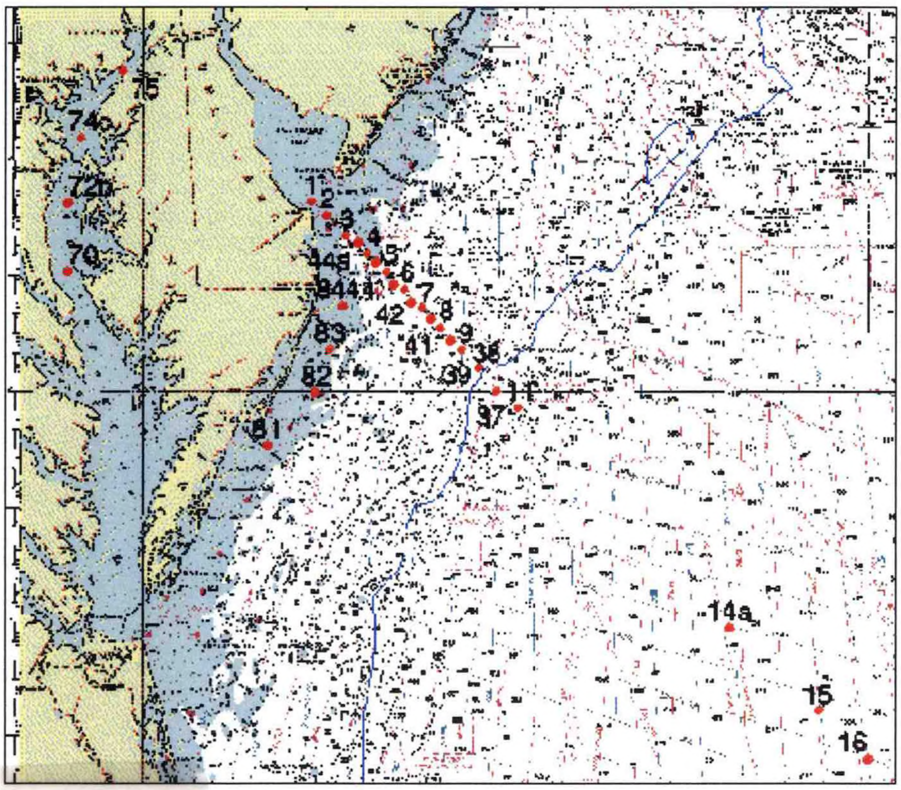
**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
**COASTAL SERVICES CENTER**
2234 S. Hobson Avenue, Charleston, SC 29405-2413

CSC Technical Report CSC 20016-PUB September 2000

# NOAA NOS Cruise OCT99MAB: Mid-Atlantic Bight Cruise




## Participants:

NOAA Coastal Services Center - Coastal Remote Sensing Program
niversity of Maryland

## CSC Technical Report: NOAA CSC 20016-PUB

# NOAA Cruise OCT99MAB: Mid-Atlantic Bight Cruise

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Abstract

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

A total of 30 stations were occupied between October 8 and 12, 1999: 3 in the Sargasso Sea, 23 in the Mid-Atlantic Bight, south of Delaware Bay, and 4 in the Chesapeake Bay. Two instruments provided in-situ measurements of spectral downwelling irradiance, and spectral upwelling radiance were made along with above-surface spectral downwelling irradiance. Samples were collected for measurement of surface chlorophyll *a* concentration. Along-track surface measurements of temperature, salinity, and fluorescence were also made.

Comparison of normalized water-leaving radiance from the two instruments indicated that this measurement is most variable in turbid waters and at higher wavelengths. The variability is due in part to variation in the attenuation coefficient used to extrapolate below water measurements above the surface. The OC2 algorithm estimated chlorophyll concentrations extremely well in the most turbid waters (Stations 1, 2), but overestimated chlorophyll by up to a factor of two at the station with the clearest waters. The freshwater outflow from North Carolina that resulted from Hurricane Floyd is seen as a jet of high chlorophyll water hugging the western wall of the Gulf Stream. The chlorophyll concentration measured in this jet was threefold higher than that found in surrounding waters. SeaWiFS overestimated the concentration by another factor of three, presumably due to the high concentrations of sediment and colored dissolved organic material in this jet.

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## Acknowledgments

We would like to thank the Captain and the crew of the R/V *Cape Henlopen*, and Rossana Del vecchio for assistance provided and Mike Mallonee for the chlorophyll analysis. This project was supported in part by a NASA Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies grant to Drs. Christopher Brown, John Brock, and Mary Culver.

## 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 and as part of the National Aeronautics and Space Administration (NASA) Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Program, scientists from the University of Maryland, College Park undertook a five-day cruise in the Mid-Atlantic Bight and the Chesapeake Bay.

## II. Objectives

The objective of this cruise was to obtain sub-surface 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 two (O'Reilly *et al.* 1998) algorithm for the NASA/OrbImage Sea-viewing Wide Field-of-view Sensor (SeaWiFS). A second objective for this cruise was to compare measurements of attenuation coefficients and normalized water-leaving radiance measured by two different instruments, the Biospherical Instruments, Inc. MER system and the Satlantic, Inc. SeaWiFS Profiling Multi-channel Radiometer (SPMR) system.

## III. Methods

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

### A. Sampling Platform

The R/V *Cape Henlopen*, belonging to the University of Delaware, was used on this cruise. The ship is designed specifically for research missions in the coastal zone with an operating range from Cape Hatteras north to the Gulf of Maine and east to Bermuda.

### B. Sampling Locations

A total of 30 stations were occupied between October 8 and 12, 1999 (Figure 1, Table 1). Most stations (23 of the 30) were located in the Mid-Atlantic Bight. Two stations (15 and 16) were located east of the Gulf Stream in the Sargasso Sea. Measurements to calculate water-leaving radiance were made at 18 of these 26 stations. Four stations (70, 72b, 74c, and 75) were located in the estuarine waters of the upper Chesapeake Bay; data from these stations are not presented here.

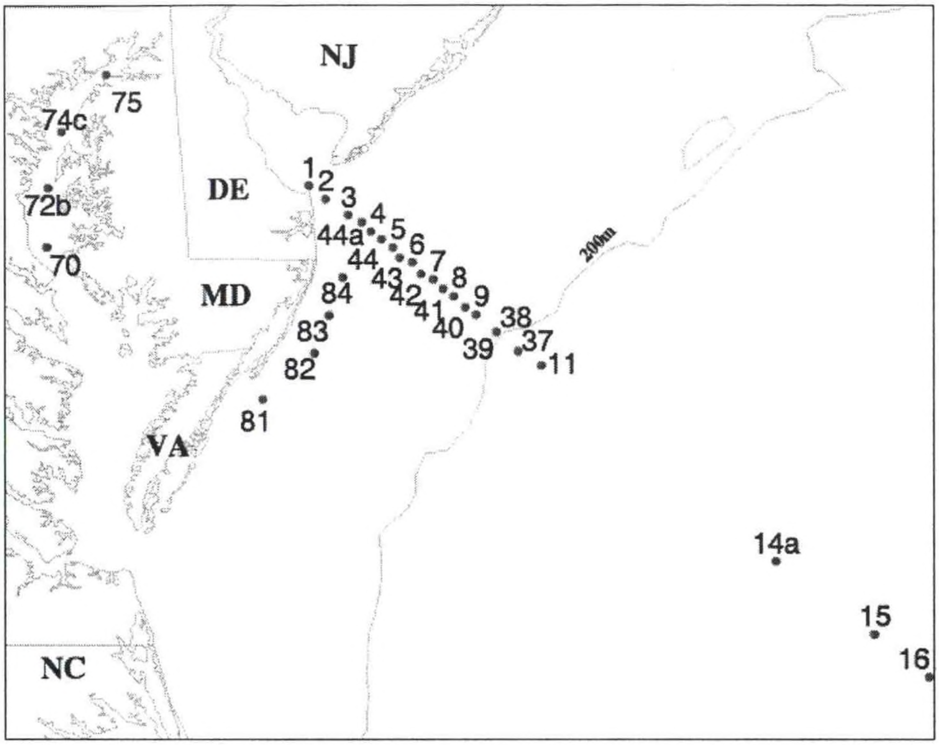


**Figure 1. Station locations.**

## C. Sample Collection Methods Summary

Surface samples were acquired by bucket at all station locations for fluorometric determination of chlorophyll concentration. Above-water downwelling irradiance, in-situ downwelling irradiance, and upwelling radiance were measured using a MER 2040 spectroradiometer deployed off the stern (Figure 2). 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 cm 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 at 13 channels. In-situ profiles of spectral absorption, attenuation coefficients were made using an WetLabs, Inc. AC9, and backscattering coefficients were measured using a HOBI Labs HydroScat-6 (Figure 3). Atmospheric aerosol optical thickness and above-surface water-leaving radiance were measured using a sunphotometer 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 |
|---|---|---|---|---|---|---|
| 1 | 10/8/99 | 13:30 | 38.8211 | -75.0826 | 20 | 1,2,4,3,5,6,7 |
| 2 | 10/8/99 | 15:00 | 38.7540 | -74.9997 | 22 | 1,2,4,3,5,6,7,8 |
| 3 | 10/8/99 | 16:15 | 38.6740 | -74.8868 | 26.5 | 1,2,4,3,5,6,7,8 |
| 4 | 10/8/99 | 17:45 | 38.5919 | -74.7729 | 22.3 | 1,2,4,3,5,6 |
| 5 | 10/8/99 | 19:00 | 38.5137 | -74.6641 | 20 | 1,2,4,3,5,6 |
| 6 | 10/8/99 | 20:10 | 38.4389 | -74.5672 | 29.1 | 1,2,4,3,5,6 |
| 7 | 10/8/99 | 21:30 | 38.3562 | -74.4647 | 36 | 1,2,5,6 |
| 8 | 10/8/99 | 23:00 | 38.2735 | -74.3629 | 44 | 1,2,5,6 |
| 9 | 10/9/99 | 00:30 | 38.1829 | -74.2515 | 43 | 1,2,5 |
| 15 | 10/9/99 | 16:00 | 36.6097 | -72.2648 | >500 | 1,2,4,3,5,7,8 |
| 16 | 10/9/99 | 18:30 | 36.3982 | -71.9964 | >500 | 1,2,4,3,5,6,7,8 |
| 14a | 10/10/99 | 2:00 | 36.9709 | -72.7505 | >500 | 1,2,5 |
| 11 | 10/10/99 | 6:15 | 37.936 | -73.9291 | >500 | 1,2,4,3,5,6 |
| 37 | 10/10/99 | 15:15 | 38.0010 | -74.0444 | 108 | 1,2,4,3,5,6 |
| 38 | 10/10/99 | 17:15 | 38.0980 | -74.1508 | 72.6 | 1,2,4,3,5,6 |
| 39 | 10/10/99 | 18:45 | 38.1820 | -74.2514 | 42 | 1,2,4,3,5,6 |
| 40 | 10/10/99 | 19:45 | 38.2178 | -74.3066 | 52.9 | 1,2,4,3,5,6 |
| 41 | 10/10/99 | 21:20 | 38.3091 | -74.4172 | 38 | 1,2,4,3,5,6 |
| 42 | 10/10/99 | 23:00 | 38.3840 | -74.5248 | N/A | 1,2,5,6 |
| 43 | 10/11/99 | 0:10 | 38.4623 | -74.6288 | 22 | 1,2,5,6 |
| 44 | 10/11/99 | 1:15 | 38.5529 | -74.7201 | 21 | 1,2 |
| 44a | 10/11/99 | 2:15 | 38.6385 | -74.8203 | 27 | 1,2 |
| 75 | 10/11/99 | 15:15 | 39.3767 | -76.1151 | 6 | 1,2,4,3,5,6,8 |
| 74c | 10/11/99 | 17:20 | 39.0912 | -76.3400 | 6 | 1,2,4,3,5,6,7,8 |
| 72b | 10/11/99 | 19:05 | 38.8098 | -76.4084 | 30 | 1,2,4,3,5,6 |
| 70 | 10/11/99 | 21:15 | 38.5144 | -76.4141 | 21 | 1,2,4,3,5,6 |
| 81 | 10/12/99 | 6:30 | 37.7671 | -75.3184 | 17 | 1,2,4,3,5,6,7,8 |
| 82 | 10/12/99 | 16:30 | 37.9919 | -75.0554 | 19 | 1,2,4,3,5,6,7,8 |
| 83 | 10/12/99 | 18:40 | 38.1787 | -74.9817 | 18 | 1,2,4,3,5,6,7,8 |
| 84 | 10/12/99 | 20:15 | 38.3662 | -74.9151 | 19 | 1,2,4,3,5,6,7,8 |

Key to Samples Collected and Instruments Used:

1: Fluorometric Chlorophyll
2: CTD
3: MER-2040
4: SMSR/SPMR
5: AC-9
6: HydroScat-6
7: SIMBAD
8: Microtops

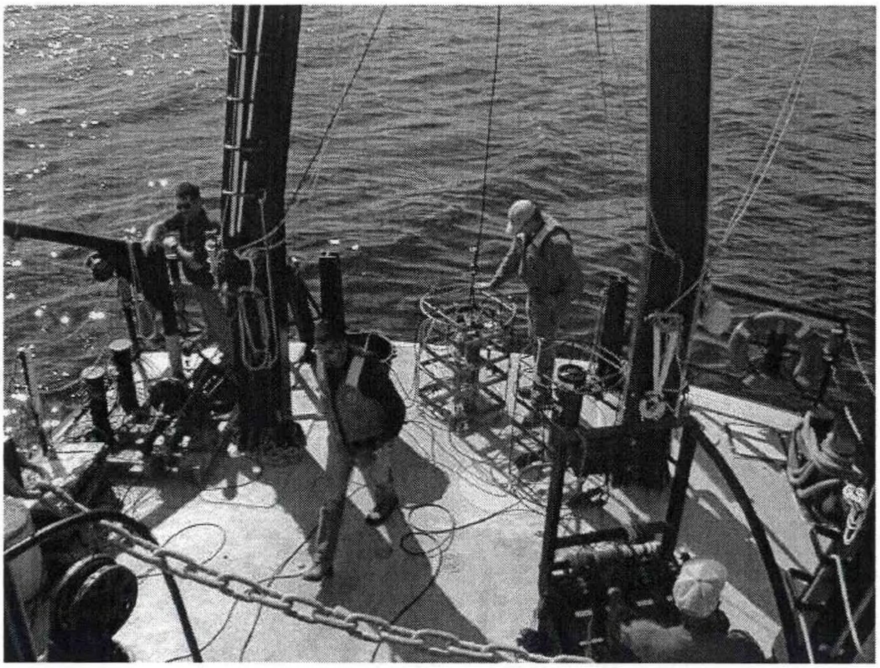

**Figure 2. Deployment of the MER-2040 off the stern.**

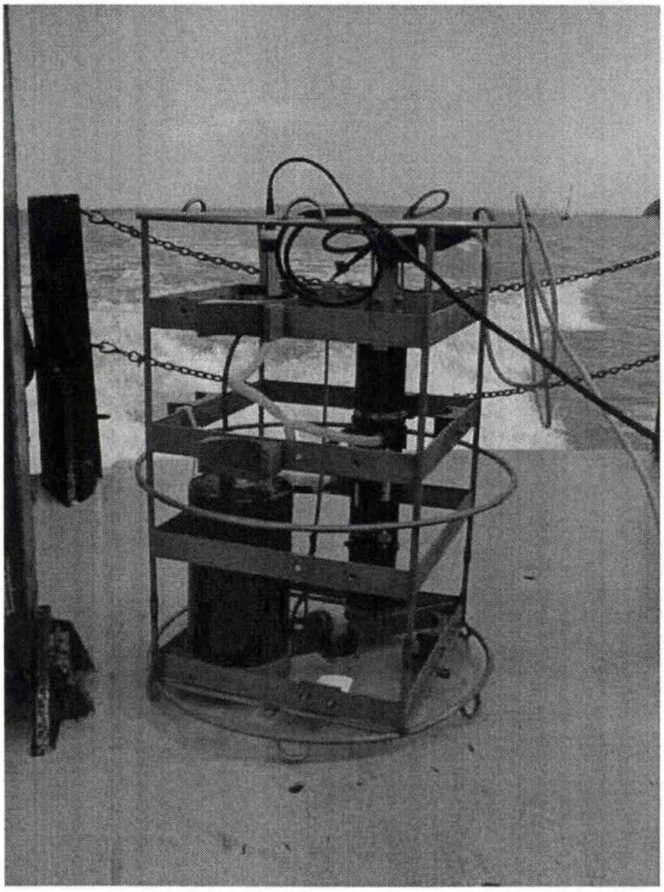

**Figure 3. Optics cage with the backscattering (Hydroscat, left) and absorption (AC9, right) instruments.**

## D. Optical Sampling Instruments and Methodology

The MER-2040 (serial number 8746) is a spectroradiometer manufactured by Biospherical Instruments, Inc. that measures in-situ spectral downwelling irradiance ($E_d$), spectral upwelling radiance ($L_u$), depth (pressure), tilt, roll, and temperature. Data are transmitted to the surface via a conducting cable. A MER-2041 surface unit (serial number 8755) was used to measure matched channels of above-water downwelling irradiance ($E_s$). Channels 1 to 13 are narrow band (10-nanometer [nm] full width at half-maximum) centered at the indicated wavelengths (Table 2). The MER 2048 surface unit was strapped onto a radio antenna near the stern of the boat.

**Table 2. Center wavelengths (nm) for the MER system.**

| Channel No. | Downwelling Irradiance Light Sensor | Upwelling Radiance Light Sensor | Surface Irradiance Sensor |
|---|---|---|---|
| 1 | 412 | 412 | 412 |
| 2 | 443 | 443 | 443 |
| 3 | 455 | 455 | 455 |
| 4 | 490 | 490 | 490 |
| 5 | 510 | 510 | 510 |
| 6 | 532 | 532 | 532 |
| 7 | 550 | 550 | 550 |
| 8 | 560 | 560 | 560 |
| 9 | 589 | 589 | 589 |
| 10 | 625 | 625 | 625 |
| 11 | 671 | 671 | 671 |
| 12 | 683 | 683 | 683 |
| 13 | 700 | 700 | 700 |

The SeaWiFS Profiling Multi-channel Radiometer (SPMR; serial number 024) and the SeaWiFS Multi-channel Surface Radiometer (SMSR; serial number 024) are multi-spectral 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 cm below the surface. It was floated away from the side of the vessel to avoid ship shadow artifacts 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.

## E. Bucket Samples

Discrete surface water samples were obtained using a bucket at the same time as the optics casts. Chlorophyll biomass was determined using a Turner Designs fluorometer (Parsons *et al.* 1984).

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 |

## F. Optical Data Processing

All 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 MER data were binned to one-meter bins and saved as ASCII files using software provided by Biospherical Instruments, Inc. The ASCII files were imported into Microsoft Excel. 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% transmission factor (i.e. $E_d(0^+)=0.96*E_d(0^-)$; O'Reilly *et al.* 1998).

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:

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

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 ($\lambda$) was calculated as the ratio of $nL_w$ to $E_s$.

The September 1998 reprocessing of the SeaWiFS OC2 algorithm (O'Reilly et al. 1998) (OC2v2) was used to calculate the satellite estimates of chlorophyll *a* (C) as:

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

where

$$X = \log_{10} \frac{R_{rs}(490)}{R_{rs}(555)}. \qquad (3)$$

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 m below the surface. The radiance measured at 0.75 m 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 nm 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 above. 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-m bins, and K was calculated using data from the top 10 m. This K was then used to propagate the $L_s$ measured 0.75 m 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. In all cases the normalized water-leaving radiance was then calculated using Equation 1, and the chlorophyll *a* concentration was calculated using Equations 2 and 3.

# IV. Results

## A. Along-Track Data

The along track data showed four distinct water types: 1) cold, low salinity i nearshore waters with high fluorescence, 2) warmer mid-shelf waters high in salinity and low in fluorescence, 3) a jet of low salinity, high fluorescence water apparently associated with outflow from North Carolina, and 4) warm, saline, low fluorescence waters of the Gulf Stream and Sargasso Sea (Figures 4 to 6).

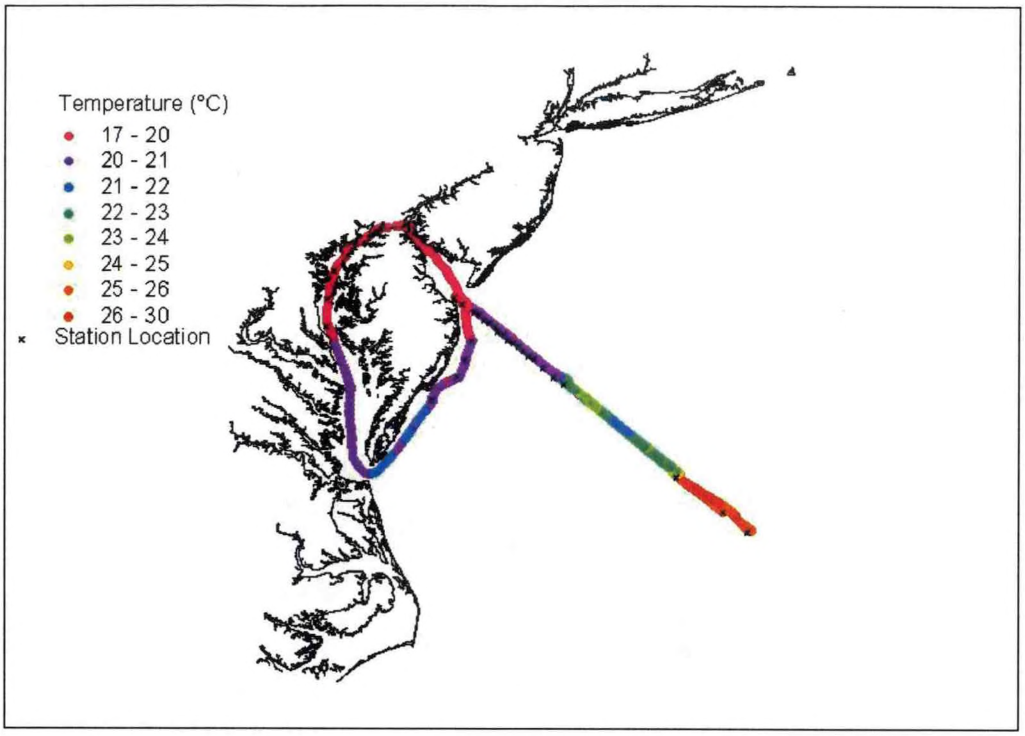


**Figure 4. Surface temperature from along-track system.**

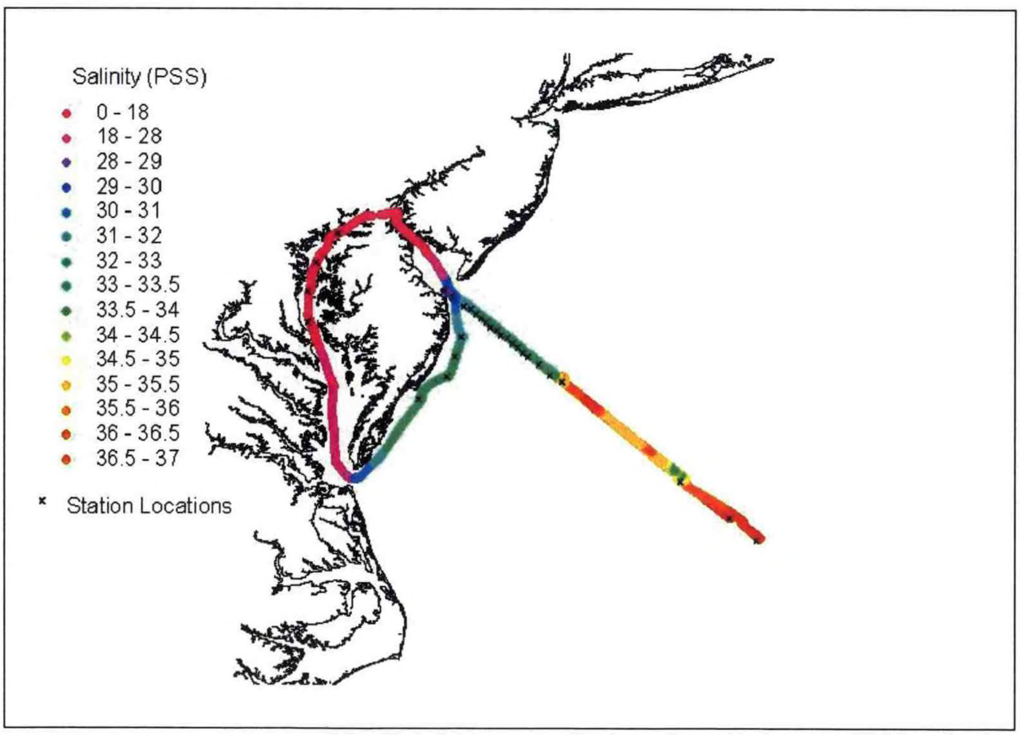


**Figure 5. Surface salinity from along-track system.**

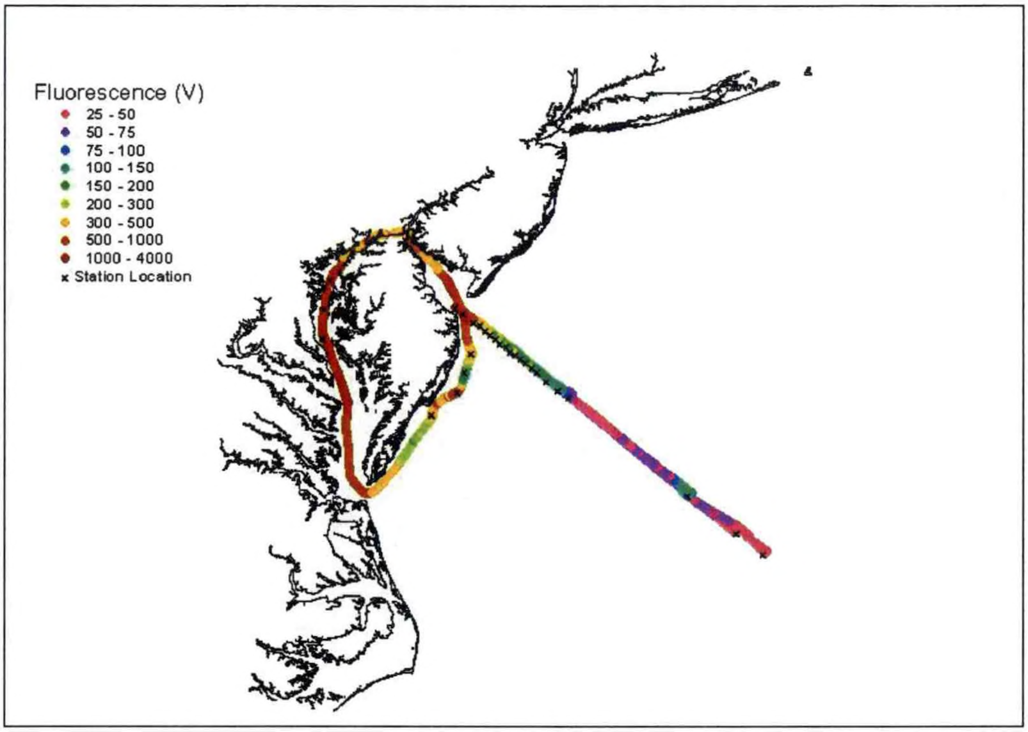


**Figure 6. Surface fluorescence from along-track system.**

## B. Meteorological Observations

To aid in the assessment of data quality, careful recordings of sky and sea states were made (Table 4). The first and last days of the cruise had the most favorable weather conditions for optical measurements, clear skies with relatively calm sea states, that allowed comparison with SeaWiFS imagery. The middle days of the cruise, with stations in the mid-shelf region, were marked by overcast sky conditions and rain.

**Table 4. Meteorological observations for each station.**

Wind Speed (knots), Wind Direction (Degrees from North), Barometric Pressure (mBar), Photosynthetically Available Radiation - PAR (quanta/$m^2$/sec), Air Temperature (°C), Humidity (percent), Sea Surface Temperature (°C), Salinity (ppt), Relative Chlorophyll Fluorescence, Sky and Sea State Observations.

| Date | Stn | Wind Speed | Wind Dir | Baro-meter | PAR | Air Temp | Humidity | Sea Temp | Salin | Fluoro | SkyState | SeaState |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/8/99 | 1 | 9 | 143 | 1031.4 | 9.55E+16 | 14.0 | 61.2 | 18.84 | 30.070 | 914 | Clear 5% in horizon | Calm 10 cm |
| 10/8/99 | 2 | 7 | 150 | 1031.6 | 1.07E+17 | 14.2 | 57.0 | 19.25 | 30.331 | 908.81 | high cirrus 5%, clear overhead | Calm 10 cm |
| 10/8/99 | 3 | 8 | 163 | 1031.7 | 1.6E+17 | 14.3 | 63.5 | 19.37 | 31.060 | 490 | high cirrus 5%, clear to sun | Calm 15 cm |
| 10/8/99 | 4 | 8 | 156 | 1030.9 | 4.92E+16 | 15.3 | 64.5 | 19.91 | 32.160 | 255.7 | scattered cumulus 70% | Calm 15 cm |
| 10/8/99 | 5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 32.471 | N/A | 80% cumulus | Calm 15 cm |
| 10/8/99 | 6 | 9 | 147 | 1029.5 | 8.17E+16 | 16.0 | 63.7 | 20.086 | 32.550 | 209.35 | 80% cumulus | Calm 15 cm |
| 10/8/99 | 7 | 10 | 153 | 1028.7 | 7.95E+16 | 16.4 | 63.2 | 19.63 | 32.955 | 151.98 | Dark | Calm 15 cm |
| 10/8/99 | 8 | 6 | 171 | 1028.3 | Dark | 17.3 | 69.3 | 19.47 | 33.145 | 221.56 | Dark | Calm 15 cm |
| 10/9/99 | 9 | 14 | 151 | 1028.2 | Dark | 17.3 | 75.3 | 19.668 | 33.225 | 219.12 | Dark | 30 cm chop |
| 10/10/99 | 11 | 8 | 201 | 1021.4 | 2.26E+16 | 21.4 | 82.9 | 22.704 | 35.395 | 64.58 | 100% overcast | Calm 15 cm |
| 10/10/99 | 14a | 5 | 255 | 1024.4 | Dark | 21.2 | 61.9 | 25.002 | 34.955 | 80.81 | Dark | N/A |
| 10/9/99 | 15 | 8 | 217 | 1026.2 | 1.33E+17 | 24.3 | 51.8 | 25.986 | 36.238 | 38.24 | scattered cumulus 50% | 60 cm swell |
| 10/9/99 | 16 | 4 | 195 | 1024.9 | 1.28E+17 | 23.2 | 55.9 | 25.687 | 36.375 | 33.3 | Clear 20% in horizon | 30 cm swell |
| 10/10/99 | 37 | 5 | 236 | 1021.1 | 1.50E+16 | 19.9 | 90.2 | 20.324 | 32.967 | 118.29 | 100% overcast, raining | Calm 15 cm |
| 10/10/99 | 38 | 3 | 191 | 1019.9 | 7.56E+16 | 19.7 | 88.9 | 20.439 | 32.884 | 147.46 | 100% overcast | Calm 15 cm |
| 10/10/99 | 39 | 11 | 186 | 1018.3 | 2.47E+16 | 19.6 | 89.8 | 20.346 | 32.887 | 169.31 | 100% overcast, raining | 30 cm ripples |
| 10/10/99 | 40 | 12 | 174 | 1017.0 | 1.61E+16 | 19.3 | 91.9 | 20.35 | 32.801 | 64 | 100% overcast, raining | 30 cm ripples |
| 10/10/99 | 41 | 15 | 181 | 1015.9 | 1.03E+16 | 19.6 | 90.9 | 20.097 | 32.978 | 182.74 | 100% overcast | 30 cm waves, |

| Date | Stn | Wind Speed | Wind Dir | Baro-meter | PAR | Air Temp | Humidity | Sea Temp | Salin | Fluoro | SkyState | SeaState |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | some whitecaps |
| 10/10/99 | 42 | N/A | N/A | N/A | Dark | N/A | N/A | 20.339 | 32.702 | 201.42 | Dark | N/A |
| 10/11/99 | 43 | 10 | 194 | 1015.6 | Dark | 20.4 | 92.2 | 20.452 | 32.435 | 245.97 | Dark | 30 cm ripples |
| 10/11/99 | 44 | 15 | 205 | 1015.5 | Dark | 19.6 | 96.2 | 20.409 | 32.352 | 202.39 | Dark | N/A |
| 10/11/99 | 44a | 10 | 222 | 1015.9 | Dark | 19.1 | 96.3 | 20.322 | 31.804 | 276.37 | Dark | N/A |
| 10/11/99 | 70 | 15 | 11 | 1018.8 | 5.65E+16 | 20.4 | 66.2 | 19.814 | 16.129 | 1720.41 | N/A | N/A |
| 10/11/99 | 72b | 15 | 6 | 1018.2 | 7.87E+16 | 20.3 | 70.2 | 19.722 | 14.66 | 2090.72 | 90% cumulus | 30 cm waves, some whitecaps |
| 10/11/99 | 74c | 10 | 342 | 1018.0 | 1.37E+17 | 20.3 | 73.6 | 19.555 | 9.860 | 2090.72 | 30% scattered cumulus, clear to sun | 30 cm waves, some whitecaps |
| 10/11/99 | 75 | 9 | 339 | 1018.0 | 1.36E+17 | 20.3 | 72.8 | 18.292 | 1.451 | 367.68 | 60% scattered dark cumulus | Calm 10 cm |
| 10/12/99 | 81 | 9 | 30 | 1026.9 | 1.09E+17 | 17.9 | 52.4 | 20.804 | 32.239 | 307.5 | Clear | 60-80 cm waves, white caps |
| 10/12/99 | 82 | 14 | 17 | 1027.4 | 1.23E+17 | 16.8 | 63 | 20.4 | 32.267 | 500 | Clear, 2% at horizon | 80 cm waves |
| 10/12/99 | 83 | 7 | 44 | 1026.5 | 1.20E+17 | 16.4 | 61.2 | 20.36 | 32.300 | 156.67 | Clear, 2% at horizon | 50 cm waves |
| 10/12/99 | 84 | | | 1026.0 | 1.04E+17 | 16.2 | 63.2 | 20.19 | 31.987 | 351.44 | Clear, 2% at horizon | 30 cm waves |

## C. Bucket Samples

The chlorophyll *a* concentrations ranged from 9.84 $mg/m^3$ at the mouth of the Delaware Bay to 0.06 $mg/m^3$ in the Sargasso Sea (Table 5). The chlorophyll value was threefold higher in the freshwater plume along the western wall of the Gulf Stream than that found at stations inshore (see SeaWiFS images, Appendix A). Additional information on water column structure is available as conductivity and temperature depth profiles in Appendix B.

**Table 5. Fluorometric chlorophyll *a* concentration at each station.**

| Station | Chlorophyll *a* ($mg/m^3$) | Station | Chlorophyll *a* ($mg/m^3$) |
|---|---|---|---|
| 1 | 9.84 | 15 | 0.13 |
| 2 | 9.23 | 16 | 0.06 |
| 3 | 4.23 | 37 | 0.49 |
| 4 | 1.22 | 38 | 0.48 |
| 5 | 1.04 | 39 | 0.56 |
| 6 | 0.54 | 40 | 0.56 |
| 7 | 0.37 | 41 | 0.50 |
| 8 | 0.57 | 81 | 1.56 |
| 9 | 0.38 | 82 | 3.52 |
| 11 | 0.16 | 83 | 0.62 |
| 14a | 0.34 | 84 | 1.88 |

## D. Optical Data

The normalized water-leaving radiance was calculated from two different instruments using three different techniques. Only the normalized water-leaving radiance calculated using the second technique discussed in the methods section (using $L_u$ and $E_s$ from SMSR and K from either the SPMR or calculated using the Morel (1988) technique) is presented in Table 6, although all the data are presented as spectra in Appendix C. The difference in normalized water-leaving radiance between the various instruments and techniques was minimal in the relatively clear Case I waters (Stations 11, 15, 16), where the relative differences were less than 10% in all channels except the far red (Table 7). The relative difference in the far red channels (670, 683 nm) was greater than 50%, but this may not be significant in absolute terms since the signal is very small at these wavelengths (less than 0.03 $\mu W\ cm^{-2}\ nm^{-1}\ sr^{-1}$). It should be noted that the relative difference at these wavelengths was smaller in turbid waters.

**Table 6. Summary of normalized water-leaving radiance ($\mu W\ cm^{-2}\ nm^{-1}\ sr^{-1}$).**

| Station | 412 | 443 | 490 | 510 | 520 | 555 | 565 | 620 | 665 | 670 | 683 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 0.288 | 0.517 | 0.867 | 0.970 | 0.932 | 1.247 | 1.352 | 0.738 | 0.487 | 0.474 | 0.451 |
| 02 | 0.340 | 0.567 | 0.956 | 1.095 | 1.063 | 1.427 | 1.543 | 0.753 | 0.494 | 0.497 | 0.472 |
| 03 | 0.289 | 0.462 | 0.770 | 0.862 | 0.833 | 1.056 | 1.091 | 0.453 | 0.293 | 0.304 | 0.306 |
| 04 | 0.260 | 0.372 | 0.550 | 0.581 | 0.553 | 0.533 | 0.517 | 0.152 | 0.102 | 0.111 | 0.121 |
| 05 | 0.264 | 0.323 | 0.438 | 0.500 | 0.480 | 0.460 | 0.429 | 0.104 | 0.078 | 0.096 | 0.139 |
| 06 | 0.278 | 0.354 | 0.438 | 0.420 | 0.382 | 0.319 | 0.290 | 0.067 | 0.049 | 0.057 | 0.071 |
| 11 | 0.729 | 0.843 | 0.844 | 0.628 | 0.505 | 0.339 | 0.297 | 0.057 | 0.037 | 0.042 | 0.041 |
| 15 | 1.235 | 1.223 | 1.001 | 0.641 | 0.479 | 0.300 | 0.255 | 0.050 | 0.031 | 0.035 | 0.030 |
| 16 | 1.668 | 1.590 | 1.155 | 0.681 | 0.500 | 0.304 | 0.258 | 0.047 | 0.030 | 0.036 | 0.027 |
| 37 | 0.405 | 0.550 | 0.651 | 0.526 | 0.446 | 0.328 | 0.298 | 0.070 | 0.041 | 0.053 | 0.055 |
| 38 | 0.298 | 0.392 | 0.475 | 0.430 | 0.380 | 0.300 | 0.274 | 0.062 | 0.043 | 0.049 | 0.059 |
| 39 | 0.314 | 0.405 | 0.497 | 0.457 | 0.409 | 0.327 | 0.302 | 0.079 | 0.053 | 0.059 | 0.072 |
| 41 | 0.347 | 0.437 | 0.538 | 0.498 | 0.445 | 0.363 | 0.338 | 0.075 | 0.054 | 0.062 | 0.077 |
| 81 | 0.569 | 0.952 | 1.536 | 1.657 | 1.590 | 1.677 | 1.683 | 0.684 | 0.457 | 0.459 | 0.400 |
| 82 | 0.283 | 0.396 | 0.606 | 0.649 | 0.641 | 0.738 | 0.777 | 0.266 | 0.175 | 0.181 | 0.204 |
| 83 | 0.319 | 0.527 | 0.845 | 0.838 | 0.759 | 0.721 | 0.686 | 0.184 | 0.118 | 0.124 | 0.113 |
| 84 | 0.239 | 0.378 | 0.605 | 0.646 | 0.603 | 0.633 | 0.628 | 0.202 | 0.139 | 0.156 | 0.164 |

Differences in K computed from measurements from the two different instruments contributed to the difference in computed normalized water-leaving radiance because of the effect of K on the calculation of $L_u(0-)$ (see Equation 1). The Morel technique applied to derive K from SMSR data was evaluated by comparing it to K calculated from the MER data (Table 8). Even though the Morel (1988) technique was not particularly accurate at calculating the chlorophyll concentration (Table 9), the K derived from that technique matched well with that calculated from the MER, except in extremely turbid waters (Stations 1, 2, 81 to 84). The mismatch was higher at the red wavelengths, possibly due to the small signal used to calculate K.

**Table 7. Percent differences between normalized water-leaving radiance calculated using SMSR/SPMR and MER data for each station.**

| Station | 412 | 443 | 490 | 510 | 555* | 565* | 670 | 683 |
|---|---|---|---|---|---|---|---|---|
| 01A | N/A | 0.584 | 0.395 | 0.356 | 0.182 | 0.162 | 0.024 | -0.055 |
| 01B | N/A | 0.573 | 0.389 | 0.349 | 0.174 | 0.150 | -0.017 | -0.085 |
| 02A | 0.236 | -0.276 | -0.179 | 0.041 | 0.009 | 0.045 | 0.297 | 0.320 |
| 03A | 0.327 | 0.179 | 0.152 | 0.190 | 0.167 | 0.173 | 0.253 | 0.272 |
| 04A | -0.067 | 0.014 | -0.009 | 0.084 | 0.077 | 0.095 | 0.412 | 0.357 |
| 04B | -0.027 | 0.044 | 0.008 | 0.095 | 0.088 | 0.109 | 0.425 | 0.371 |
| 05A | -0.220 | -0.233 | -0.124 | 0.025 | 0.041 | 0.054 | 0.215 | 0.217 |
| 06A | -0.068 | -0.083 | -0.116 | -0.005 | 0.012 | 0.020 | 0.578 | 0.466 |
| 11C | -0.013 | -0.040 | -0.085 | 0.040 | 0.064 | 0.083 | 0.651 | 0.524 |
| 11D | -0.015 | -0.043 | -0.084 | 0.039 | 0.062 | 0.008 | 0.650 | 0.525 |
| 15A | -0.047 | -0.056 | -0.072 | 0.034 | 0.036 | 0.051 | 0.722 | 0.694 |
| 15B | -0.017 | -0.030 | -0.033 | 0.067 | 0.072 | 0.080 | 0.729 | 0.703 |
| 16A | -0.008 | -0.001 | -0.012 | 0.062 | 0.081 | 0.094 | 0.728 | 0.703 |
| 16B | -0.015 | -0.012 | -0.024 | 0.052 | 0.069 | 0.081 | 0.728 | 0.698 |
| 37A | 0.303 | 0.230 | 0.139 | 0.221 | 0.234 | 0.267 | 0.779 | 0.713 |
| 37B | 0.298 | 0.223 | 0.132 | 0.217 | 0.234 | 0.265 | 0.779 | 0.716 |
| 38A | 0.127 | 0.101 | 0.052 | 0.156 | 0.173 | 0.196 | 0.648 | 0.594 |
| 38C | 0.129 | 0.105 | 0.058 | 0.163 | 0.178 | 0.202 | 0.650 | 0.594 |
| 39A | 0.222 | 0.211 | 0.151 | 0.258 | 0.304 | 0.332 | 0.785 | 0.659 |
| 39B | 0.202 | 0.127 | 0.058 | 0.144 | 0.135 | 0.141 | 0.770 | 0.647 |
| 41A | 0.252 | 0.212 | 0.108 | 0.232 | 0.275 | 0.295 | N/A | N/A |
| 41B | 0.254 | 0.211 | 0.105 | 0.228 | 0.272 | 0.294 | N/A | N/A |
| 74cA | N/A | N/A | 0.689 | 0.526 | 0.347 | 0.344 | 0.673 | 0.536 |
| 72bA | N/A | N/A | 0.514 | 0.472 | 0.361 | 0.364 | 0.554 | 0.459 |
| 70A | N/A | N/A | 0.784 | 0.625 | 0.557 | 0.548 | 0.479 | 0.146 |
| 81A | -0.083 | -0.158 | -0.307 | -0.206 | -0.233 | -0.217 | 0.332 | 0.360 |
| 82A | 0.240 | 0.192 | 0.159 | 0.225 | 0.228 | 0.247 | 0.487 | 0.433 |
| 83A | -0.081 | -0.068 | -0.092 | 0.016 | 0.005 | 0.017 | 0.475 | 0.505 |
| 84A | 0.127 | -0.061 | -0.107 | -0.013 | -0.031 | -0.019 | 0.399 | 0.367 |

*The MER Channels were 550 and 560 nm.

**Table 8. Percent difference between attenuation coefficients calculated from SMSR/SPMR and MER data for each station.**

| Station | 412 | 443 | 490 | 510 | 555* | 565* | 670 | 683 |
|---|---|---|---|---|---|---|---|---|
| 1 | N/A | 0.228 | 0.132 | 0.008 | -0.297. | -0.364 | 0.075 | 0.120 |
| 2 | -0.170 | -0.148 | -0.151 | -0.194 | -0.435 | -0.450 | -0.040 | -0.065 |
| 3 | -0.071 | 0.046 | 0.058 | -0.031 | -0.219 | -0.235 | -0.078 | -0.149 |
| 4 | -0.359 | -0.051 | 0.038 | 0.034 | -0.045 | -0.034 | -0.386 | -0.499 |
| 5 | -0.508 | -0.368 | -0.130 | -0.061 | -0.001 | 0.042 | -0.299 | -0.432 |
| 6 | -0.375 | -0.189 | -0.068 | -0.017 | 0.005 | 0.017 | -0.662 | -0.741 |
| 11 | -0.632 | -0.629 | -0.578 | -0.336 | -0.175 | -0.126 | -0.566 | -0.582 |
| 15 | -0.232 | -0.274 | -0.123 | 0.048 | 0.090 | 0.131 | -0.621 | -0.718 |
| 16 | -0.238 | -0.343 | -0.205 | -0.021 | 0.033 | 0.071 | -0.558 | -0.734 |
| 37 | 0.032 | 0.180 | 0.232 | 0.153 | 0.076 | 0.114 | -0.787 | -0.746 |
| 38 | -0.475 | -0.202 | -0.011 | 0.055 | 0.101 | 0.158 | -0.653 | -0.736 |
| 39 | -0.449 | -0.096 | 0.056 | 0.115 | 0.152 | 0.188 | -0.743 | -0.652 |
| 41 | -0.369 | -0.122 | -0.102 | 0.028 | 0.136 | 0.180 | N/A | N/A |
| 70 | N/A | N/A | 0.539 | 0.395 | 0.341 | 0.311 | -0.299 | -0.126 |
| 72b | N/A | N/A | 0.190 | 0.092 | -0.094 | -0.119 | -0.242 | -0.152 |
| 81 | -0.555 | -0.370 | -0.540 | -0.671 | -0.984 | -1.027 | 0.078 | 0.034 |
| 82 | -0.131 | 0.00 | 0.034 | -0.028 | -0.133 | -0.128 | -0.247 | -0.295 |
| 83 | -0.277 | 0.026 | 0.141 | 0.113 | 0.045 | 0.048 | -0.333 | -0.481 |
| 84 | -0.177 | -0.033 | 0.055 | 0.019 | -0.079 | -0.078 | -0.247 | -0.311 |

*The MER Channels were 550 and 560 nm.

## E. Algorithm Evaluation and SeaWiFS Derived Data

The chlorophyll *a* concentration estimated by the OC2 algorithm compared extremely well with the measured chlorophyll *a* concentration in very turbid waters (Stations 1, 2), and it over-predicted the chlorophyll *a* concentration by a factor of almost two at the clearest station. There were differences between the OC2 value derived from the MER and the SMSR at the more turbid stations, presumably due to instrument size and deployment techniques (Table 9 and Figure 7).

There were only two stations (6, 16) in relatively clear water and under clear sky. At these two stations, there was good agreement between measured and SeaWiFS-derived normalized water-leaving radiance. At the coastal stations (1, 2, 81, 82, 83) there were atmospheric correction problems that produced negative values for SeaWiFS normalized water-leaving radiance at the 412 and 443 wavelengths (Figure 8). The difference between the measured chlorophyll *a* (as well as OC2-derived chlorophyll *a*) and the SeaWiFS-derived chlorophyll *a* concentrations can be attributed to atmospheric correction errors (Stations 1, 2, 82, 83, 84). At mid-shelf (Stations 7 to 9), the SeaWiFS-derived chlorophyll *a* concentrations matched measurements extremely well (Table 10). Images processed for this cruise are provided in Appendix A.

**Table 9. Chlorophyll *a* concentration measured fluorometrically, derived from radiance measurements using three methods, and as measured by the SeaWiFS sensor.**

| Station | Fluorometric | Morel | SPMR OC2 | MER OC2 | SeaWiFS |
|---|---|---|---|---|---|
| 1 | 9.84 | 30.96 | 9.30 | 38.90 | 21.384 |
| 2 | 9.23 | 25.08 | 10.92 | 5.41 | 34.815 |
| 3 | 4.23 | 14.39 | 7.65 | 7.14 | 3.354 |
| 4 | 1.22 | 4.00 | 2.24 | 1.73 | 5.509 |
| 5 | 1.04 | 2.74 | 2.89 | 1.77 | N/A |
| 6 | 0.54 | 1.66 | 1.01 | 0.75 | 1.270 |
| 7 | 0.37 | N/A | N/A | N/A | 0.369 |
| 8 | 0.57 | N/A | N/A | N/A | 0.542 |
| 9 | 0.38 | N/A | N/A | N/A | 0.396 |
| 15 | 0.13 | 0.06 | 0.15 | 0.12 | N/A |
| 16 | 0.06 | 0.03 | 0.11 | 0.09 | 0.064 |
| 14a* | 0.34 | N/A | N/A | N/A | 0.906 |
| 11 | 0.16 | 0.17 | 0.28 | 0.21 | N/A |
| 37 | 0.49 | 0.43 | 0.44 | 0.34 | N/A |
| 38 | 0.48 | 0.84 | 0.72 | 0.53 | N/A |
| 39 | 0.56 | 0.87 | 0.79 | 0.51 | N/A |
| 40 | 0.56 | N/A | N/A | 0.63 | N/A |
| 41 | 0.50 | 0.81 | 0.84 | 0.52 | N/A |
| 81 | 1.56 | 7.80 | 3.28 | 2.70 | 2.797 |
| 82 | 3.52 | 8.01 | 4.84 | 3.57 | 44.240 |
| 83 | 0.62 | 3.56 | 1.53 | 1.19 | 3.063 |
| 84 | 1.88 | 7.05 | 2.86 | 2.29 | 6.065 |

* SeaWiFS overpass 15 hours after the station was sampled.

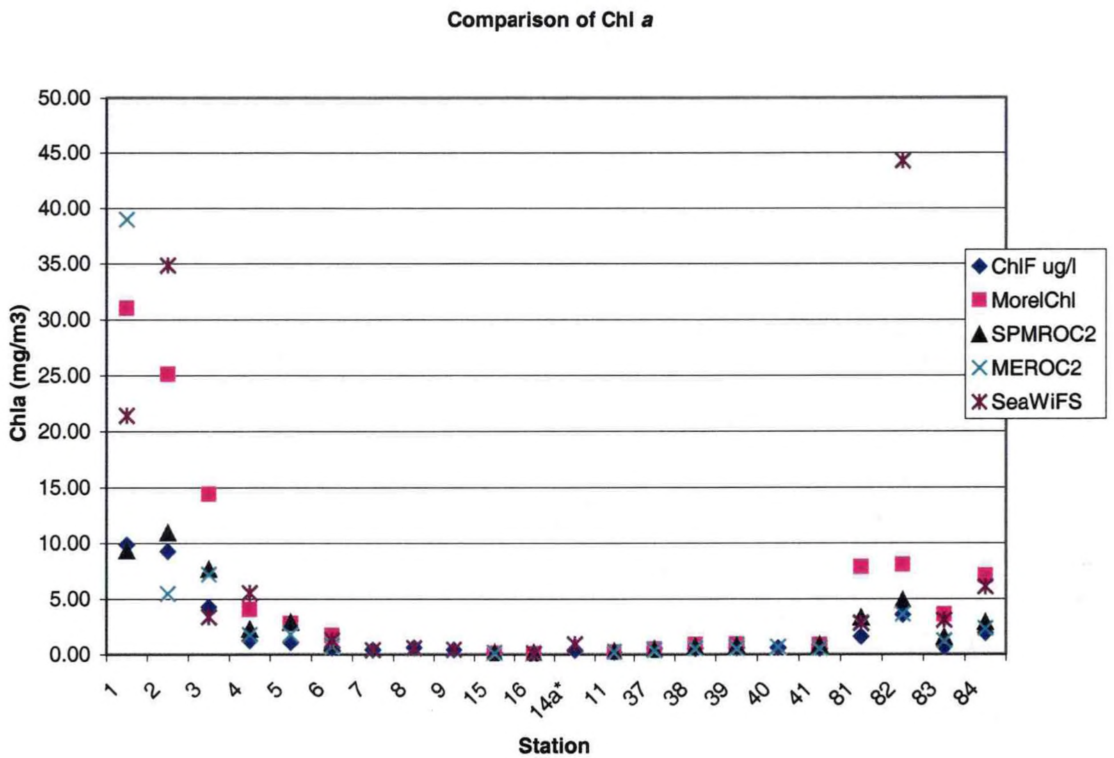


**Figure 7. Comparison of chlorophyll *a* values computed using different instruments or techniques.**

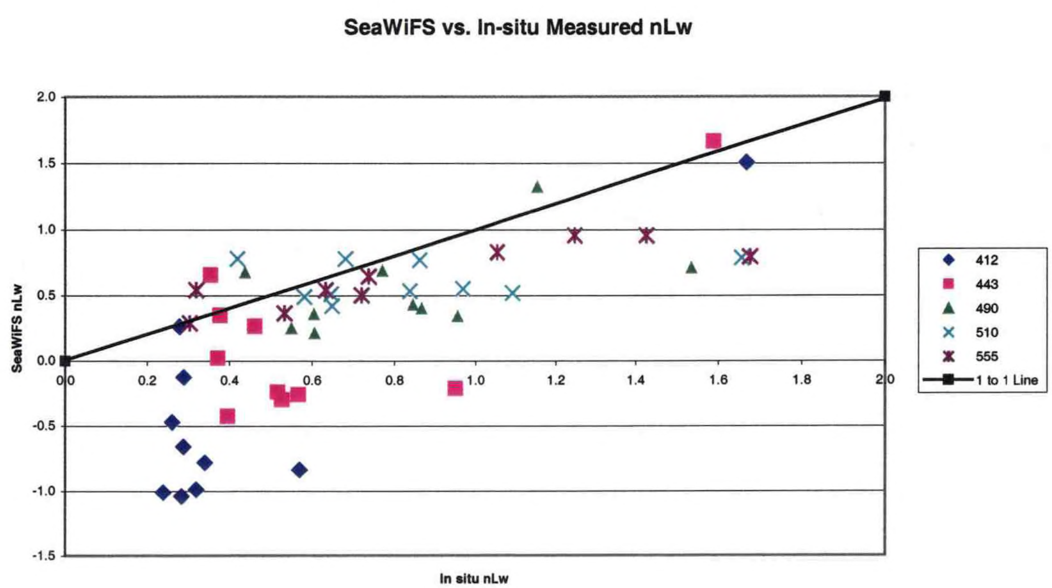


**Figure 8. Comparison of SeaWiFS-derived and measured normalized water-leaving radiance ($nL_w$).**

**Table 10. Evaluation of OC2 chlorophyll *a* concentration (mg $m^{-3}$) algorithm.**

| Station | $R_{rs}(490)$ | $R_{rs}(555)$ | X (Eq. 3) | Expo (Eq. 3) | OC2Chl (Eq. 2) | Measured Chl | OC2Chla/ MeasChl |
|---|---|---|---|---|---|---|---|
| 01 | 0.0045 | 0.0067 | -0.1768 | 0.9705 | 9.30 | 9.84 | 0.95 |
| 02 | 0.0049 | 0.0077 | -0.1931 | 1.0400 | 10.92 | 9.23 | 1.18 |
| 03 | 0.0040 | 0.0057 | -0.1561 | 0.8857 | 7.65 | 4.23 | 1.81 |
| 04 | 0.0028 | 0.0029 | -0.0059 | 0.3588 | 2.24 | 1.22 | 1.84 |
| 05 | 0.0023 | 0.0025 | -0.0403 | 0.4667 | 2.89 | 1.04 | 2.78 |
| 06 | 0.0023 | 0.0017 | 0.1191 | 0.0200 | 1.01 | 0.54 | 1.87 |
| 15 | 0.0052 | 0.0016 | 0.5043 | -0.7193 | 0.15 | 0.13 | 1.16 |
| 16 | 0.0060 | 0.0016 | 0.5616 | -0.8194 | 0.11 | 0.06 | 1.86 |
| 11 | 0.0044 | 0.0018 | 0.3767 | -0.4997 | 0.28 | 0.16 | 1.73 |
| 37 | 0.0034 | 0.0018 | 0.2789 | -0.3215 | 0.44 | 0.49 | 0.89 |
| 38 | 0.0025 | 0.0016 | 0.1798 | -0.1197 | 0.72 | 0.48 | 1.50 |
| 39 | 0.0026 | 0.0018 | 0.1626 | -0.0815 | 0.79 | 0.56 | 1.41 |
| 41 | 0.0028 | 0.0020 | 0.1522 | -0.0577 | 0.84 | 0.50 | 1.67 |
| 81 | 0.0079 | 0.0090 | -0.0570 | 0.5217 | 3.28 | 1.56 | 2.11 |
| 82 | 0.0031 | 0.0040 | -0.1047 | 0.6882 | 4.84 | 3.52 | 1.37 |
| 83 | 0.0044 | 0.0039 | 0.0503 | 0.1969 | 1.53 | 0.62 | 2.47 |
| 84 | 0.0031 | 0.0034 | -0.0392 | 0.4631 | 2.86 | 1.88 | 1.52 |

## V. Summary

A total of 30 stations were occupied between October 8 and 12, 1999 to provide calibration and evaluation measurements for the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). Two instruments, an Satlantic, Inc. SPMR system and a Biospherical Instruments, Inc. MER system, provided in-situ measurements of spectral downwelling irradiance, and spectral upwelling radiance. Comparison of normalized water-leaving radiance from the two instruments indicated that this measurement is most variable in turbid waters and at higher wavelengths. The variability is due in part, to variation in the attenuation coefficient used to extrapolate below water measurements above the surface. When entered into the OC2 equation to calculate chlorophyll, these measurements estimated chlorophyll concentrations well in the most turbid waters (Stations 1, 2), but overestimated chlorophyll by up to a factor of two at the station with the clearest waters. An exception to this pattern is seen in the outflow into the mid-Atlantic bight from North Carolina that resulted from Hurricane Floyd. This feature can be seen in the imagery as a jet of high chlorophyll water hugging the western wall of the Gulf Stream. The chlorophyll concentration measured in this jet was threefold higher than that found in surrounding waters, SeaWiFS overestimated the concentration by another factor of three, presumably due to the high concentrations of sediment and dissolved colored organic material in this jet.

## VI. References

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## VII. Metadata

## Identification Information:

### Citation:

#### Citation Information:

Originator: Ajit Subramaniam, Earth Systems Science Interdisciplinary Center, University of Maryland, College Park, MD
Originator: Neil Blough, Department of Chemistry, University of Maryland, College Park, MD
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Originator: Christopher W. Brown, NOAA/NESDIS, Camp Springs, MD
Originator: Mary Culver, NOAA Coastal Services Center, Charleston, SC
Publication Date: 2000
Title: NOAA CSC/CRS Cruise OCT99MAB: Mid-Atlantic Bight Bio-optical Cruise
Geospatial Data Presentation Form: profile
Series Information:
Series Name: CSC Technical Report
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Publication Place: Charleston, South Carolina
Publisher: NOAA Coastal Services Center
Online Linkage: http://www.csc.noaa.gov/crs/cruises/oct99mab/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.

**Purpose:** The objective of this cruise was to obtain bio-optical data from diverse water types in the Mid-Atlantic Bight and Chesapeake Bay, extending from estuarine (bay) to coastal, and finally to open ocean regimes.

#### Time Period of Content:

Time Period Information:
Range of Dates/Times:
Beginning Date: 19991008
Ending Date: 19991012
Currentness Reference: Publication Date

### Status:

Progress: Complete
Maintenance and Update Frequency: Unknown

### Spatial Domain:

#### Bounding Coordinates:

West Bounding Coordinate: - 76.4084
East Bounding Coordinate: - 71.9964
North Bounding Coordinate: 39.3767
South Bounding Coordinate: 36.3982

**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
Theme Keyword: in-situ optical profiling
Theme Keyword: ocean color satellites
Theme Keyword: coastal ocean algorithm development
Theme Keyword: river plumes
Theme Keyword: downwelling irradiance
Theme Keyword: upwelling radiance
Theme Keyword: temperature
Theme Keyword: chlorophyll
Theme Keyword: salinity
Theme Keyword: spectral attenuation
Theme Keyword: spectral absorption
Theme Keyword: beam attenuation
Theme Keyword: light scattering
Theme Keyword: fluorescence

**Place:**

Place Keyword Thesaurus: None
Place Keyword: Maryland
Place Keyword: Mid-Atlantic Bight
Place Keyword: Chesapeake Bay
Place Keyword: Delaware Bay
Place Keyword: Delaware
Place Keyword: Virginia
Place Keyword: United States

**Temporal:**

Temporal Keyword Thesaurus: None
Temporal Keyword: Autumn
Temporal Keyword: October, 1999

**Access Constraints:** None

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

**Point of Contact:**

**Contact Information:**

Contact Organization Primary:

Contact Organization: NOAA Coastal Services Center

Contact Address:

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

**Data Set Credit:** Master and crew of R/V *Cape Henlopen.* NOAA/Coastal Services Center. University of Maryland, Horn Point Laboratories.

## Data Quality Information:

**Attribute Accuracy:**

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

**Logical Consistency Report:** A computer equipped with a Socket Communications PCMCIA card using Trimble Navigation's Global Positioning System (GPS) was used to log time, latitude, longitude, speed, and course of vessel. The clocks on the various computers were synchronized to GPS time, and the time stamp on each measurement was used to merge the GPS location with the parameters measured. The MER data was processed using the Bermuda Bio-Optics Project (BBOP) processing software. A least common denominator (LCD) file was created from the binary data files, the cast card files, the calibration files, and cruise notes. The LCD file header contains the metadata for the cast and includes information on the parameters sampled, parameters derived, filters used, and the statistical results of the regression used to extrapolate light to the sub-surface. The pressure channel data was recalculated using an offset to adjust for the distance of the pressure sensor from the cosine collector. The tops and bottoms of the individual profiles were marked using an interactive Matlab® script and the corresponding record numbers were inserted into the LCD header section. Data

less than the dark threshold was replaced by $-9.9x10^{35}$. Then the data was quality-controlled using flags for data with tilt and roll angles greater than 10° (flag value greater than 0 in the "aq-1Tilt-1Roll" field), and records where the surface incident irradiance was not uniform (flag value greater than 0 in the "kq-1ed412" field). The temperature, transmissometer, and fluorometer data were despiked, in two passes, with a difference threshold. A moving average was calculated for these channels. The data were separated into upcast and downcast profiles and then binned to 0.5-m bins. Spectral attenuation coefficients were calculated for the optical channels over a five-point moving window. Subsurface downwelling irradiance and upwelling radiance were extrapolated to just below the surface using data from the top three meters. The statistics for calculation of subsurface irradiance and radiance are shown in Appendix C. The HydroScat-6 data were processed using IDL software. A calibrated data file was created using software provided by HOBI Labs, Inc. Data less than the dark threshold were replaced by $-9.9x10^{35}$. The data were despiked, in two passes, with a difference threshold. A moving average was calculated for these channels. The data were separated into upcast and downcast profiles and then binned to 0.5-m bins.
**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
    Methodology Keyword: spectral upwelling radiance
    Methodology Keyword: temperature measurement
    Methodology Keyword: bottle sampling
    Methodology Keyword: CTD profiles
    Methodology Keyword: water sampling
  **Methodology Description:** The MER-2048 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. Other casts included a Hydro-Optics, Biology, and Instrumentation Laboratories, Inc. (HOBI Labs) HydroScat-6 spectral backscattering sensor, a WET Labs, Inc. AC-9 spectral transmittance and absorption meter. Following the MER cast, deployments of the Satlantic SMSR (SeaWiFS Multichannel Surface Radiometer) and SPMR (SeaWiFS Profiling Multichannel Radiometer) occurred simultaneously. In-situ temperature, salinity, and density were also measured at some stations with a Conductivity-Temperature-Depth (CTD) instrument. On-deck use of the Microtops II Sun Photometer was also made at each station. The clocks on the various computers were synchronized to GPS time and the time stamp on each measurement was used to merge the GPS location with the parameters measured. Surface water samples for chlorophyll biomass were obtained 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% acetone (10% water), was measured using a spectrophotometer and used to calibrate the Turner Designs Model 10-AU fluorometer. Aboard ship, a measured volume of seawater was filtered onto a Whatman GF/F filter and stored in liquid nitrogen until lab analysis. In the lab, the filter was ground and extracted in 10 ml of 90% acetone and left in a freezer (-20 C) overnight. After centrifugation, the chlorophyll concentration in the supernatant was measured using the fluorometer.

**Methodology Citation:**

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

**Process Step:**

**Process Description:** Calibration of the Biospherical MER-2041 MER Spectroradiometer.

**Process Date:** 19980223

**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 MER-2048 MER Spectroradiometer.

**Process Date:** 19980223

**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 HydroScat-6 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 AC-9 Spectral Absorption and Attenuation Meter.
**Process Date:** 19960821
**Process Contact:**
Contact Information:
Contact Organization Primary:
Contact Organization: WET Labs, Inc.
Contact Address:
Address Type: mailing and physical address
Address: 620 Applegate Street
City: Philomath
State or Province: Oregon
Postal Code: 97370
Country: USA
Contact Voice Telephone: (541) 929-5650

**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@csc.noaa.gov
Hours of Service: 8AM-5PM, M-F
**Resource Description:** OCT99MAB Cruise Report CSC 20016-PUB
**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/oct99mab/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@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. SeaWiFS chlorophyll *a* images during Oct99MAB cruise.

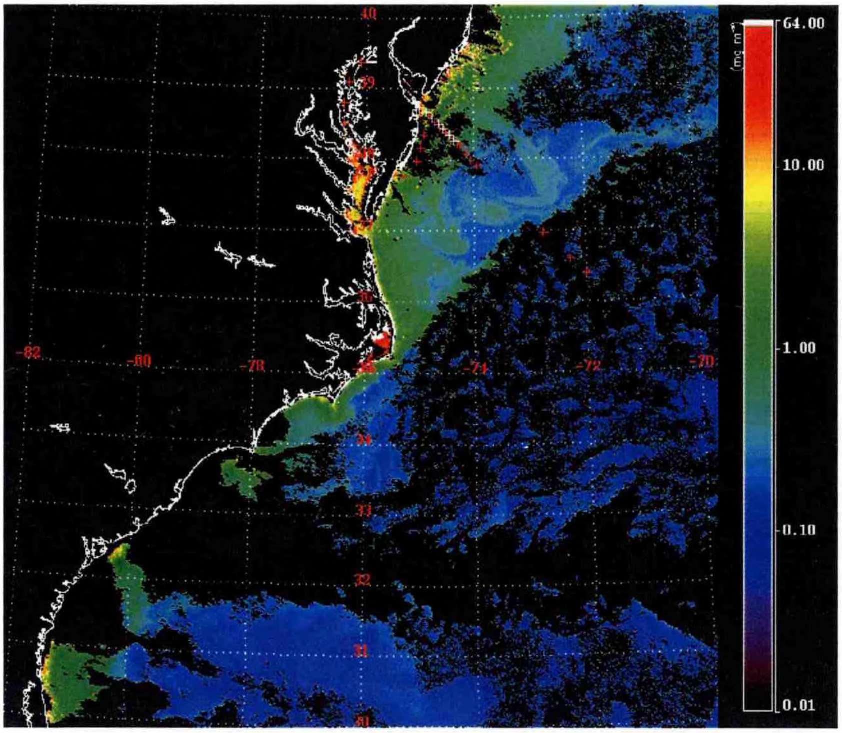



**Figure A-1. 8 October 1999. The station corresponding to the day of the image is shown in white. The other stations are shown in red.**

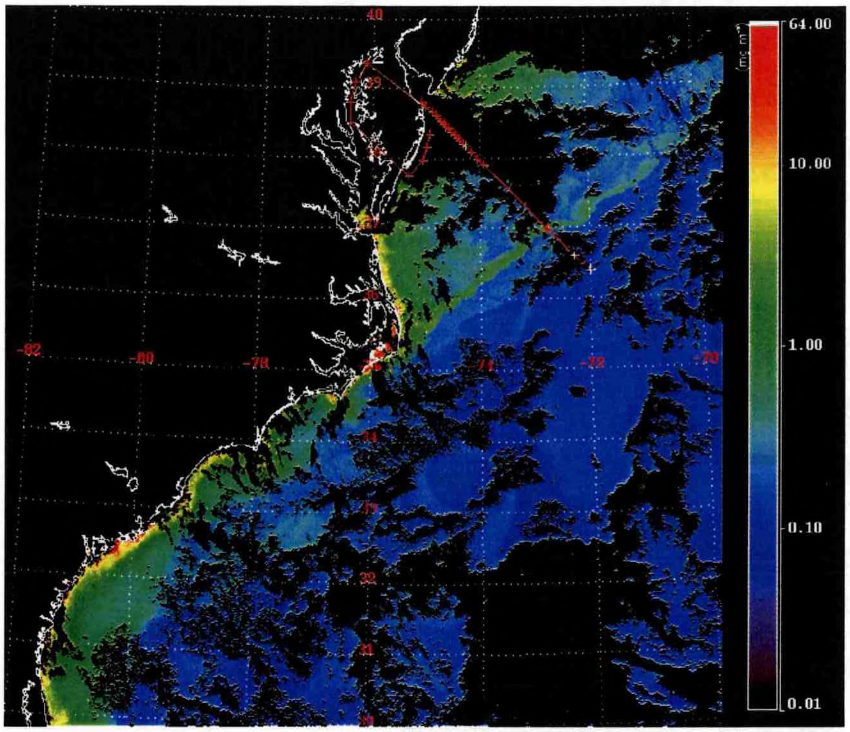



**Figure A-2. 9 October 1999. The freshwater plume is seen as a jet of high chlorophyll extending from the Outer Banks.**

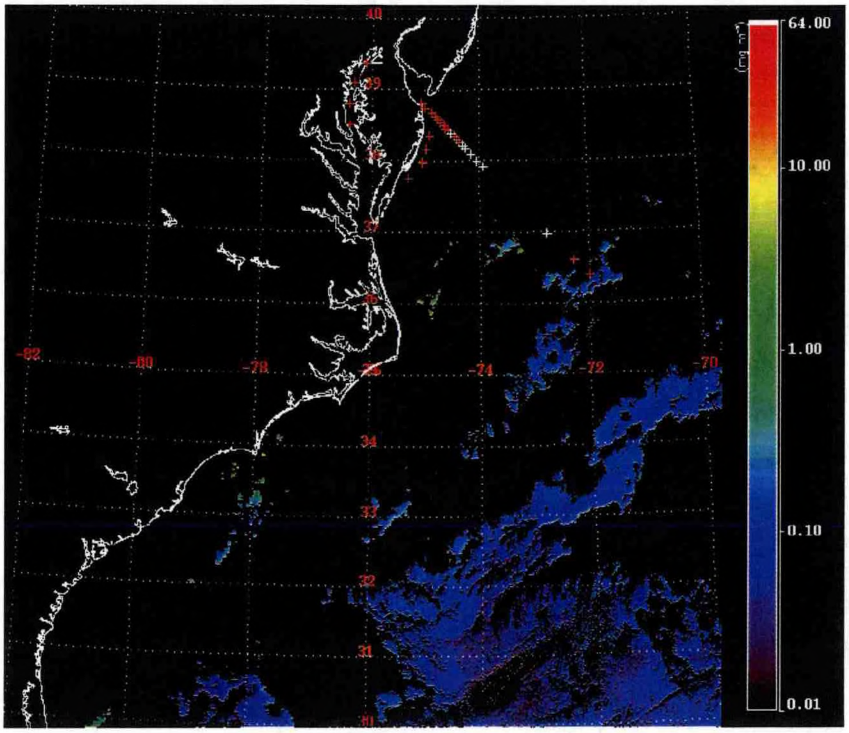



**Figure A-3. 10 October 1999.**

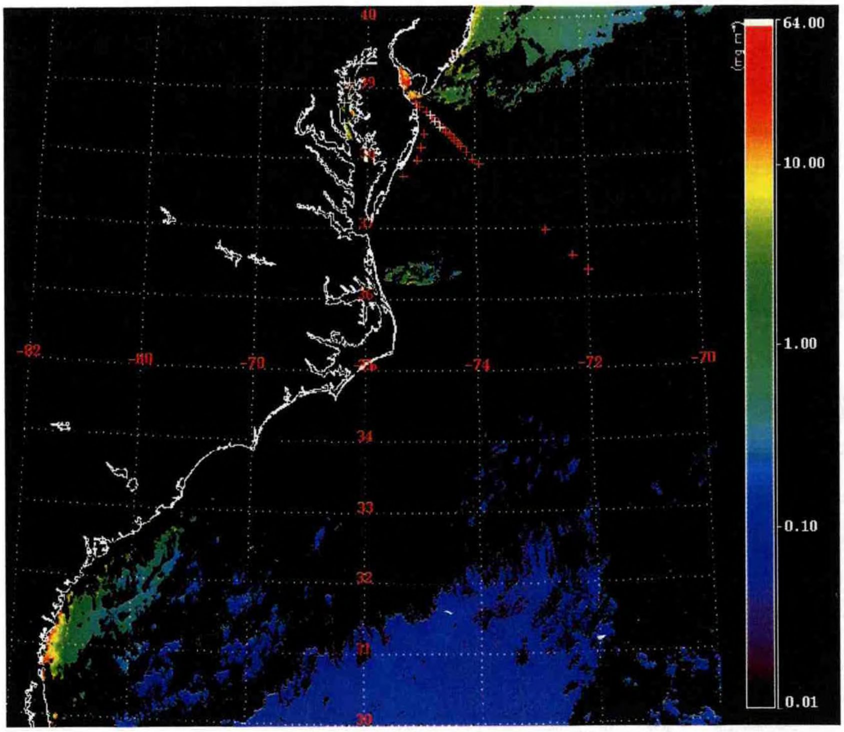



**Figure A-4. 11 October 1999.**

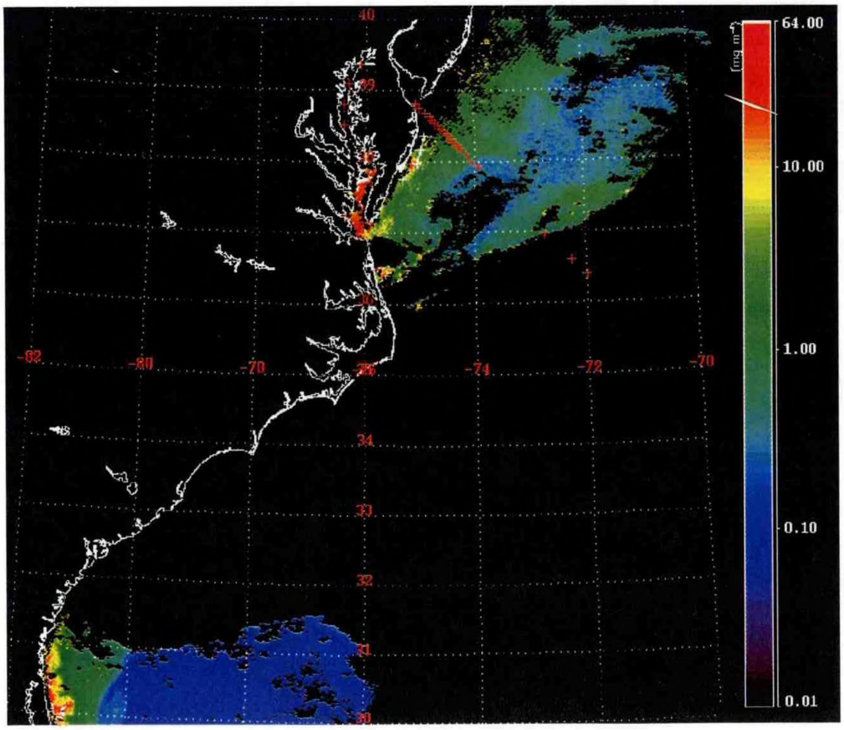
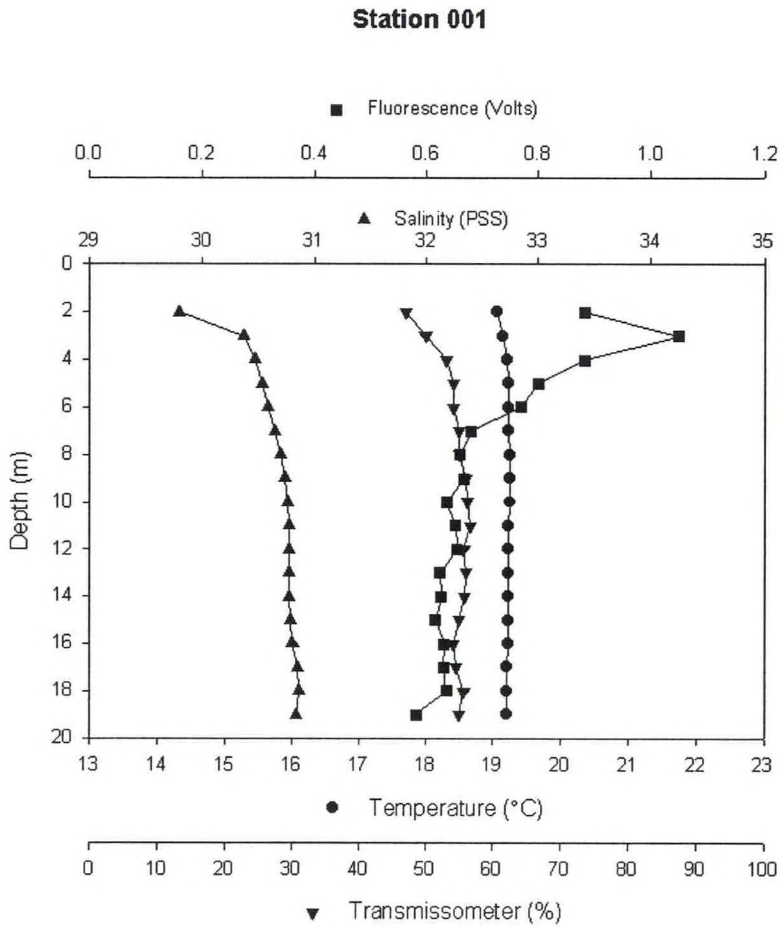
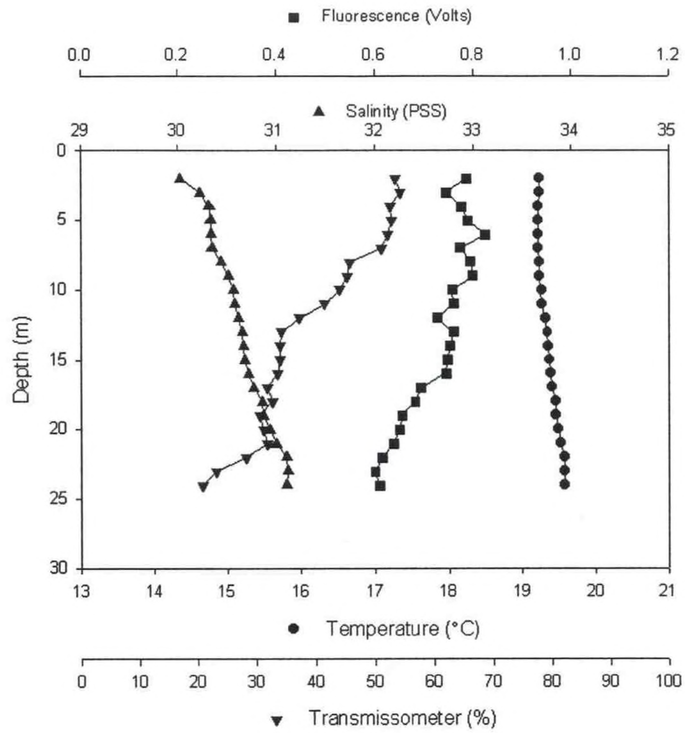



**Figure A-5. 12 October 1999.**

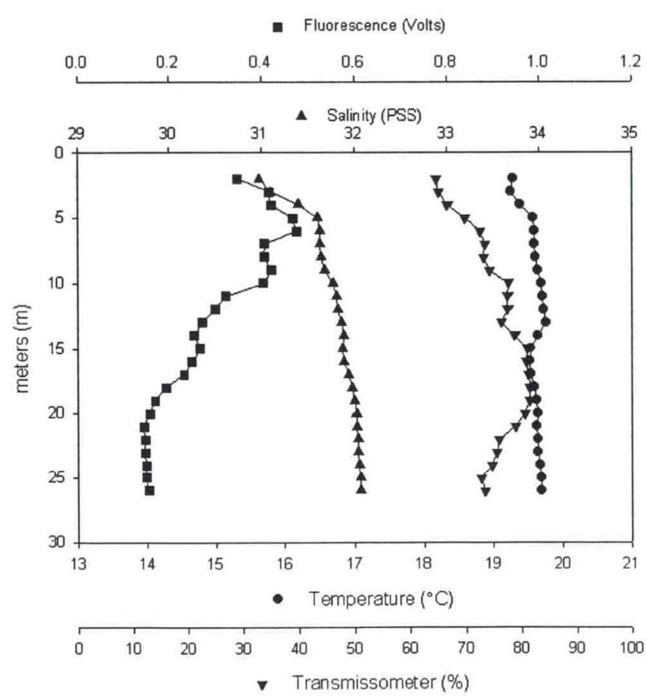
## IX. Appendix B. Temperature, Salinity, Beam Attenuation, and Fluorescence Profiles



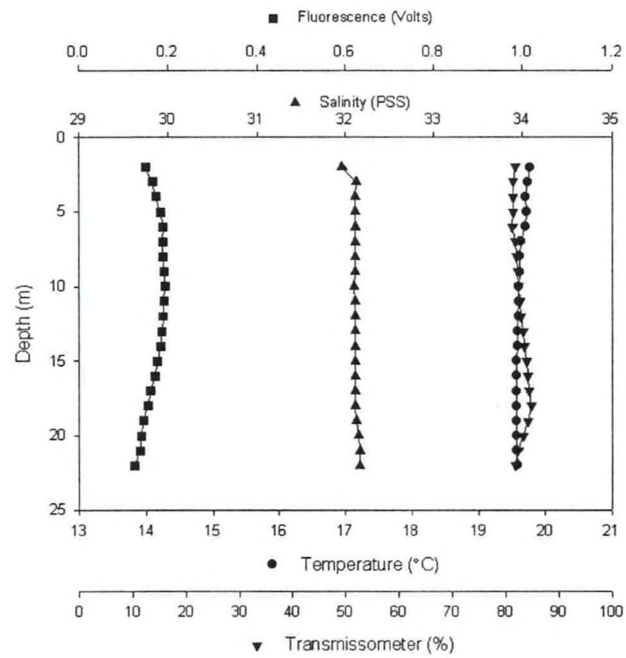
**Station 002**



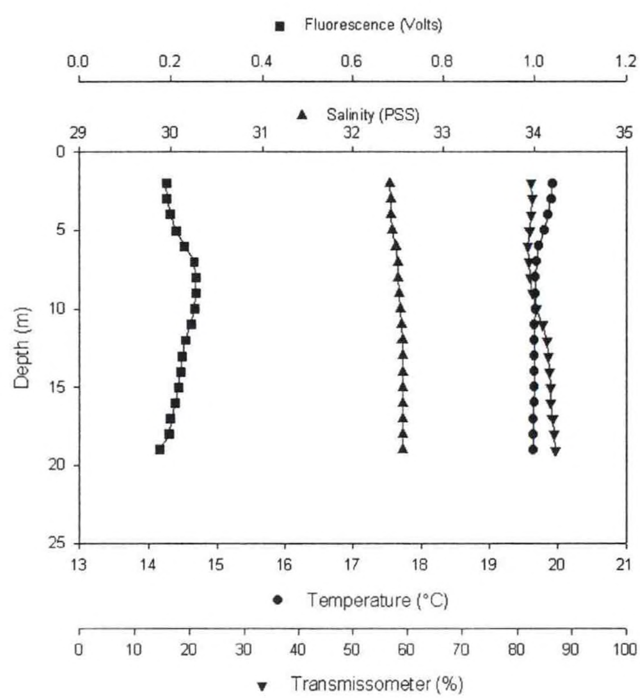

**Station 003**



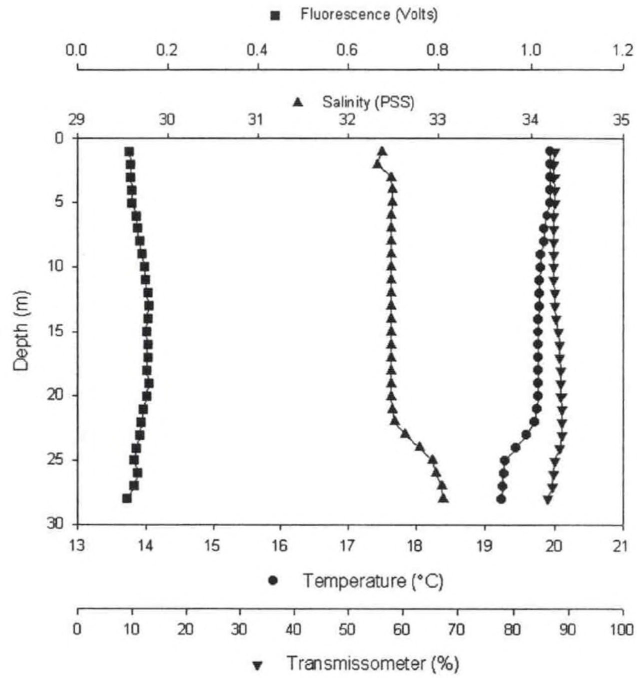
**Station 004**



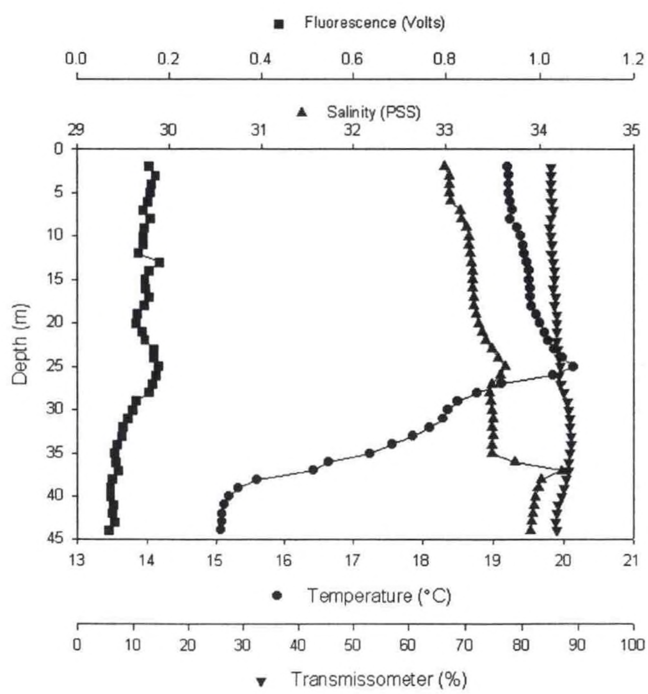

**Station 005**



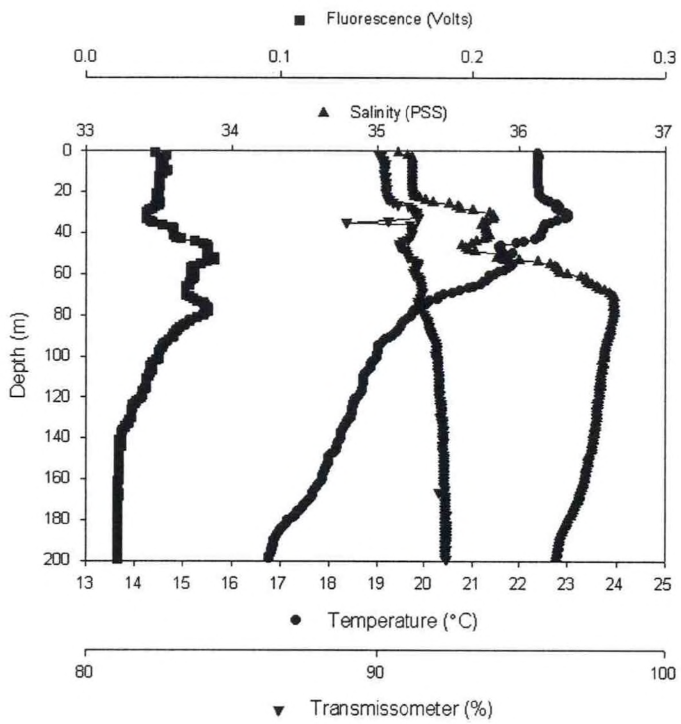
**Station 006**



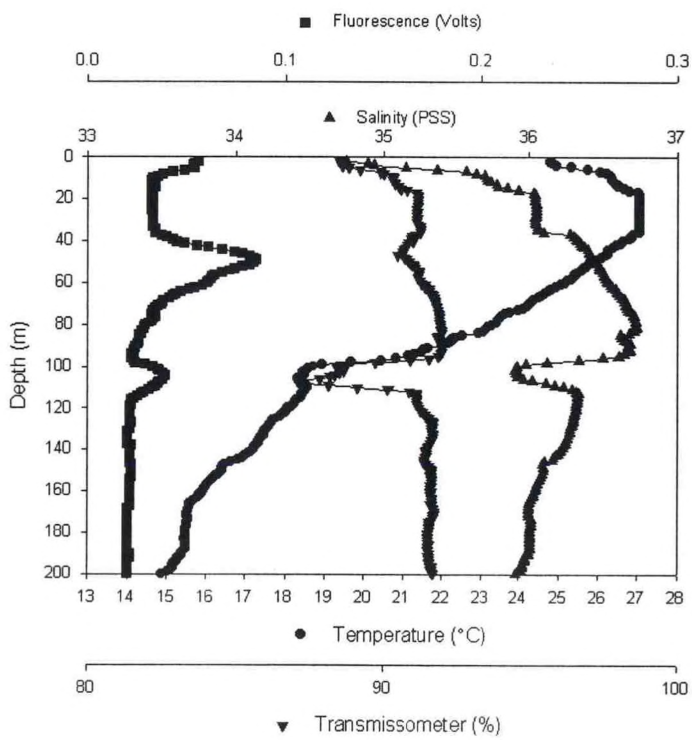

**Station 008**



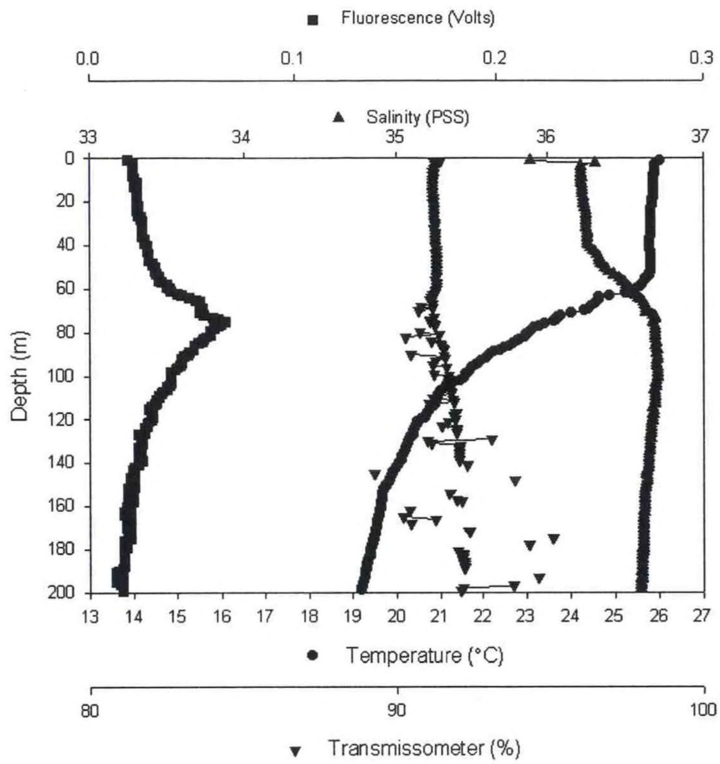
## Station 011



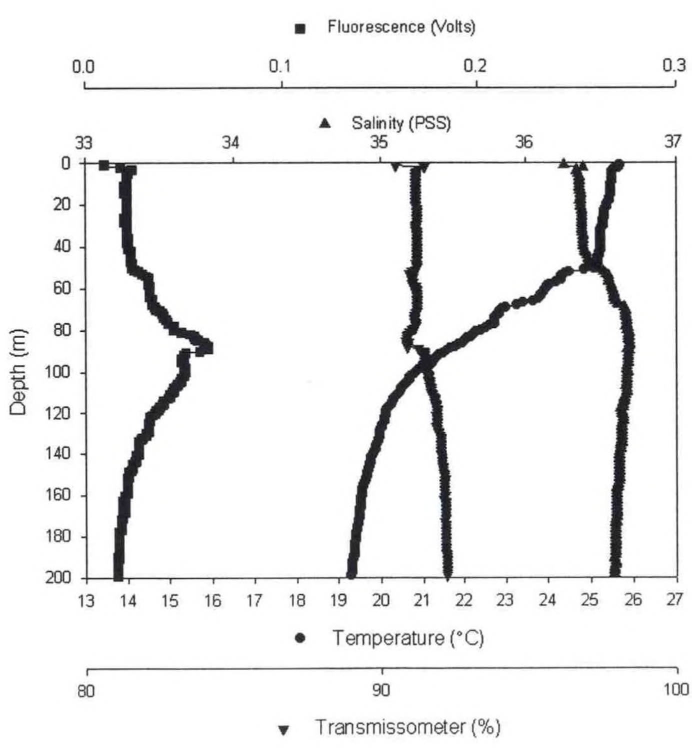

## Station 014a



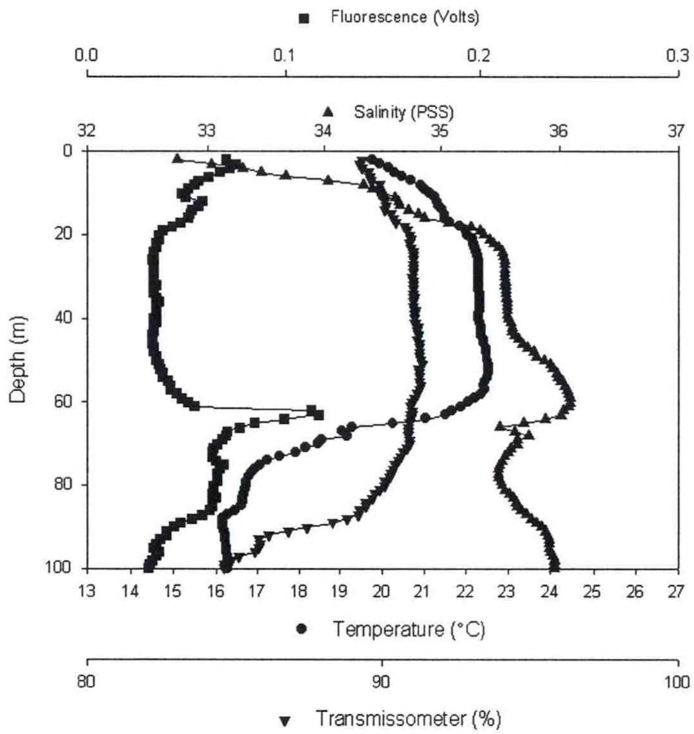
**Station 015**



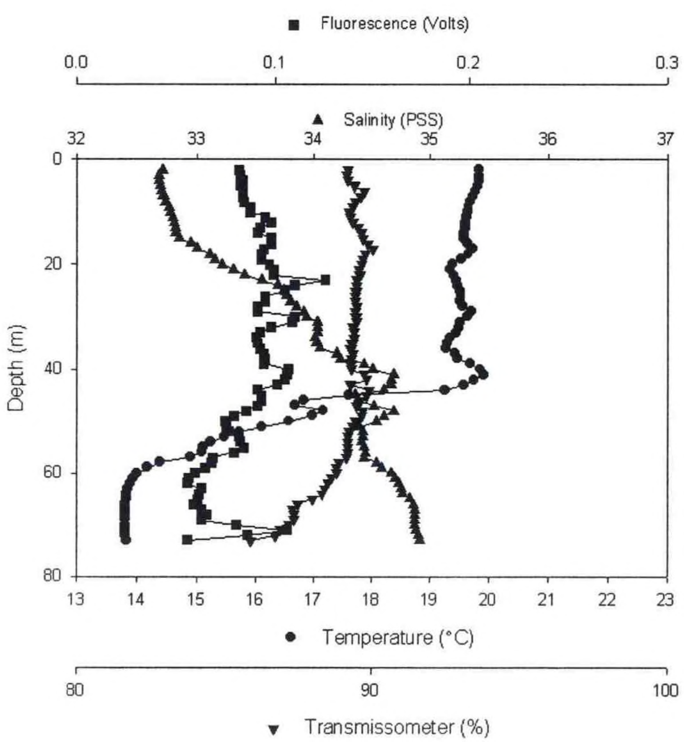

**Station 016**



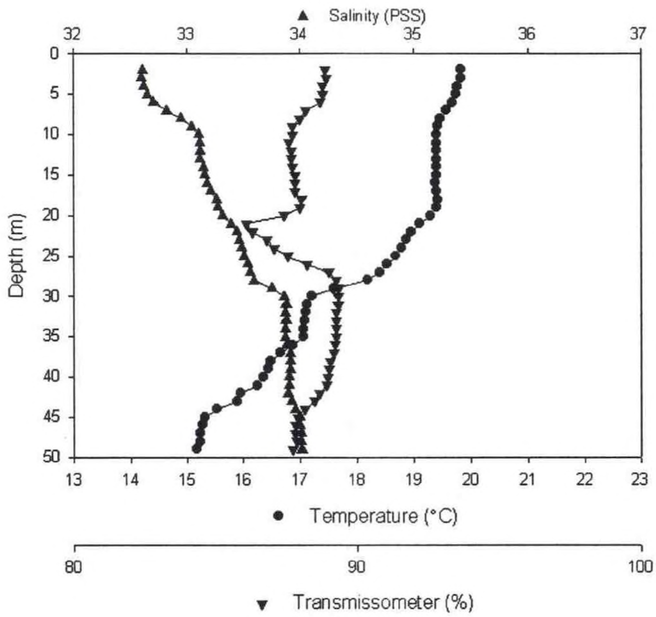
**Station 037**



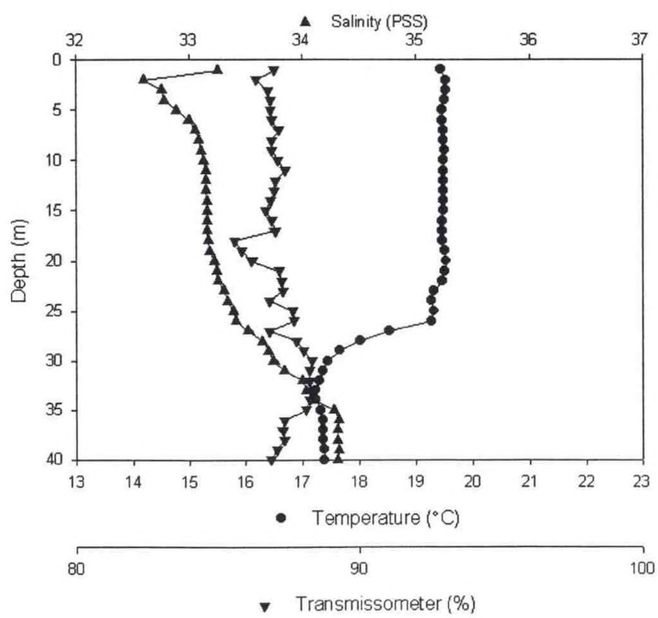

**Station 038**



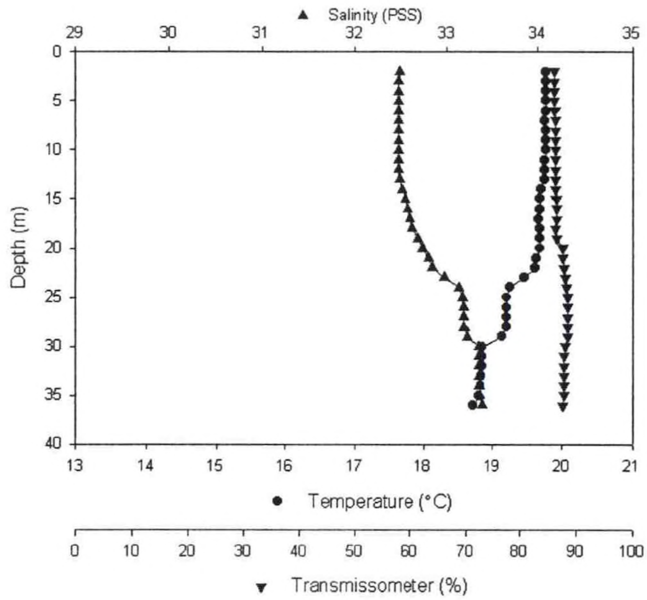
**Station 040**



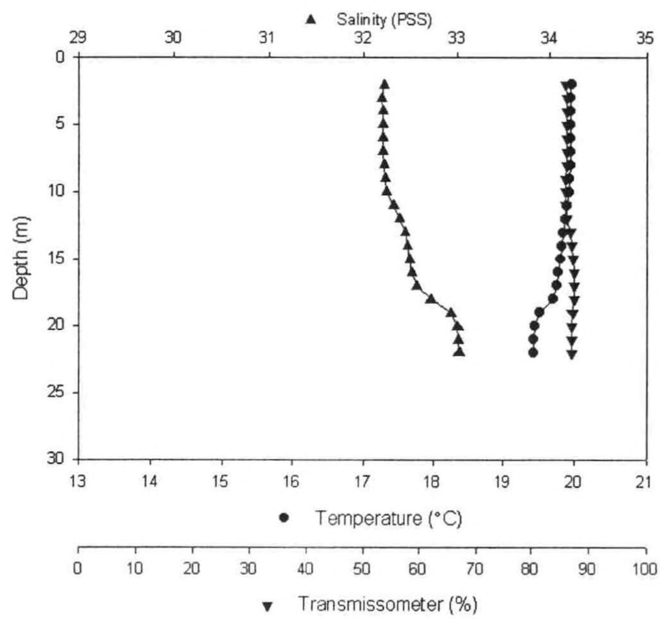

**Station 041**



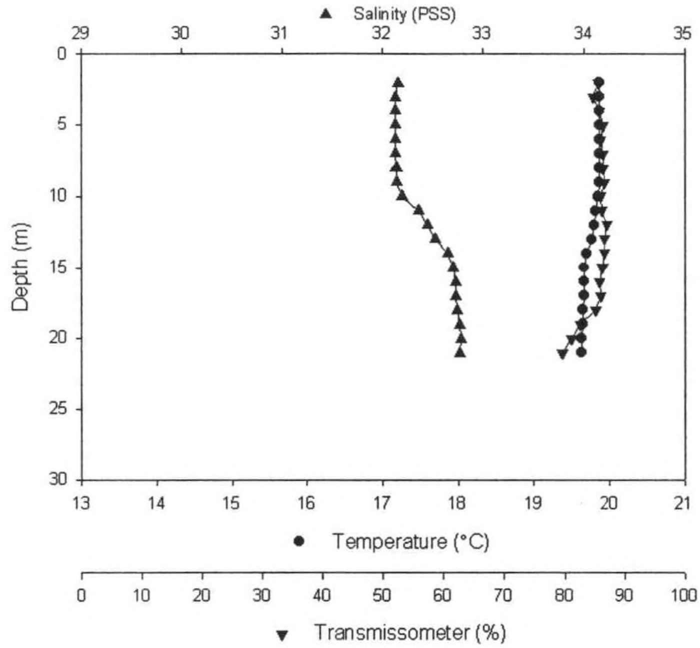
**Station 042**



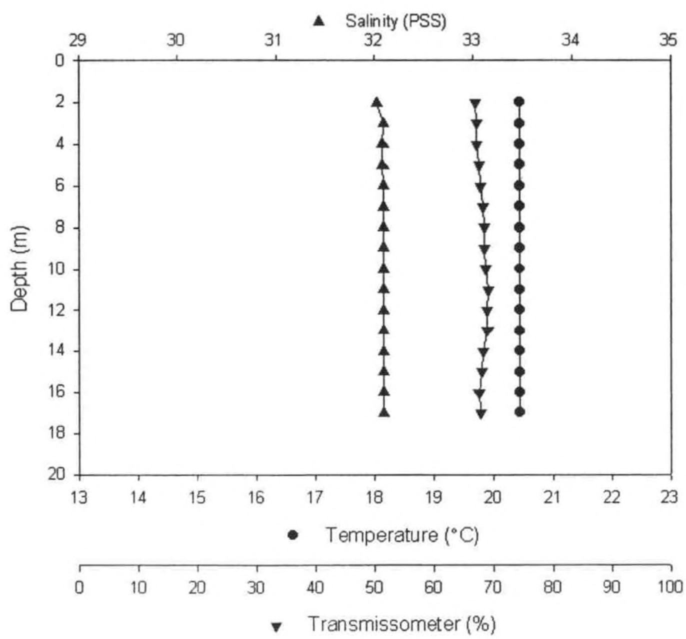

**Station 043**



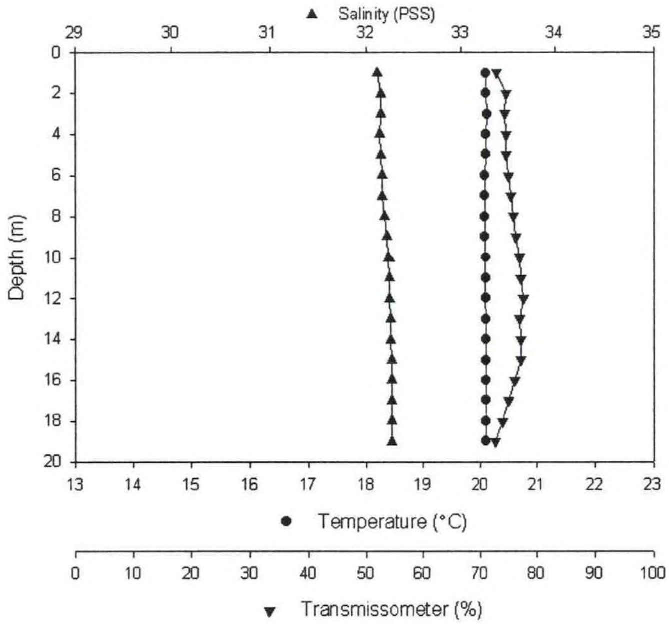
**Station 044**



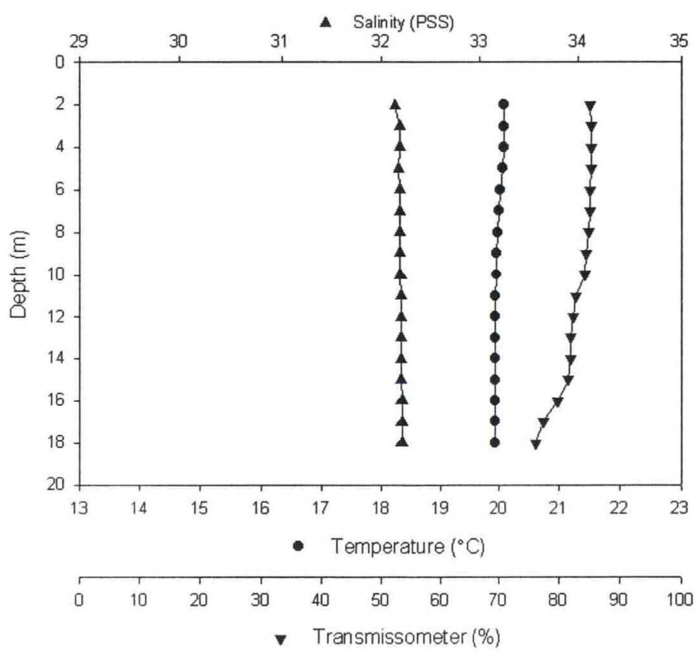

**Station 081**



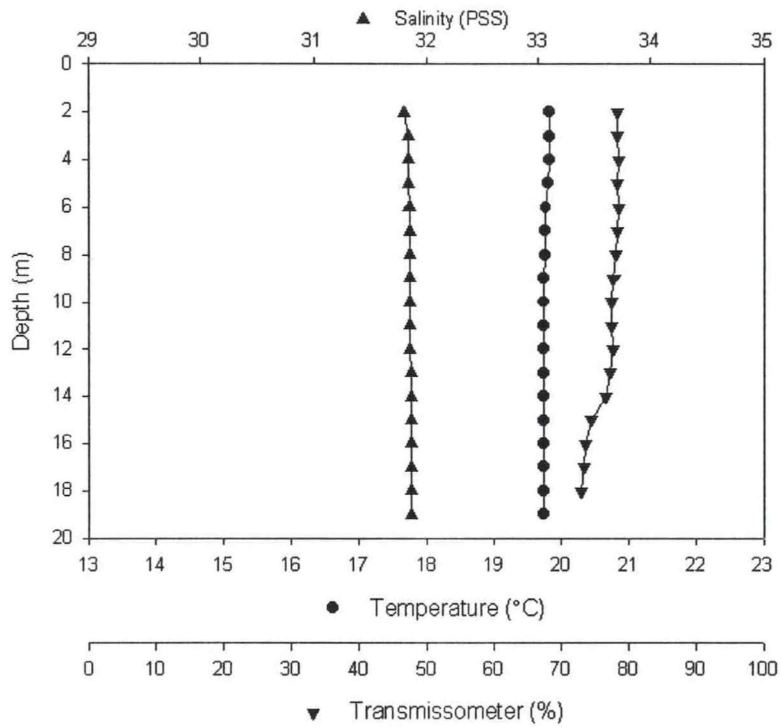
**Station 082**




**Station 083**

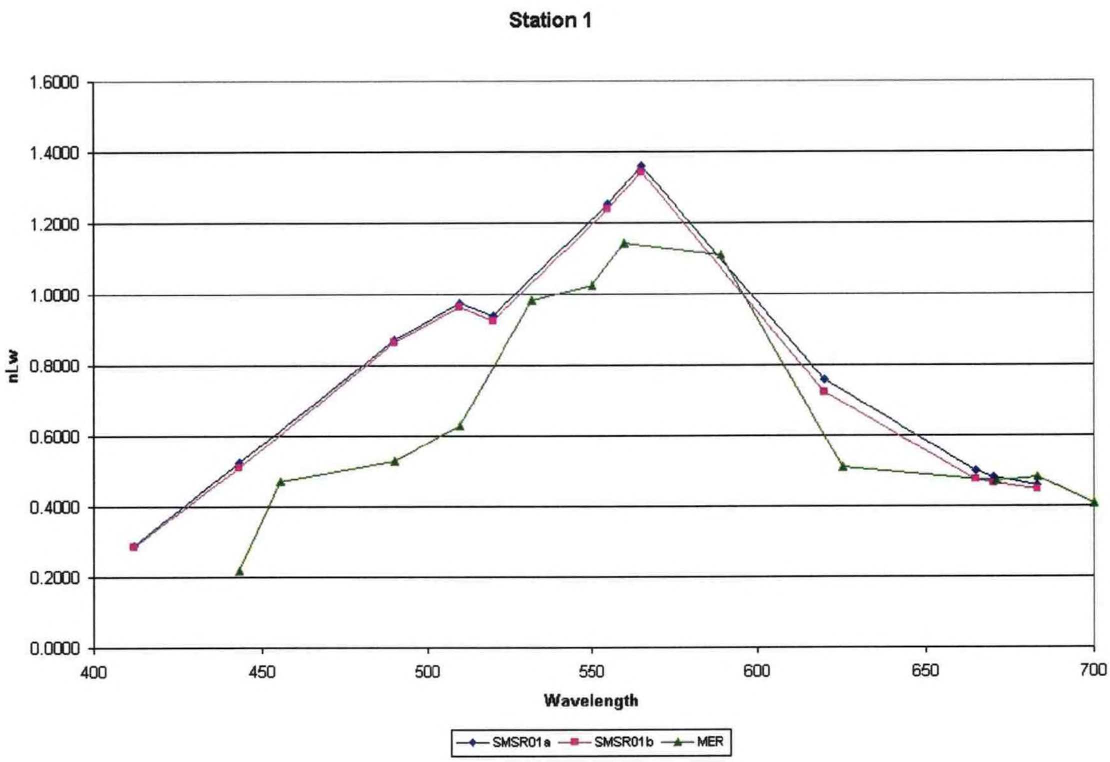


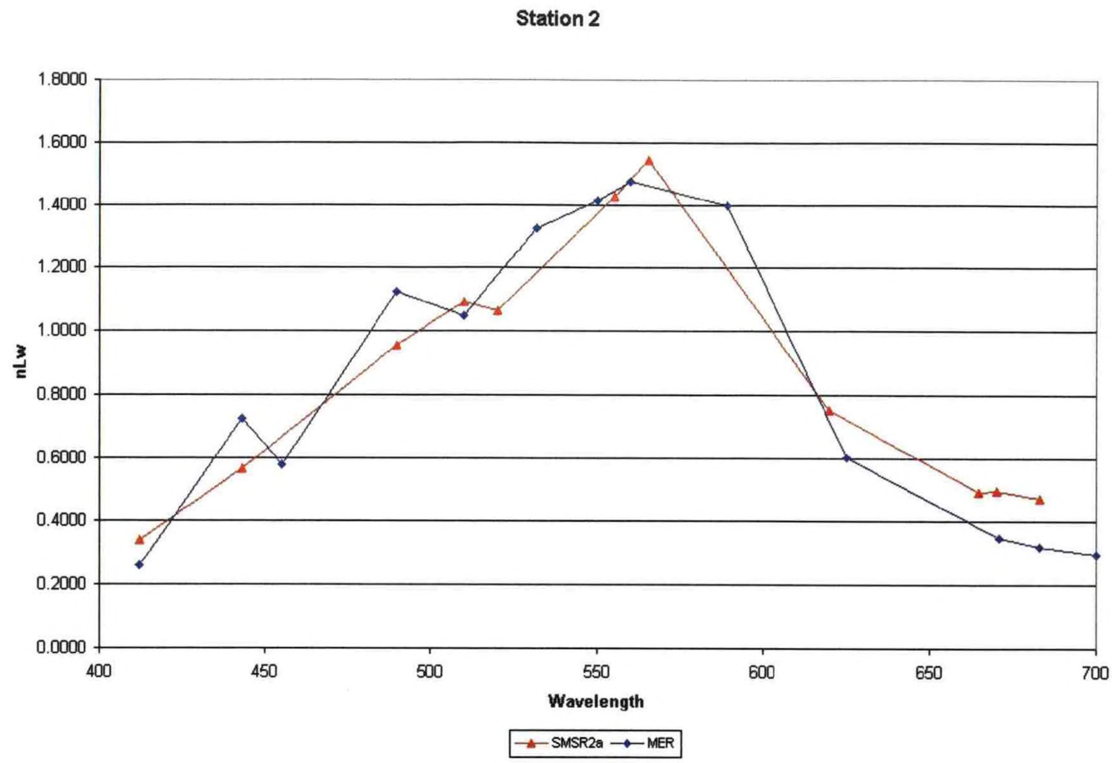
**Station 084**

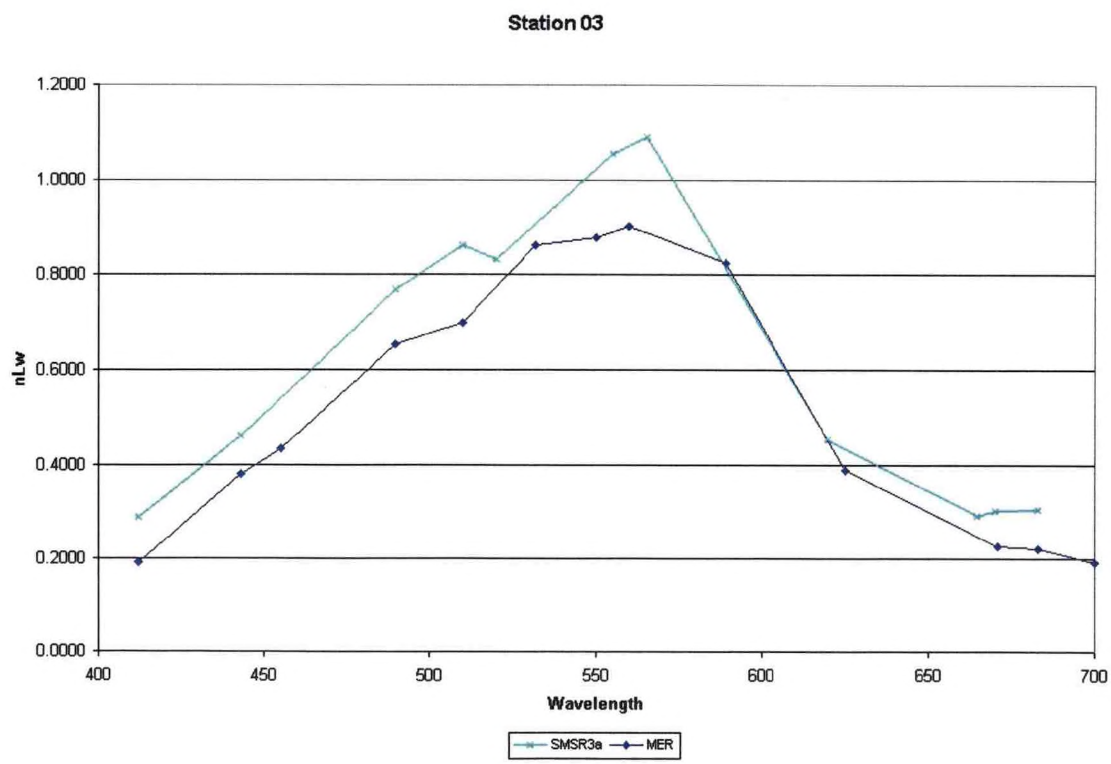


Salinity (PSS)
29
30
31
32
33
34
35
0
2
4
6
8
10
12
14
16
18
20
Depth (m)
13
14
15
16
17
18
19
20
21
22
23
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
100
Transmissometer (%)

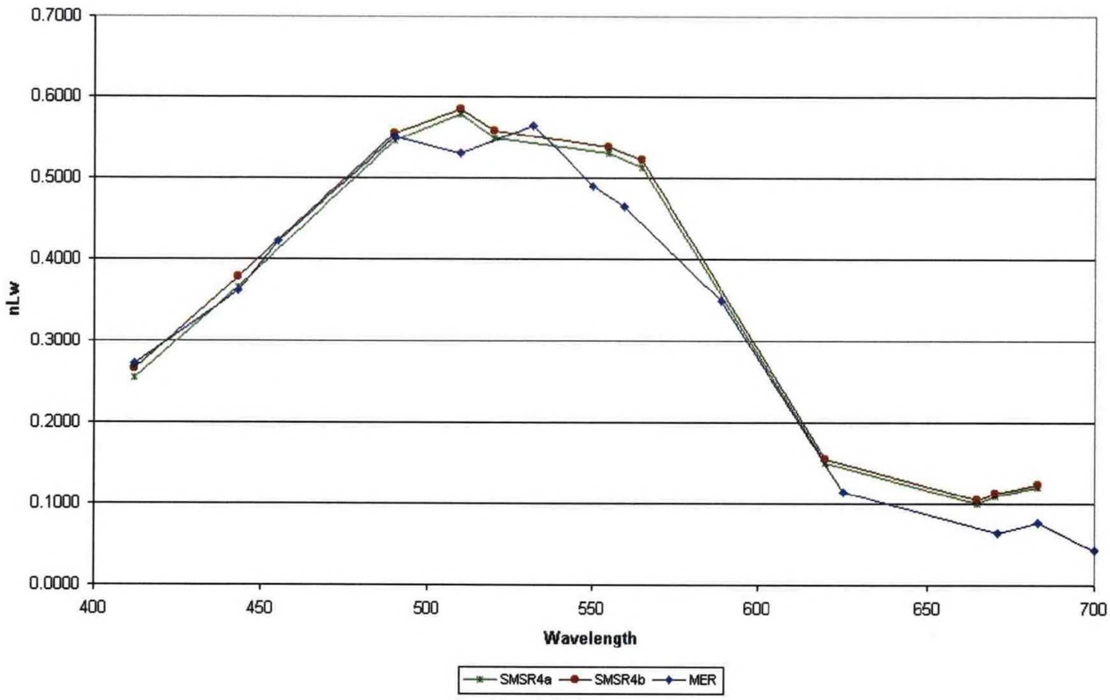
# X. Appendix C. Normalized Water-Leaving Radiance Spectra



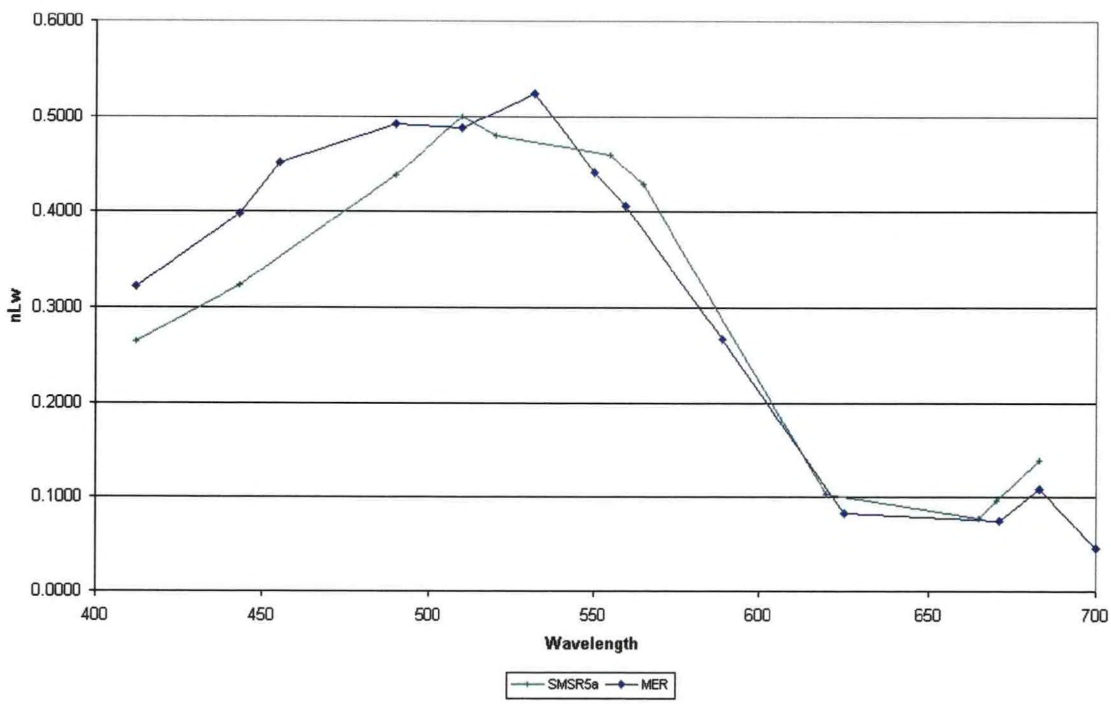

Station 2
1.8000
1.6000
1.4000
1.2000
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
nLw
400
450
500
550
600
650
700
Wavelength
SMSR2a
MER


Station 03
1.2000
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
nLw
400
450
500
550
600
650
700
Wavelength
SMSR3a
MER

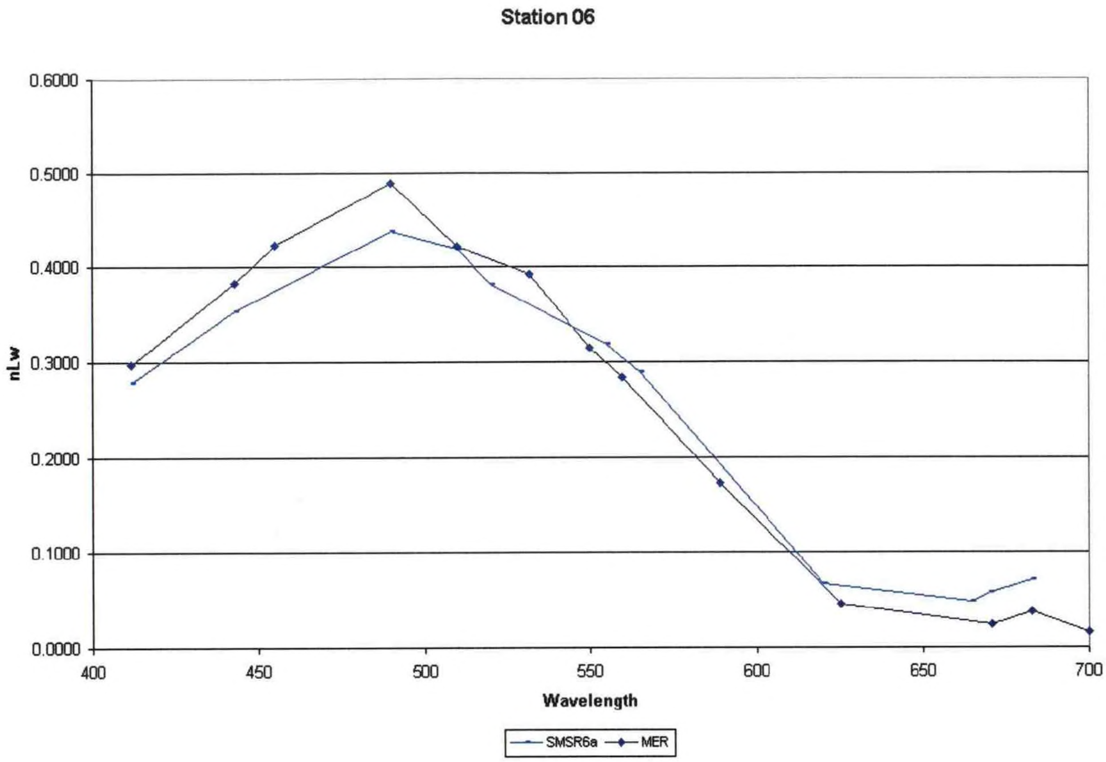
Station 04



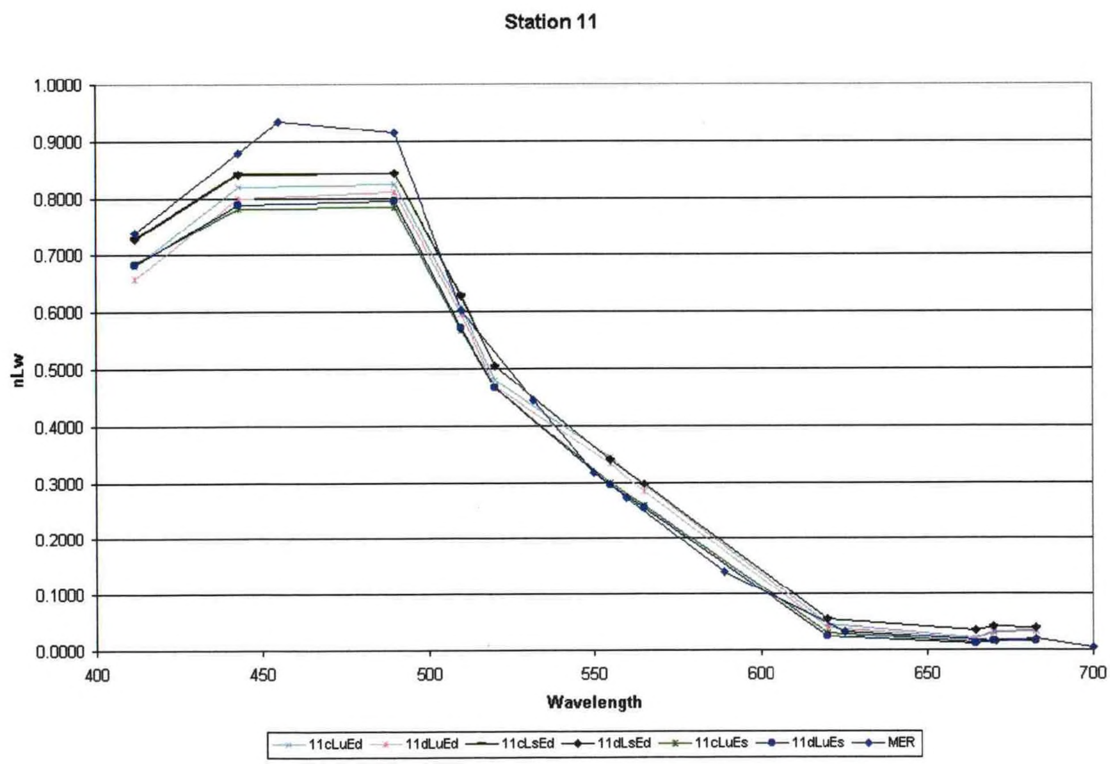

Station 5



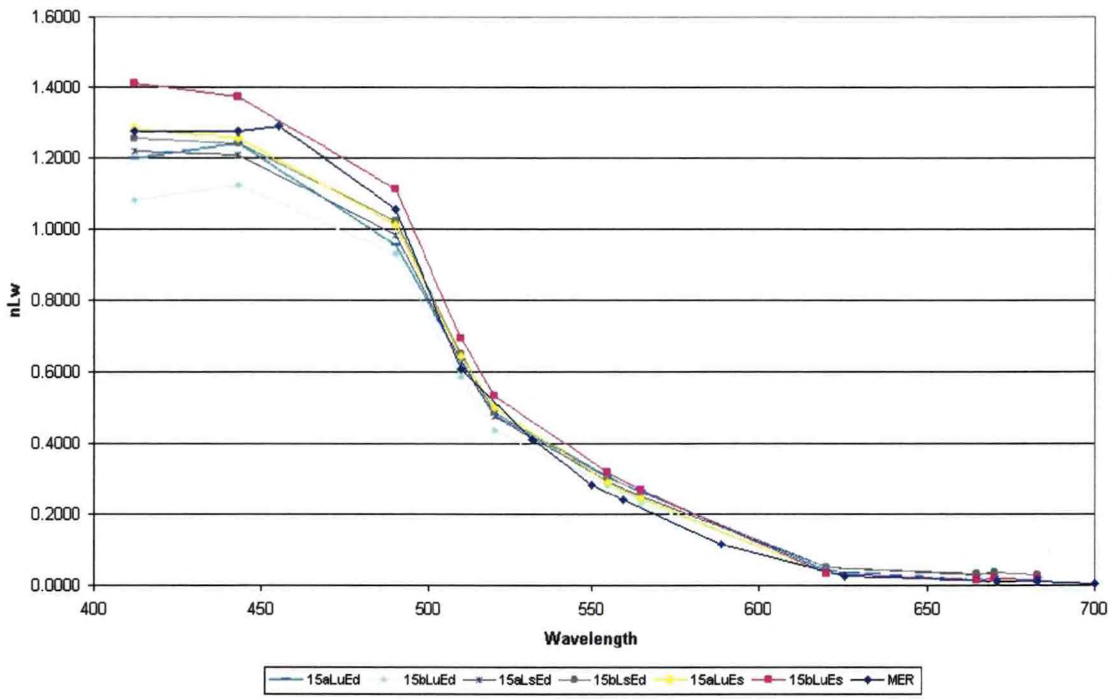
## Station 06



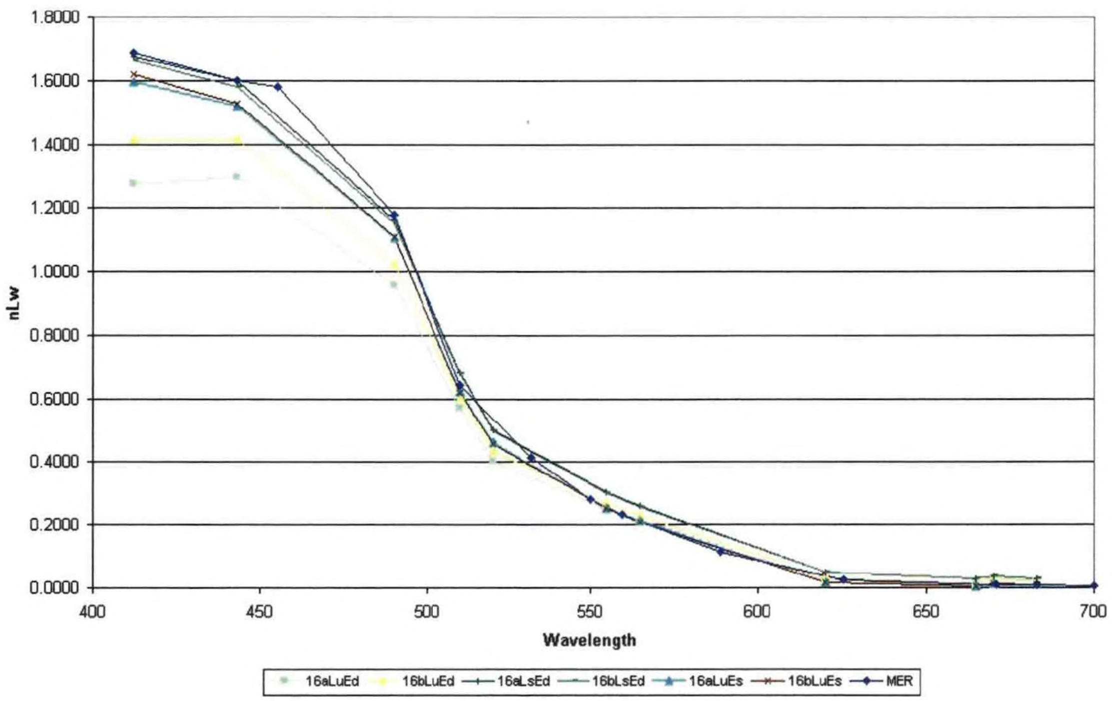

## Station 11



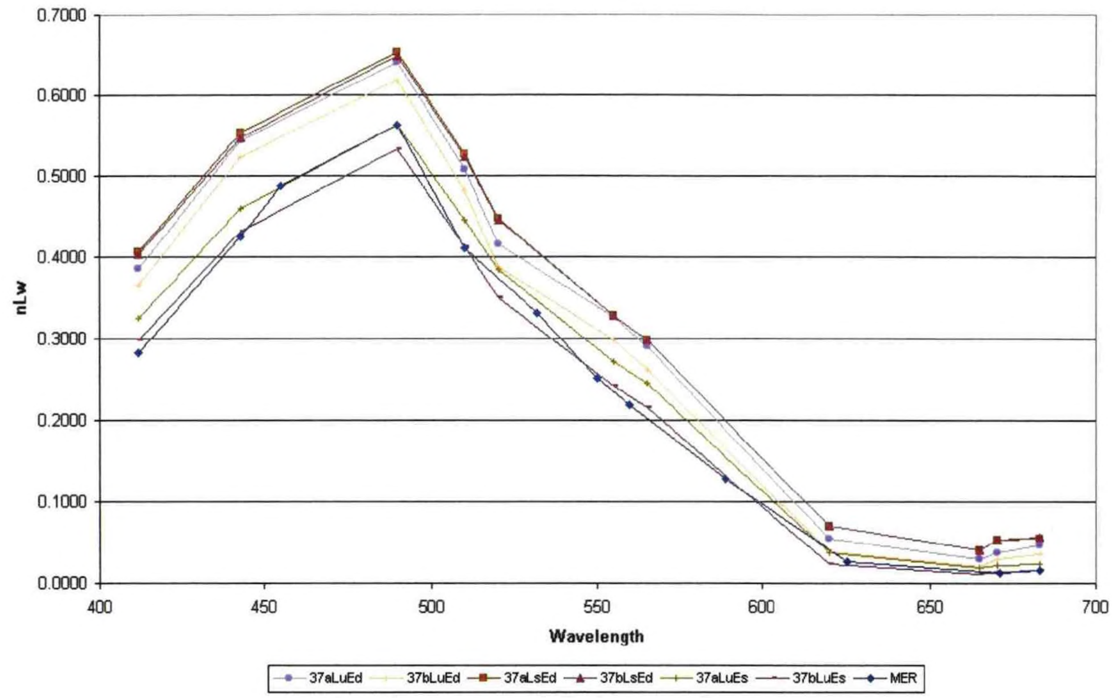
Station 15



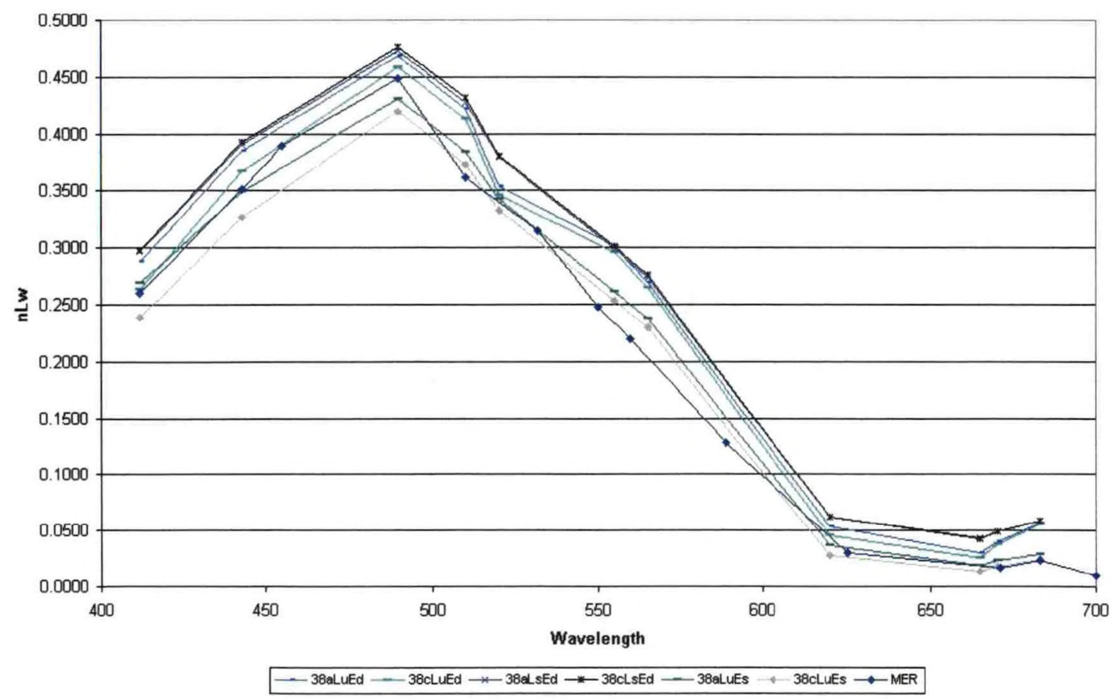

Station 16

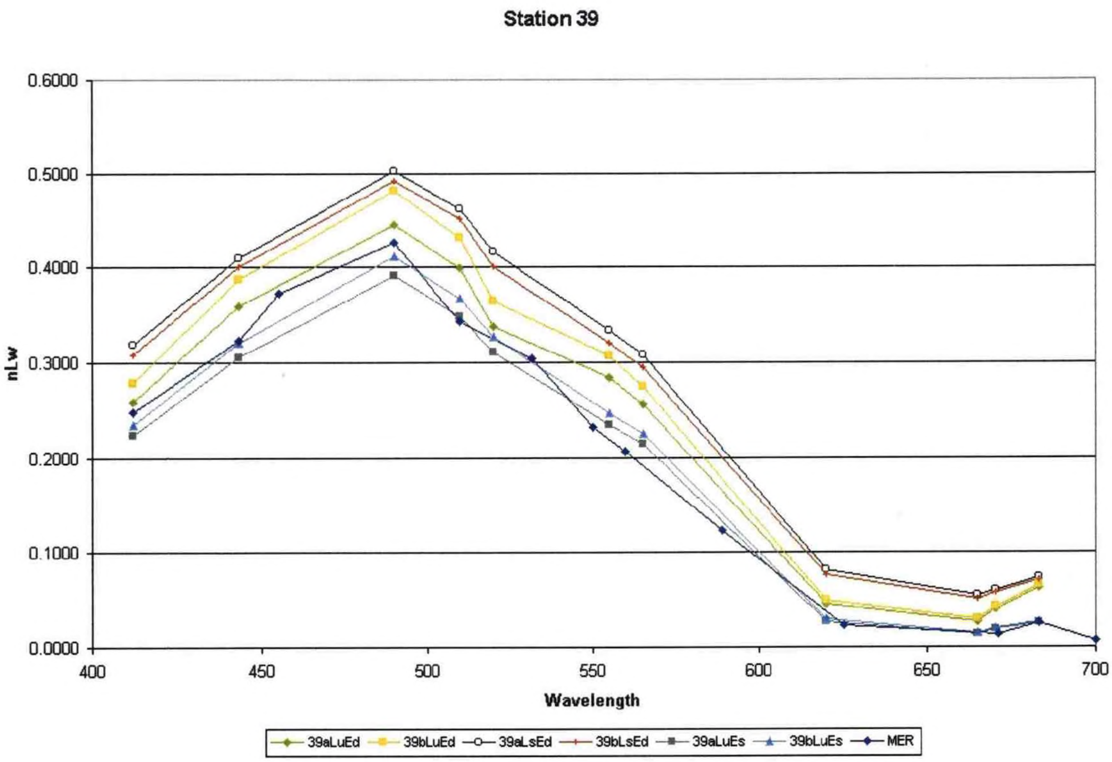


Station 37

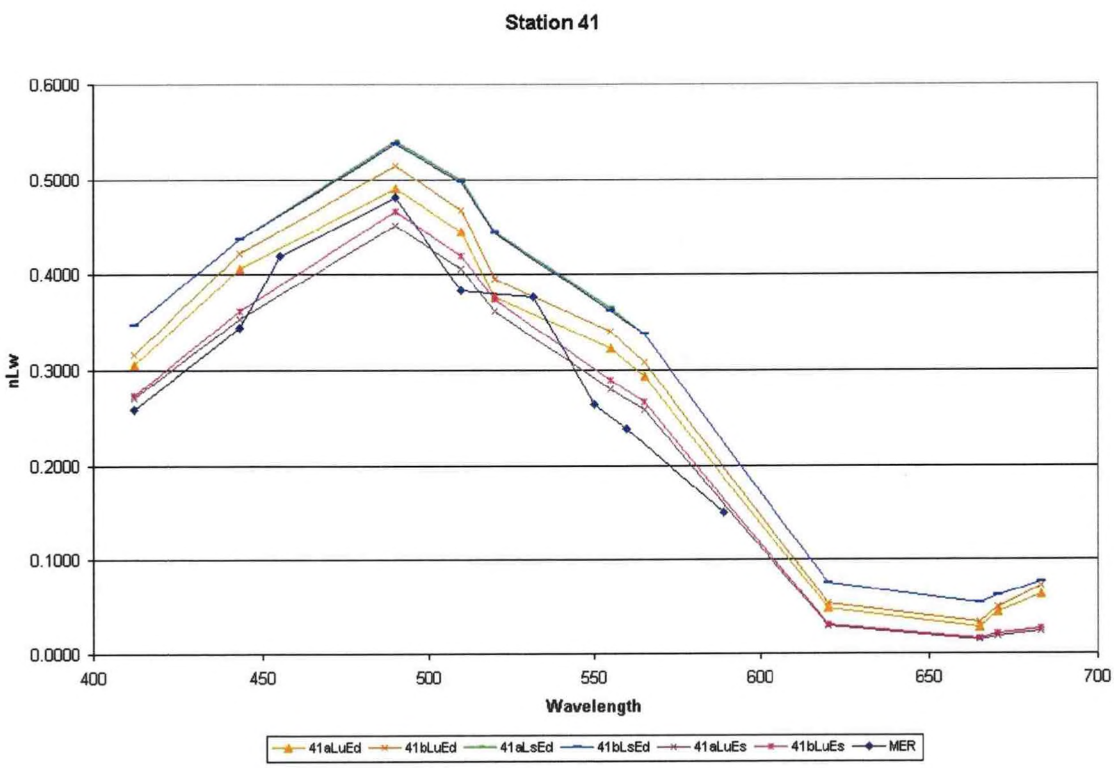



Station 38



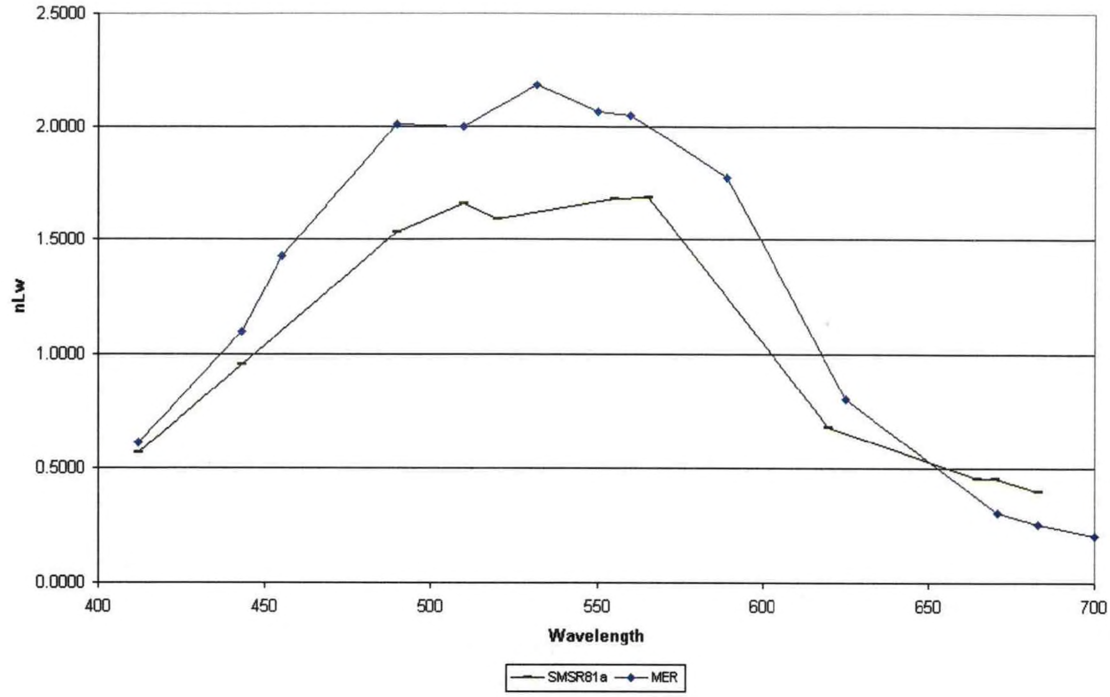


Station 39
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
nLw
400
450
500
550
600
650
700
Wavelength
39aLuEd
39bLuEd
39aLsEd
39bLsEd
39aLuEs
39bLuEs
MER

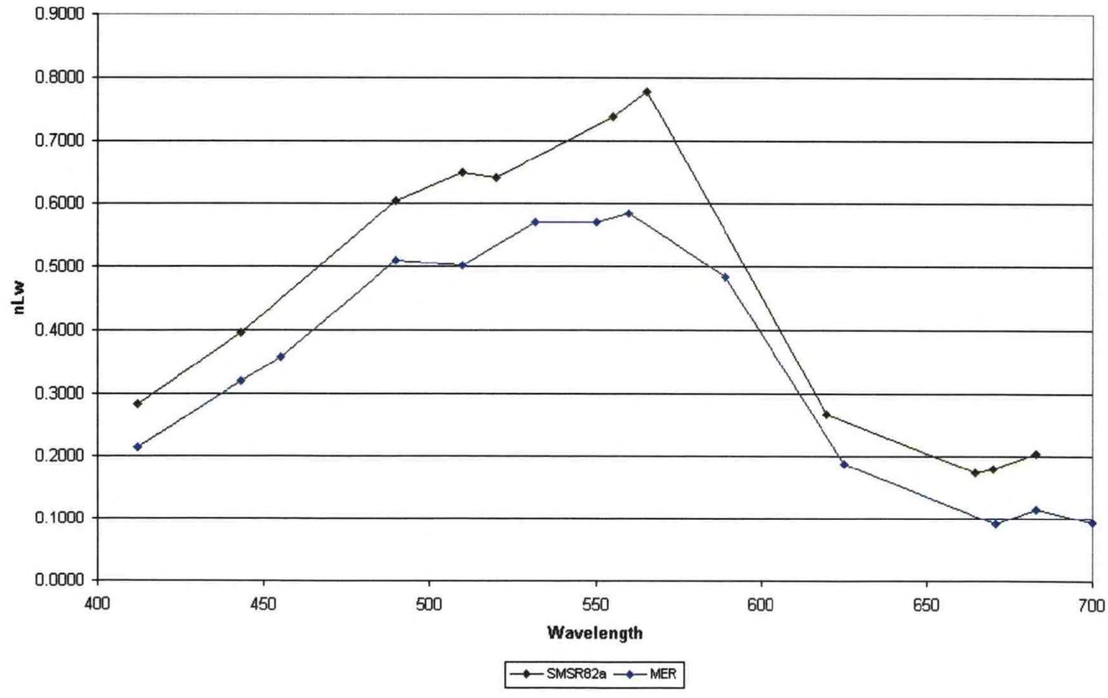



Station 41
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
nLw
400
450
500
550
600
650
700
Wavelength
41aLuEd
41bLuEd
41aLsEd
41bLsEd
41aLuEs
41bLuEs
MER

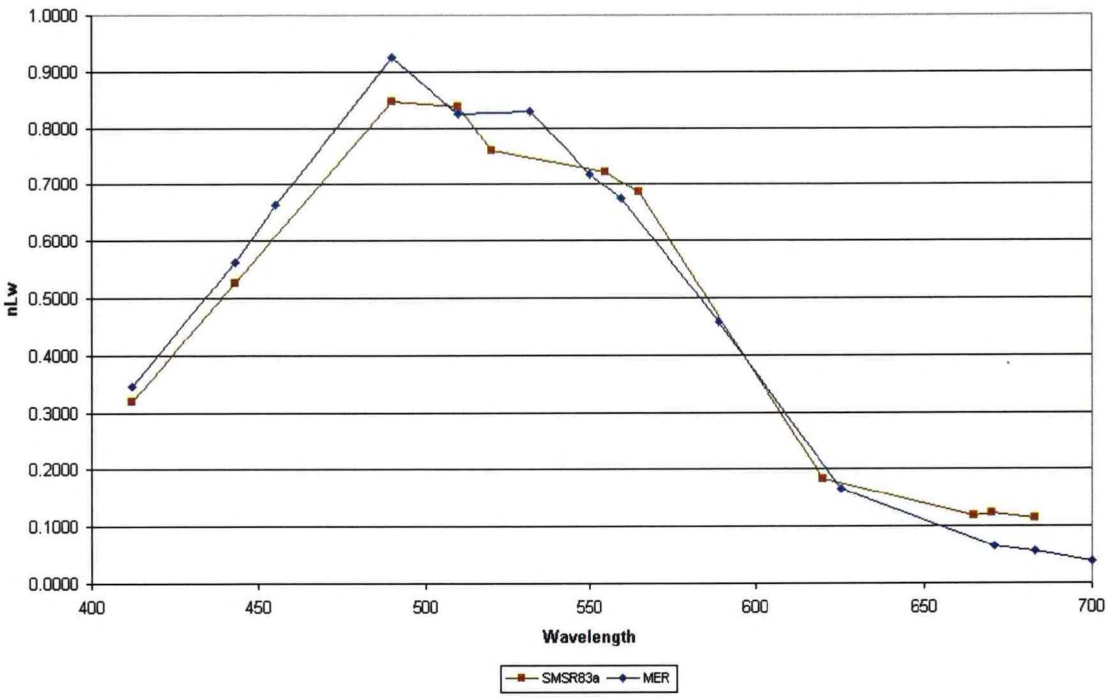
Station 81




Station 82



Station 83




Station 84