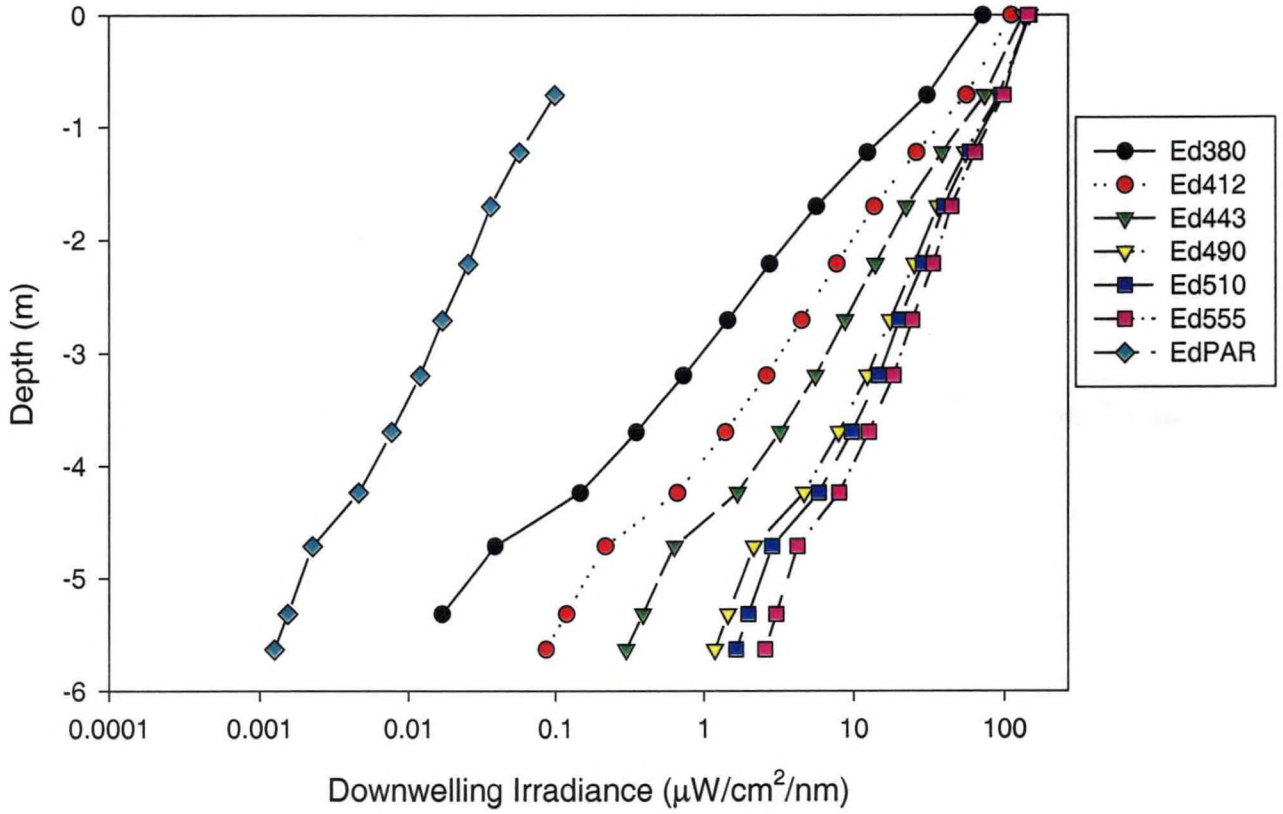
Contact Information:
Contact Organization Primary:
Contact Organization: NOAA, Coastal Services Center
Contact Position: Metadata Specialist
Contact Address:
Address Type: mailing and physical address
Address: 2234 South Hobson Avenue
City: Charleston
State or Province: South Carolina
Postal Code: 29405-2413
Country: USA
Contact Voice Telephone: (843) 740-1200
Contact Facsimile Telephone: (843) 740-1224
Contact Electronic Mail Address: csc@noaa.gov
Hours of Service: 8AM-5PM, M-F

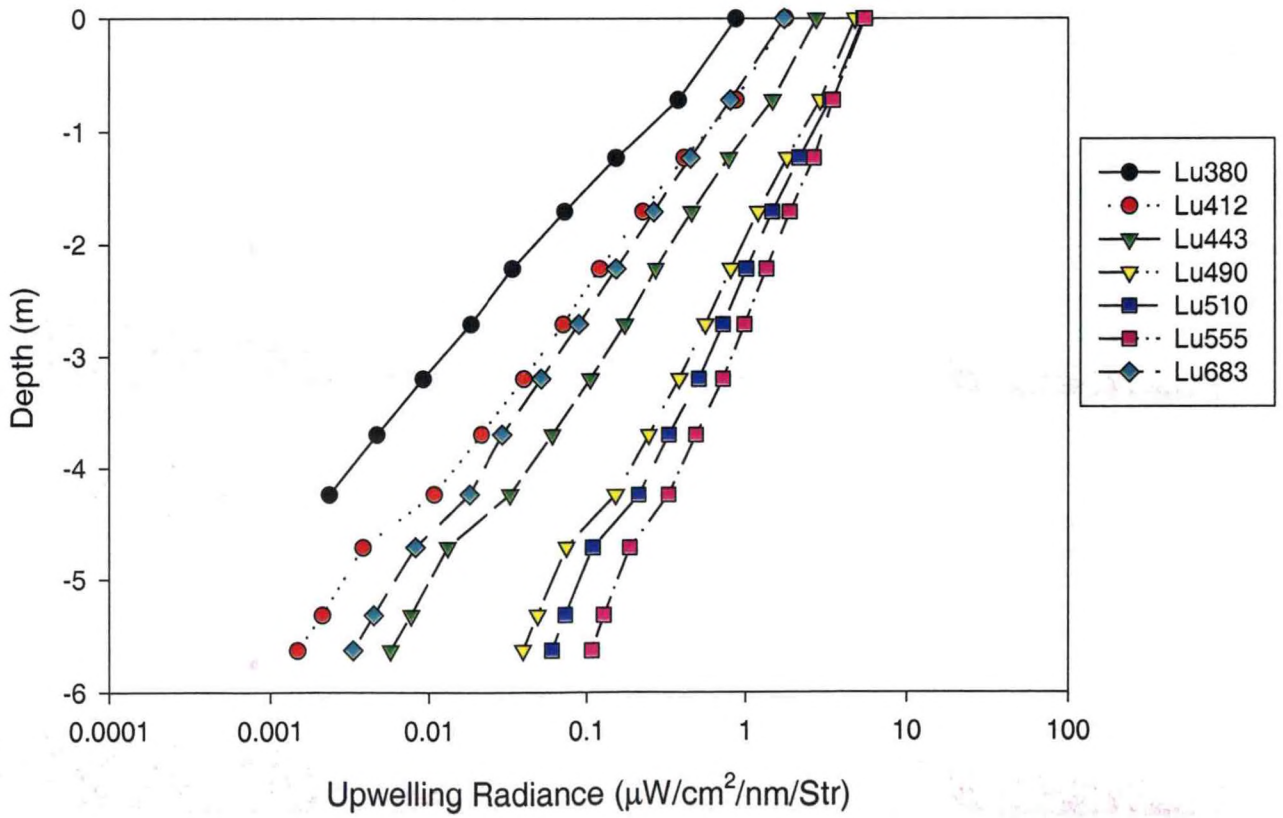
Metadata Standard Name: Content Standard for National Biological Information Infrastructure Metadata

Metadata Standard Version: December 1995

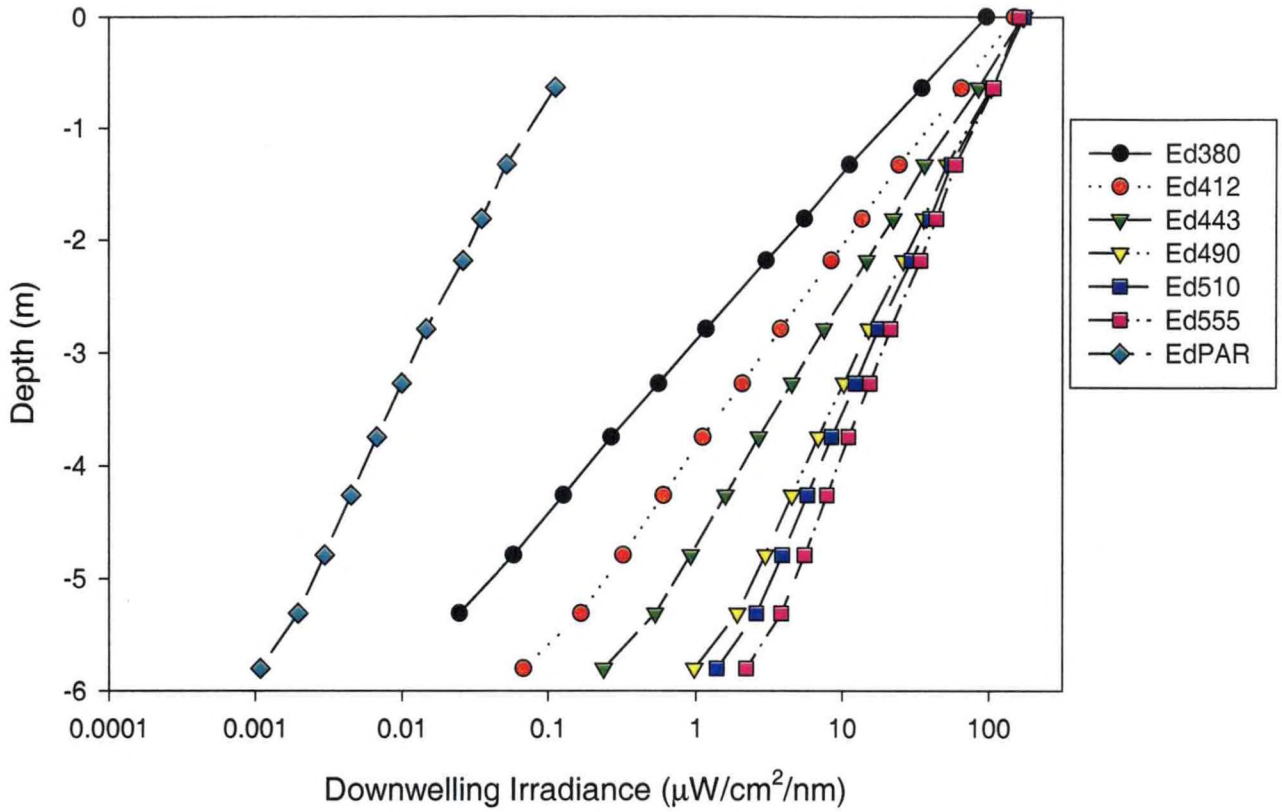
VIII. Appendix A. Irradiance and Radiance Profiles

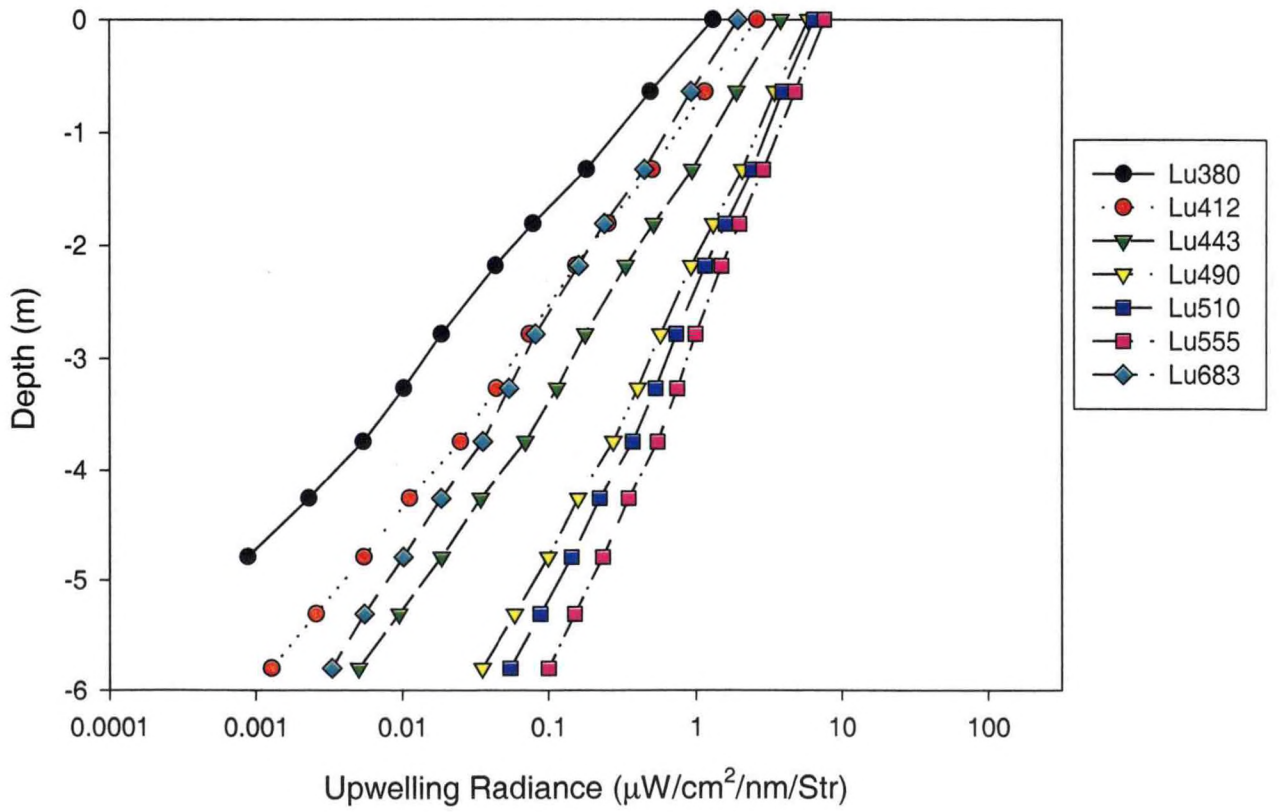
Station 51 Downcast



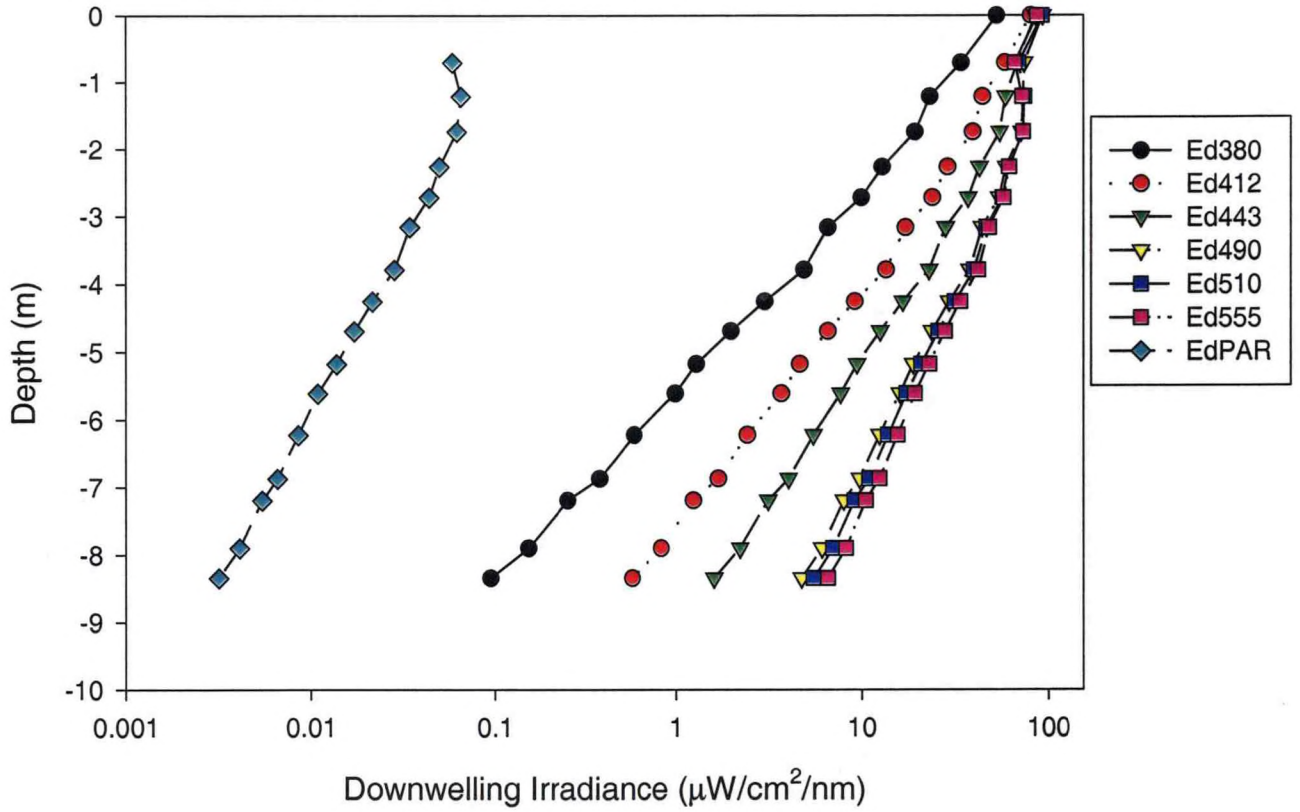


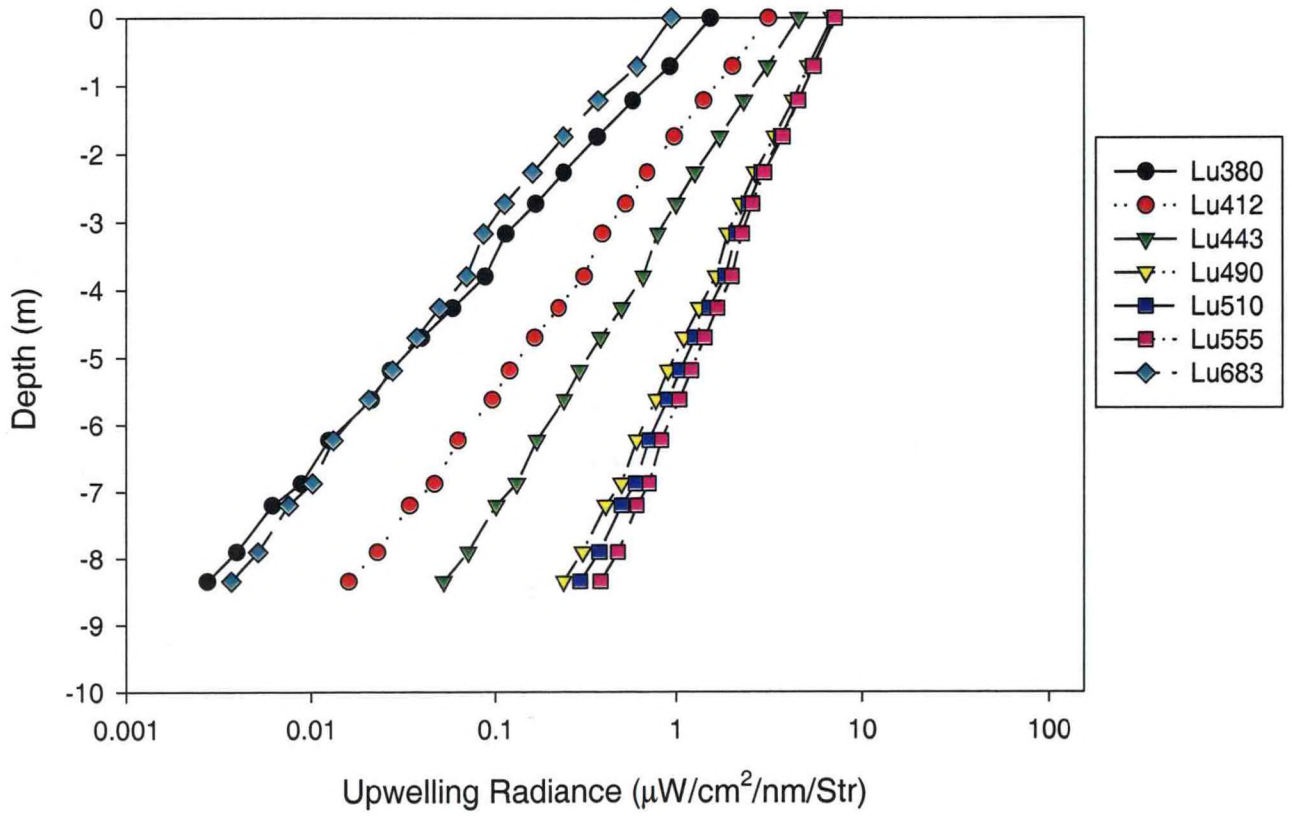
Station 51 Upcast



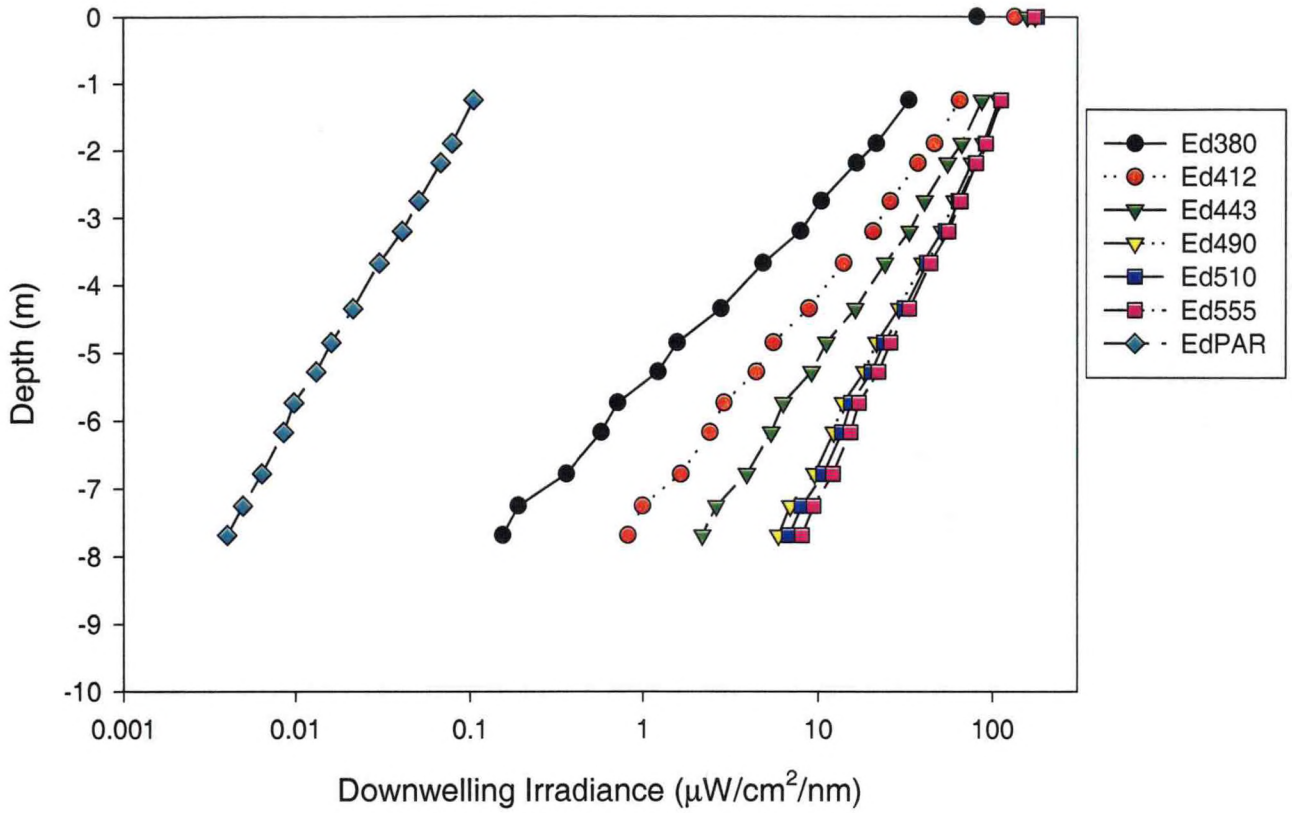


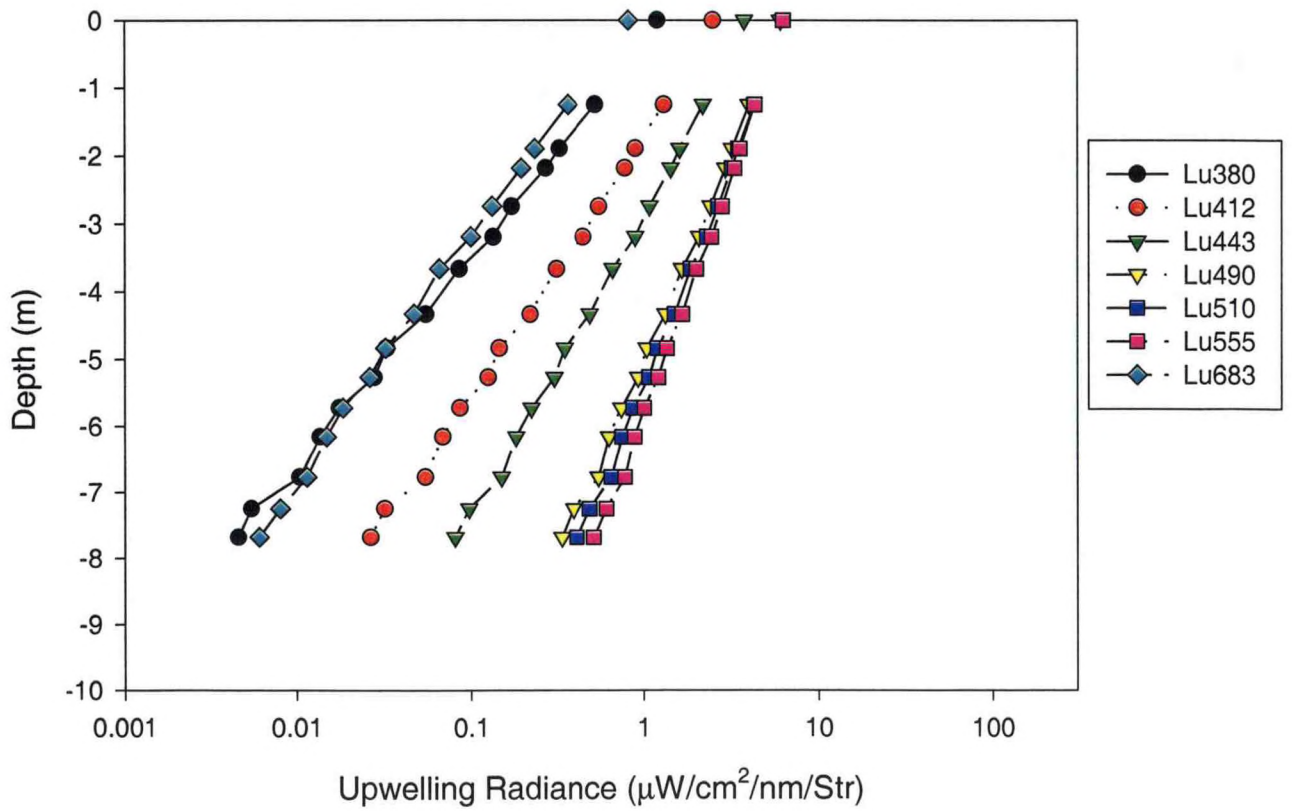
Station 50 Downcast





Station 50 Upcast





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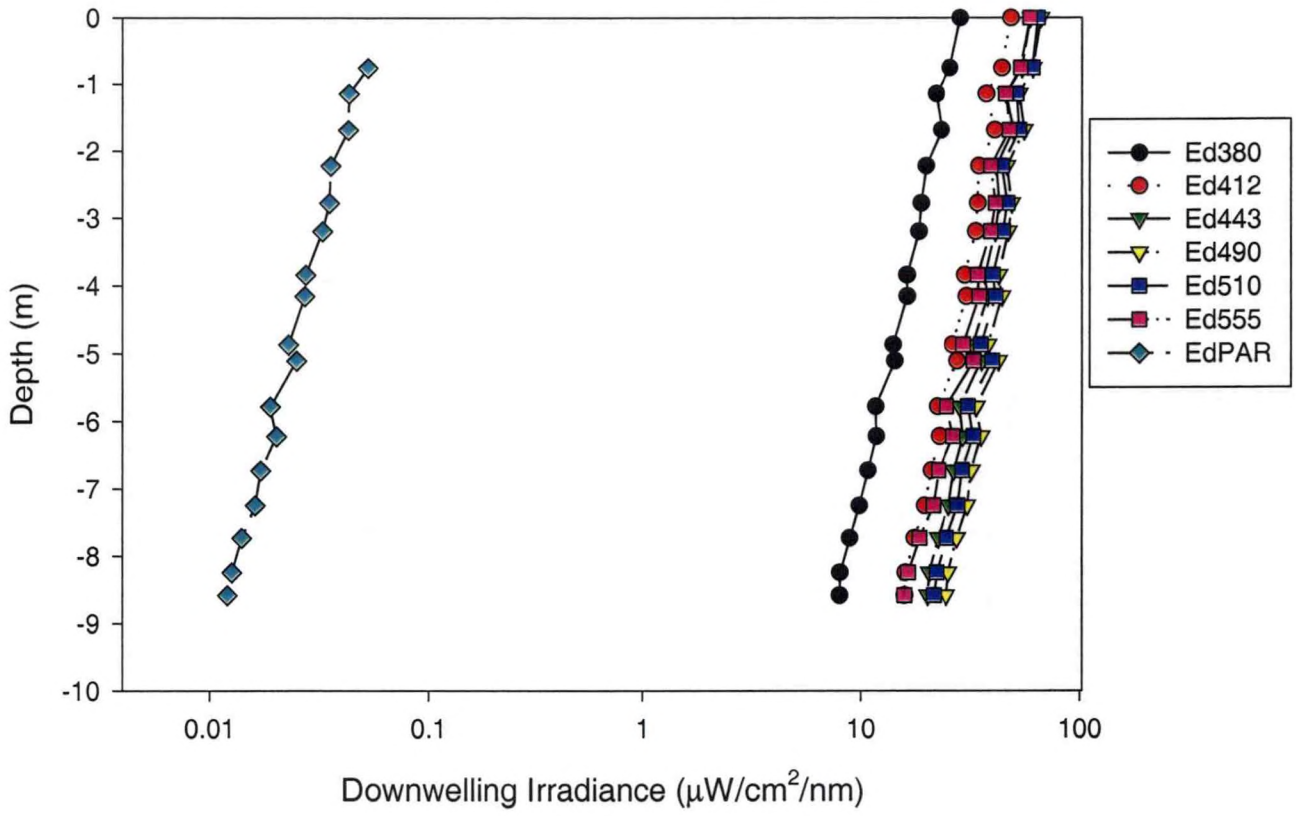
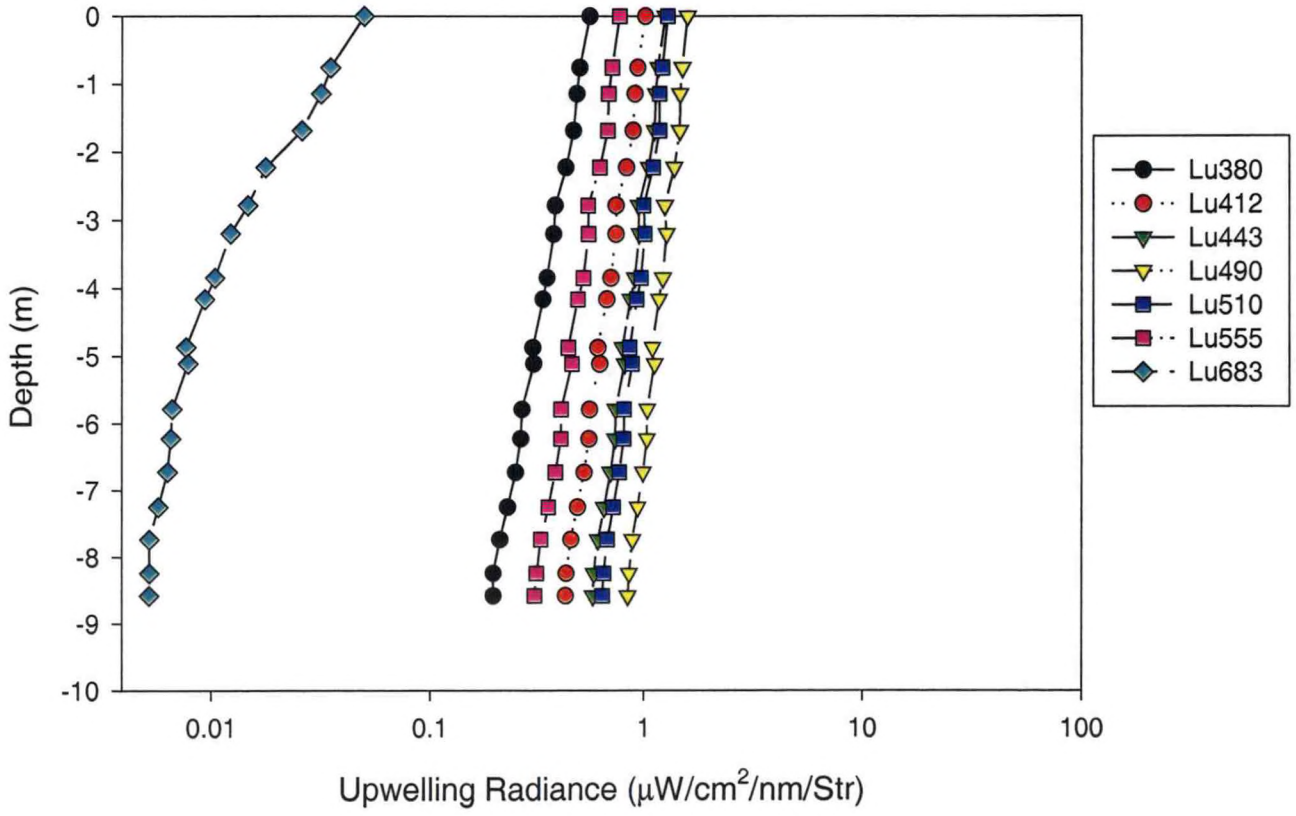
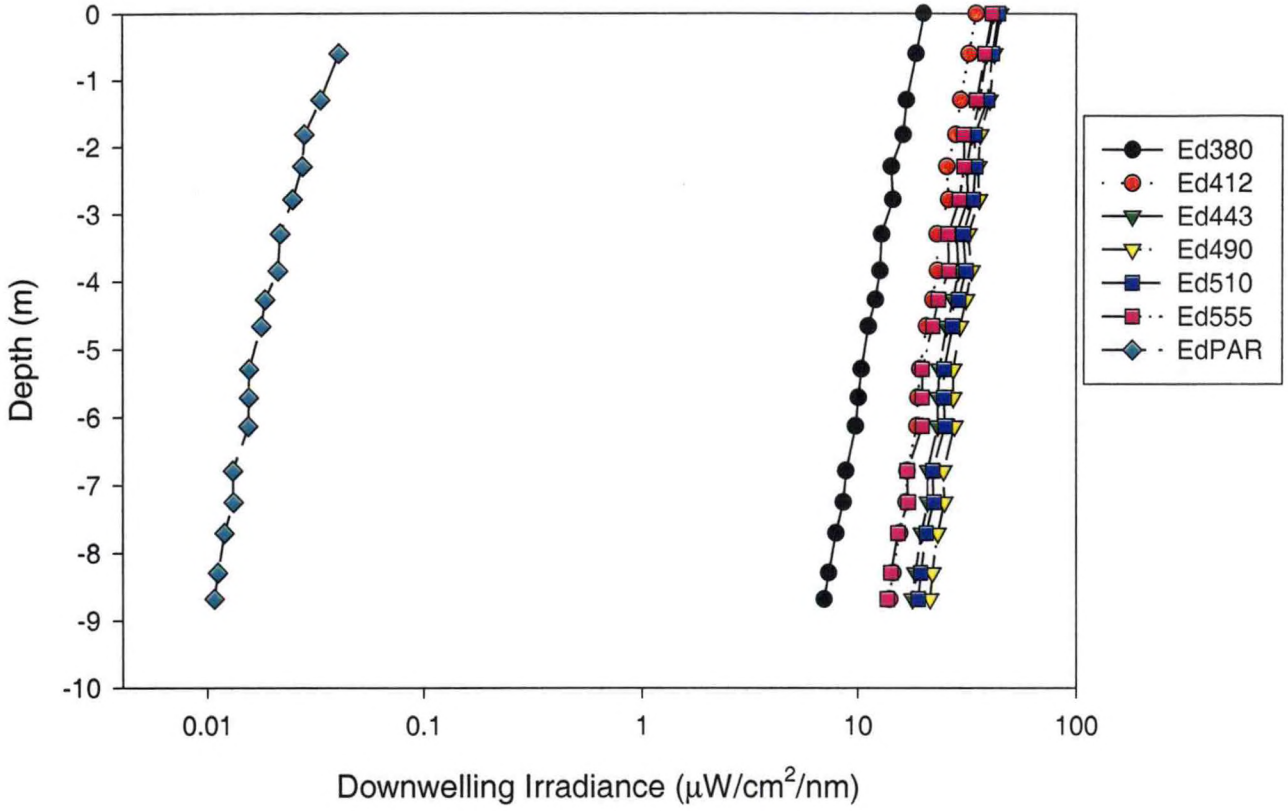
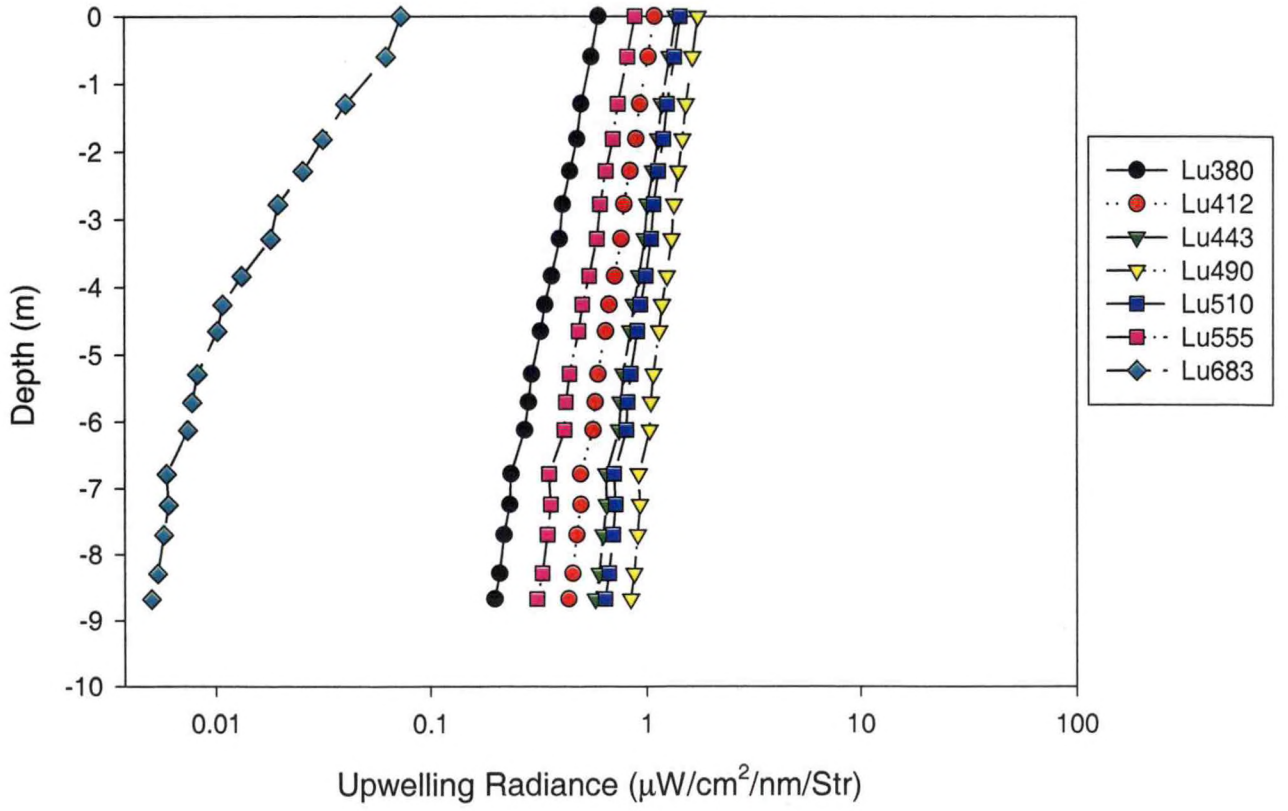


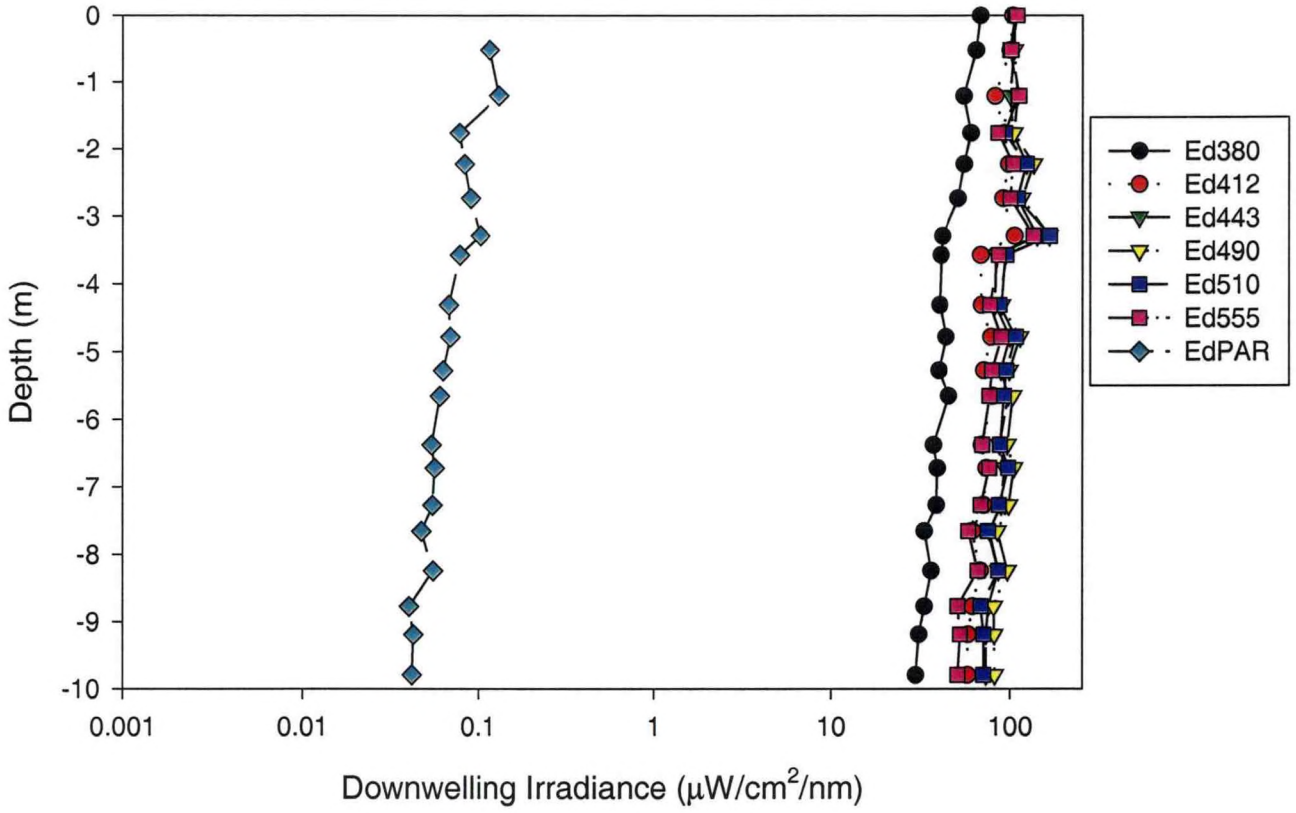


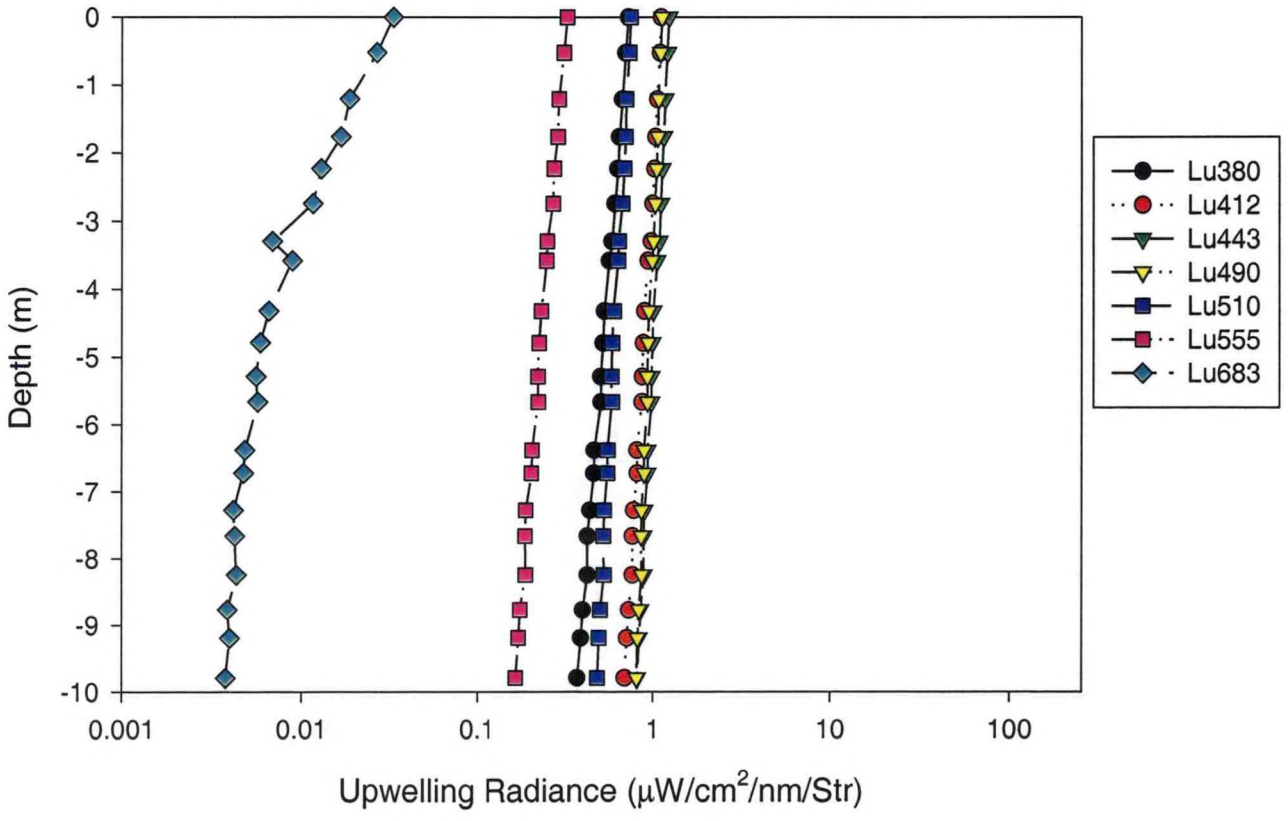
Station 46 Upcast



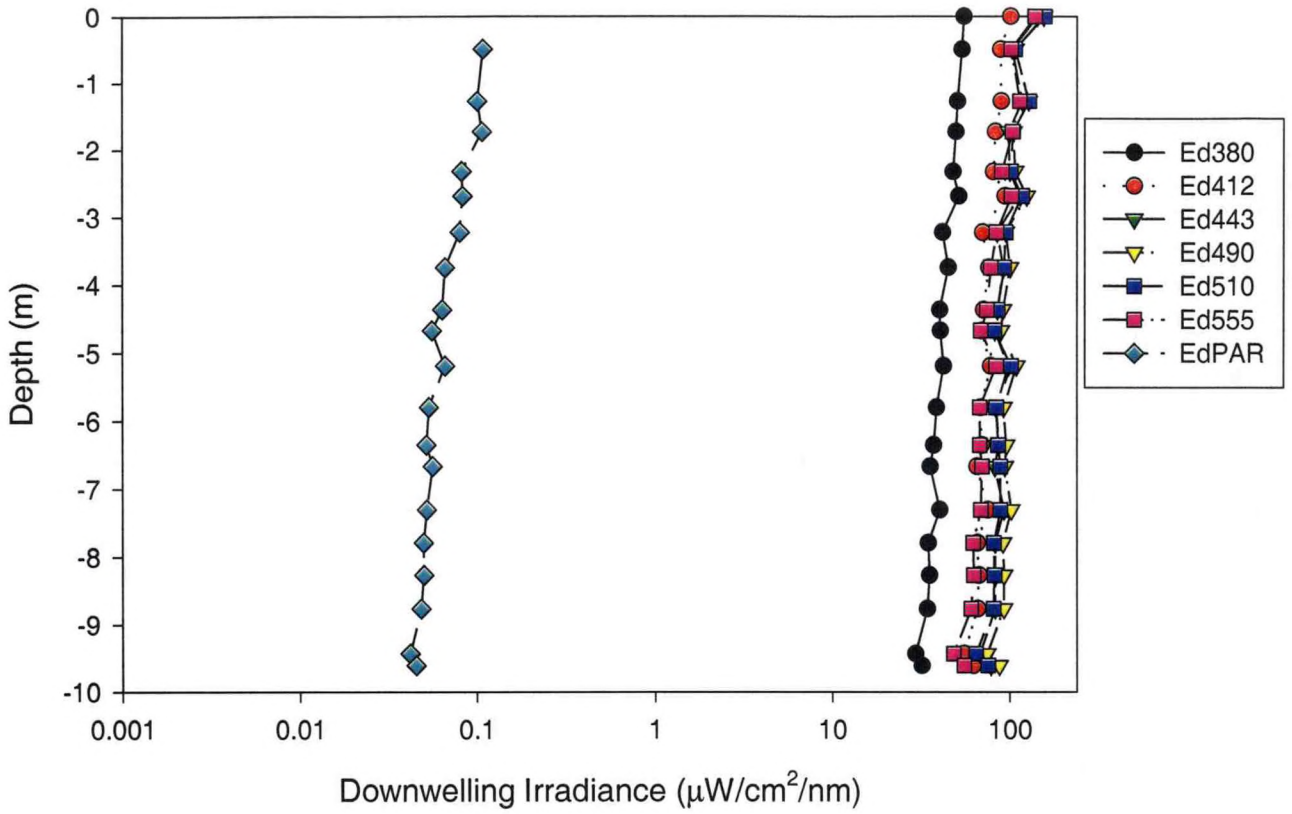


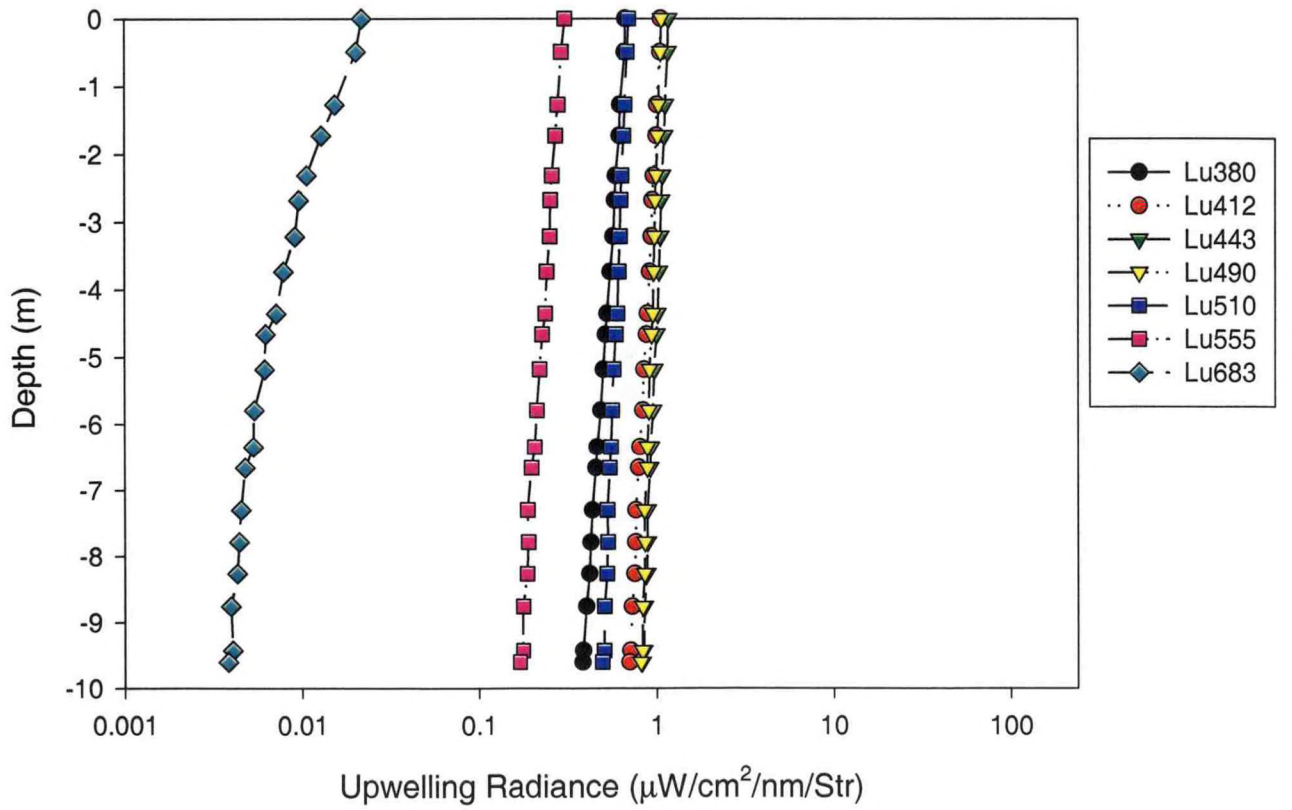
Station 94 Downcast



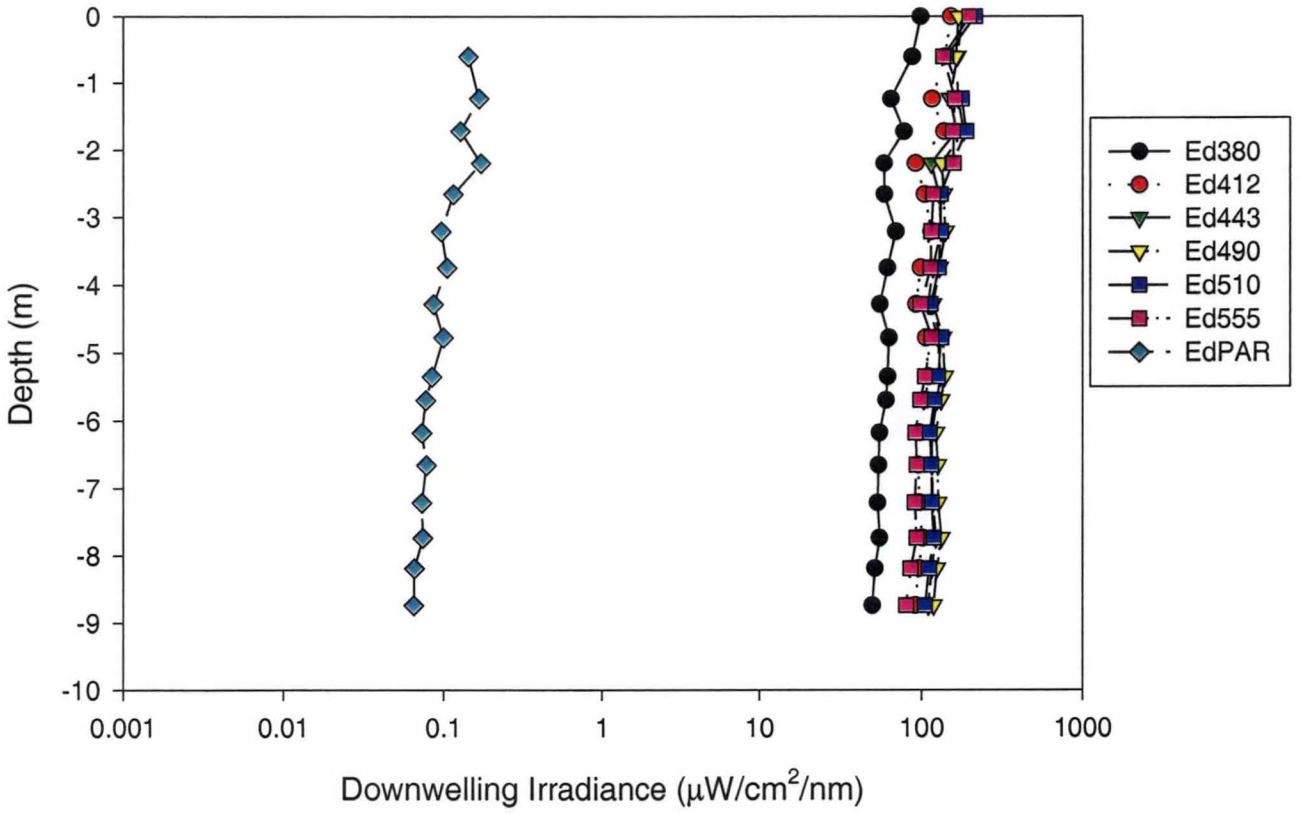


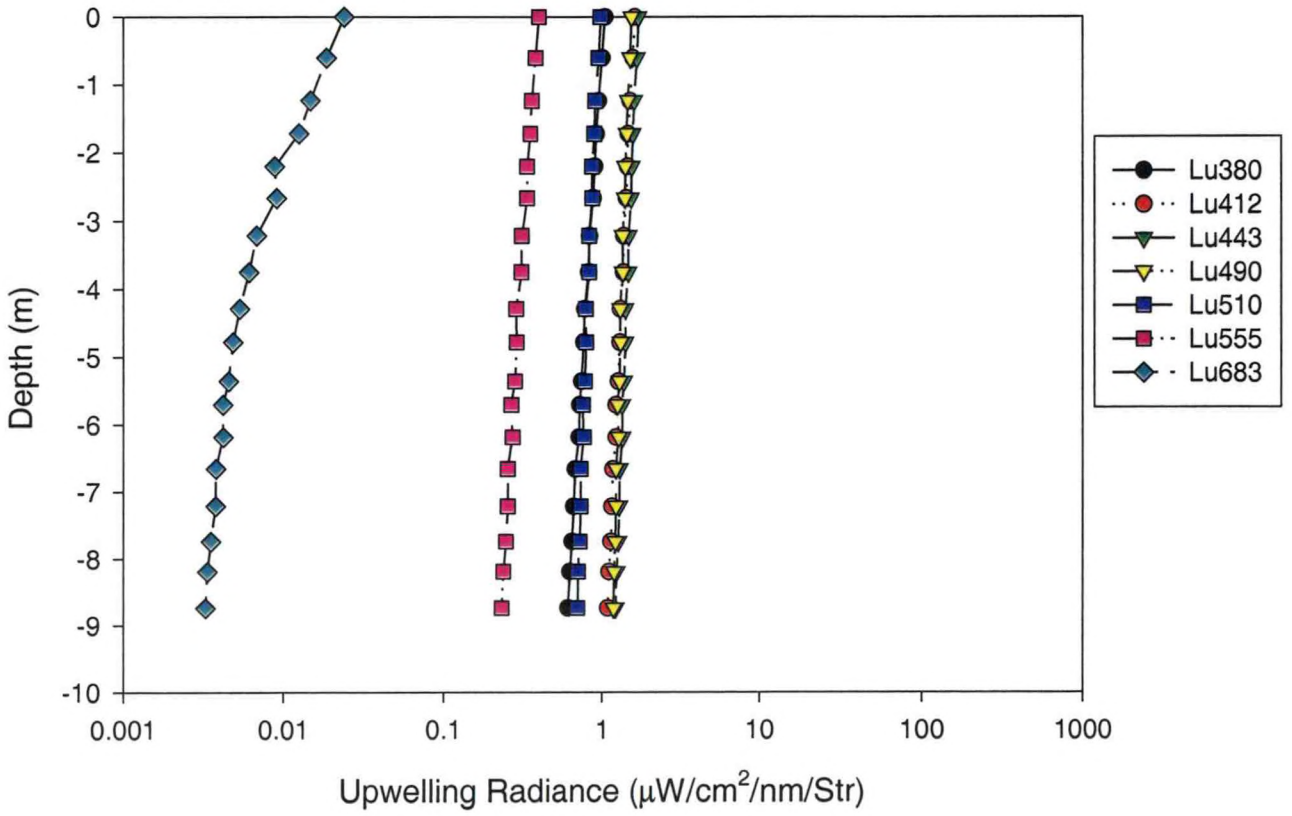
Station 94 Upcast



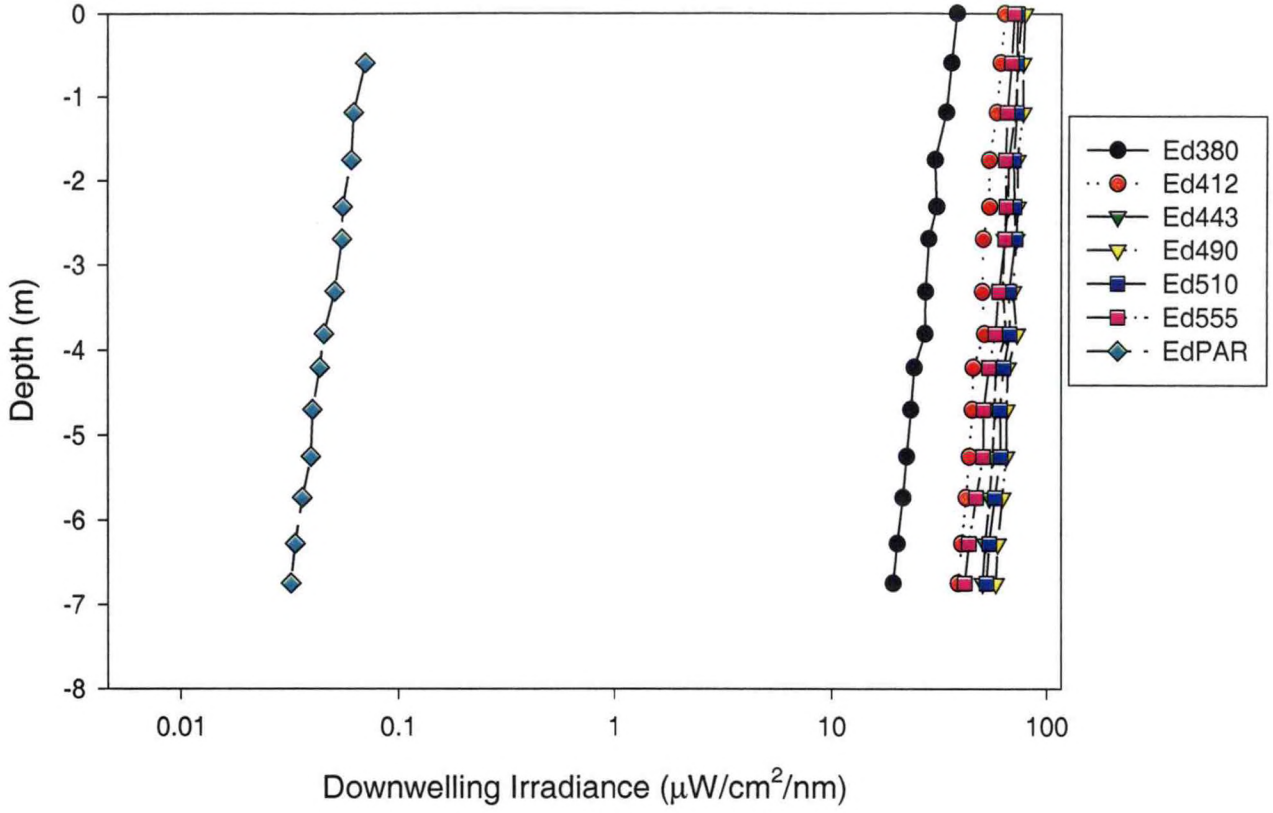


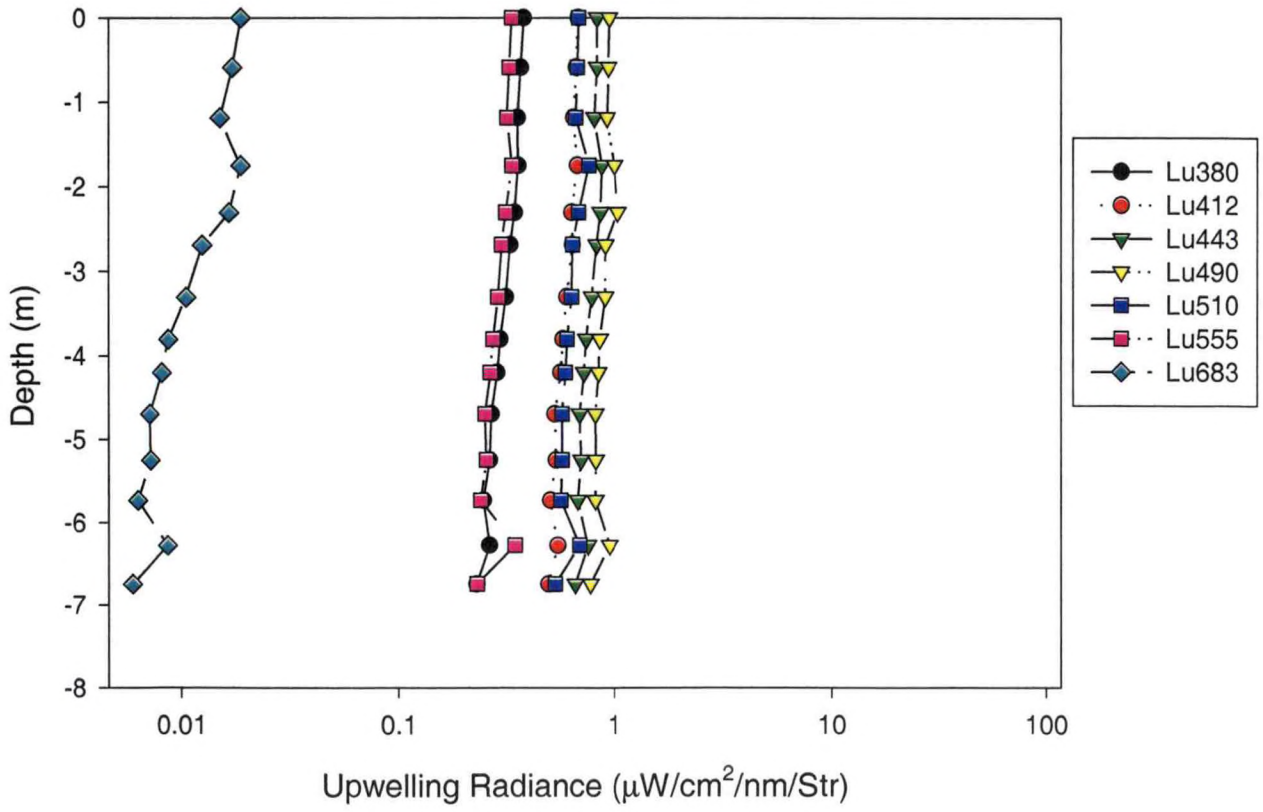
Station 10 Upcast





Station 7 Downcast





Station 7 Upcast