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NOAA/MLML Radiometric Data Acquisition and Processing

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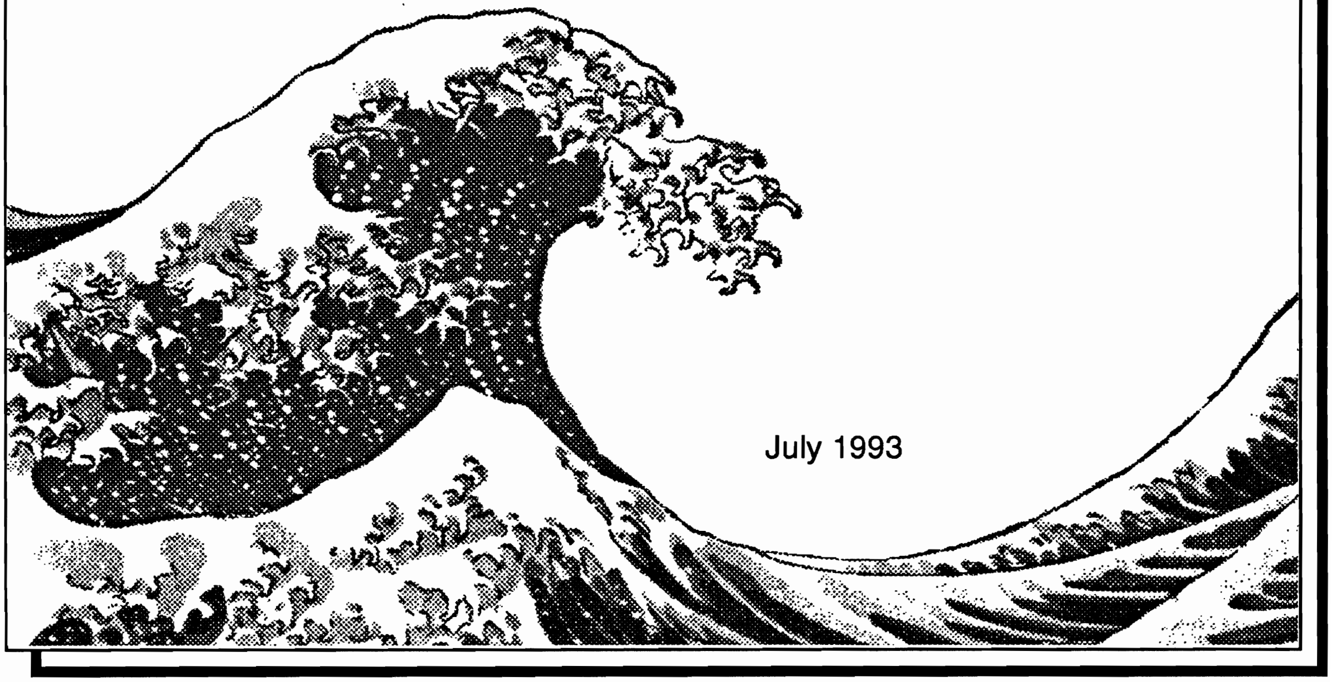

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Abstract

This report is a detailed description of data processing of NOAA/MLML spectroradiometry data. It introduces the MLML_DBASE programs, describes the assembly of diverse data files, and describes general algorithms and how individual routines are used. Definitions of data structures are presented in Appendices.

Introduction

The purpose of this report is to document data processing of radiometric data obtained in support of the NOAA/MLML participation in the SeaWiFS project. This report presents details of program use, but a companion report (Broenkow, *et al.* 1993) presents a graphical, less-detailed summary of methods described here.

In 1978 the MLML oceanography group participated with the NOAA/NESDIS CZCS project by writing programs to acquire and process spectroradiometer data. Our current work provides similar support for the NOAA/NESDIS Marine Optical Characterization Experiment, MOCE, in preparation for the launch of the new ocean color satellite, SeaWiFS. During CZCS experiments, an 80-channel scanning radiometer measured in-water spectral upwelled radiance, $L_u(z,\lambda)$, and spectral downwelled irradiance, $E_d(z,\lambda)$, in the visible spectrum from 400 to 700 nm. A similar instrument onboard ship measured surface spectral irradiance, $E_s(\lambda)$. *In situ* observations of spectral L_u, E_d and E_s were required for calibration and validation of the spectral water-leaving radiance, $L_W(\lambda)$, as retrieved from the CZCS satellite sensor. These radiometric measurements were also used to develop and validate bio-optical algorithms and atmospheric correction algorithms.

The purpose of the data acquisition and reduction programs described here are similar to those of the CZCS program, and many of these programs directly parallel those used in the CZCS work. The purpose of the SeaWiFS project is to achieve remotely-sensed, water-leaving radiances within 5% accuracy, and chlorophyll *a* concentration within 35% over the range 0.05 to 50 mg m^{-3}. New instruments were developed by Dennis Clark of NOAA/NESDIS to surface-truth the SeaWiFS sensor. The dual spectrograph (340 to 900 nm) Marine Optical System, MOS, measures in-water $L_u(z,\lambda)$ and $E_d(z,\lambda)$. The instrument can be used either in the Marine Optical Buoy (MOBY) or by deployment from a ship. Data from either mode are processed identically. A 38-channel Surface Irradiance Spectrometer, SIS, measures $E_s(\lambda)$ at the sea surface. An older 80-channel PMT spectroradiometer, Fastie (named after its optical designer), is also used from time to time. As part of the the NOAA/NESDIS project MLML, has provided C and FORTRAN software to acquire data from these instruments. Unlike their earlier CZCS counterparts, the new instruments are controlled by a VAXStation 4000.

Measurements of L_u, E_d, and E_s are used to calculate normalized water-leaving radiance, $L_{WN}(\lambda)$. These near nanometer resolution spectra are weighted by the eight SeaWiFS response functions to simulate SeaWiFS-determined radiances. The SeaWiFS $L_{WN}(\lambda)$ will be used for "vicarous" satellite sensor calibrations. In addition, these data observations will be used for development of bio-optical and atmospheric correction algorithms.

Measurements of $L_u(z,\lambda)$ and $E_d(z,\lambda)$, made over the upper few optical depths, are required to compute the diffuse attenuation coefficients $K_E(z,\lambda)$ and $K_L(z,\lambda)$. Optical depth, $\tau(z,\lambda)$, in the context of this report is the reciprocal integral of $K(z,\lambda)$ (for either radiance or irradiance), from the surface to a given depth z. Profiles of $E_d(z,\lambda)$ and $L_u(z,\lambda)$ must be normalized to account for changes during a cast in solar zenith angle, cloud cover and aerosols, hence the need for measuring $E_s(z,\lambda)$. $K_L(\lambda)$ is used to extrapolate profiles of $L_u(z,\lambda)$ to an infinitesimal depth below the surface ($z = 0^-$), $L_u(0^-,\lambda)$, which, when propogated through the sea surface leads to the estimated value of $L_W(\lambda)$. To standardize SeaWiFS in-water algorithms, it is necessary to normalize $L_W(\lambda)$ for sun zenith angle, earth-sun distance, and atmospheric transmittance, yielding $L_{WN}(\lambda)$.

In conjunction with oceanographic and atmospheric measurements, MOS and SIS spectroradiometers are operated shipboard at a bio-optics station. MOS is attached to a floating tetrahedron and lowered to typically three depths. The tetrahedron is floated away from the ship to avoid measuring a light field contaminated by the ship's shadow or reflection. Subsurface measurements are taken near local apparent noon, LAN, and require approximately two hours to complete. Typical sampling depths are 1, 6, and 11 m in eutrophic waters or 1, 11 and 21 m is oligotrophic waters. Simultaneous with underwater measurements, SIS measures $E_s(\lambda)$ to account for changing sky conditions. During the data acquisition session the workstation is used to control both instruments, to display the data in real-time and to save data in the MLML_DBASE format (Broenkow and Reaves, 1993).

MOS and SIS produce data sets, composed of several spectral scans and ancillary information. Each scan consists of two 500-channel spectra: the blue from about 340 to 640 nm; the red from about 600 to 900 nm. The spectral output from a diode array is measured as dark scans with the shutter closed and as radiance or irradiance scans when the shutter is open. MOS also contains light-emitting diodes for field calibration. The dark scans account for instrument background noise and are subtracted from radiance or irradiance measurements. Spectra are scanned in sets, typically composed of two dark scans followed by five radiance or irradiance scans, followed by another two dark scans. The number of scans is controlled by the operator depending on wave noise, sky variability and the achieved signal to noise ratio. MOS contains sensors to measure external water pressure and temperature, internal and array temperatures, instrument tilt and heading, heat exchanger cooler flow, and battery voltages. SIS measures internal temperature and reference voltages.

VAX FORTRAN and C software was developed at MLML to acquire and process large amounts of data gathered by the MOS and SIS spectroradiometers. Instrument control and acquisition software provides the interface between the person operating the instruments and the hardware. Control of MOS is done by sending FORTH commands to the instrument. MOS is controlled internally by a TattleTale 7 FORTH system described by Reaves and Broenkow (1993). The VAX MOS and SIS programs display menus, accept commands from the operators terminal, send commands to, and receive data from the instruments, and display spectral scans and ancillary data to the operator. Acquisition programs save all data in MLML_DBASE or *PLOT* binary files. These scan-sets, are subsequently processed by converting raw data from digital counts to radiometric units, and by deriving required radiometric products. Broenkow and Reaves (1993), "Introduction to MLML_DBASE Programs", discusses *PLOT* terminology which will be used throughout this report. Broenkow, *et al.* (1993), "Processing NOAA Spectroradiometer Data", provides a terse, graphical outline of the NOAA/MLML data processing system.

A completely processed optical profile from a MOCE bio-optics station is contained in a single file and consists of:

1. L_u, E_d, and E_s spectral scans at three depths with ancillary information.
2. Radiance and irradiance diffuse attenuation coefficients, K_L and K_E.
3. Water-leaving radiances, L_{WN}, normalized for time of day, location, atmospheric scattering functions, and L_{WN} weighted for the eight SeaWiFS bands.
4. Photosynthetically available radiation, PAR, solar zenith angle, airmass, and normalization factor, F_N.

Each file contains a header identifying: cruise and ship name; station name, GMT date and time, geographic location; cloud cover and type, sky conditions; wind direction and velocity, sea state; Secchi depth and Munsell color; instrument identification; calibration date and file identification; processing methods and algorithms; and observer names.

Data Acquisition Outline

Data acquisition programs control MOS, SIS and Fastie spectroradiometers via four X-Windows displays:

1. The control window displays a menu of commands to start and stop scans, setup

Table 1. The NOAA Main Menu for Processing Radiometric Data. Note that some program names are the same as those used in the main MLML_DBASE program *PLOT.*

#	Program	Description
1	CONVERT	Apply System Response, Immersion Factor
2	EDIT	Replace erroneous data with NaN
3	SMOOTH	Apply N-Point Running Mean Smoothing
4	ADJUST	Average Radiance & Dark; %Error; Rad-Drk; SNR
5	AVERAGE	Calculate Spectral Mean and %Error
6	MERGE	Combine E_d, L_u, E_s's from *Archive* Files
7	CLIP	Replace Low SNR Data with NaN
8	DERIVE	Derive K_E, K_L, L_W, L_{WN}; Apply SeaWiFS Weights
9	GRAPH	Plot 2-Page, 3-Panel X-Y Graphs
10	LIST	Print Data Report Listings
11	PROCESS	Execute Script Commands Files on *Archive* File List

operating parameters, and save data. Commands are selected via a mouse-driven menu bar and executed by "clicking" on the highlighted command.

2. Program prompts are displayed in a text window. All keyboard input is read from this window.

3. A third window displays intrument analog information and scan counters.

4. X-Y line graphs of spectral scan information are displayed in a graphics window.

MOS Data Acquisition

This section is in preparation.

SIS Data Acquisition

This section is in preparation.

Fastie Data Acquisition

This section is in preparation.

Data Processing Outline

The SeaWiFS Prelaunch Science Working Group has recomended that $E_s(\lambda)$, $E_d(z,\lambda)$, and $L_u(z,\lambda)$ data should be recorded and archived at 4 levels:

Level 0: Raw instrument digital ouput.

Level 1: Instrument output in volts (or frequency) and depth.

Level 2: Calibrated radiance/irradiance, ancillary measurements in appropriate geophysical or biological units, and depth, corrected for dark/zero offsets.

Level 3: Smoothed profiles of $K(z,\lambda)$ and associated $L_u(z,\lambda)$ or $E_d(z,\lambda)$ normalized by measured $E_s(\lambda)$.

Level 4: Level 3 data normalized to clear-sky, zenith sun at mean earth-sun distance, and spectrally adjusted to match SeaWiFS reference wavelengths and FWHM bandwidths.

NOAA/MLML radiometric data acquisition software (the SIS, MOS and Fastie programs) produces level 0 files in output units of raw digital counts. Before numerical processing begins, the various files taken at a single optics station must be assembled and inspected. This is done using a set of routines for "merging" file names into a file called MERGE.LIS. These files are then "grouped" timewise. Following that, spectral data from these files are inspected by the NOAA_LOOK program. After the files have been assembled into logical units constituting a single radiometer station, the programs described in Table 1 produce level 2 through level 4 files. The order in which those programs are applied to MOS and SIS data sets is usually top-down, i.e. Program 1 through Program 10, though this order can vary. Program 11 incorporates one or more of Programs 1 through 10 for batch-mode processing.

Data Description

A level 0 scan-set is acquired and saved to an *Archive* file, which consists typically of the following 10 *Variables* (the order of *Variables* 2 through 10 corresponds to the temporal sequence in which they were acquired):

Variable #

1. Nominal Wavelength (nm)
2. Dark Scan # 1 (counts)
3. Dark Scan # 2 (counts)
4. L_u or E_d or E_s Scan # 1 (counts)
5. L_u or E_d or E_s Scan # 2 (counts)
6. L_u or E_d or E_s Scan # 3 (counts)
7. L_u or E_d or E_s Scan # 4 (counts)
8. L_u or E_d or E_s Scan # 5 (counts)
9. Dark Scan # 3 (counts)
10. Dark Scan # 4 (counts)

Each of the above *Variables* contains 1000 *Elements* for a MOS $L_u(z,\lambda)$ or $E_d(z,\lambda)$ scan, or 48 *Elements* (38 spectral channels + 10 reference channels) for a SIS $E_s(z,\lambda)$ scan. Each *Element* contains the 16-bit (0-65535) intensity level of a single diode array pixel. All raw scan data units are counts, and wavelengths are un-calibrated nominal values in nm. The *Variable Header* for each scan contains an *Extension* which holds the following information collected at the time of the individual scan (see Appendix 5 for definitions of MLML_DBASE MOS, SIS and Fastie data structures):

> Scan, Cruise, Station, Cast, Instrument Serial #, Instrument Configuration #, Multiplexer Serial # (MOS only), Scan Time, Navigation Type, Latitude, Longitude, Time of Last Satellite Overpass, Variable Type, Variable Subtype, Processing Code, Smoothing Code, Interpolation Code, Beginning Interpolation Wavelength, Interpolation Wavelength Interval, Number of Averages (SIS only), Multiplexer Position (MOS only), Mirror Position (MOS only), Comments, Number of Points Edited, Number of Errors.

E_d and L_u *Variable Header Extensions* contain the following for each of the two (blue and red) MOS spectrographs:

> Cooler Intensity, Intensifier Setting, LED Level, Data Length, Gain, Integration Time.

E_s *Variable Extensions* contain the following for the SIS spectrograph:

> Shutter Setting, Number of Channels, Gain and Timeout for each channel.

Type, value, gain and average are saved for the following analog channels:

> MOS
> Internal Temperature, External Temperature, Pressure Transducer Temperature, External Pressure (depth), Battery Voltage, High and Low Voltage References, LED Temperature, Compass Direction, X-tilt, Y-tilt, Blue and Red Array Temperature, Heat Exchanger Cooler Flow, Compass Direction.
>
> SIS
> Internal Temperature, Battery Voltage, X-tilt, Y-tilt, Array temperature.

Appendix 5 provides the definition and ranges of values for data codes such as Variable Type, Processing Code, Cooler Intensity and Shutter Setting.

Level 1 files are not produced for the MOS and SIS instruments. This is because the diode array detectors with their integral analog to digital converters are calibrated as single units: their digital outputs are directly converted to radiometric units. This is also the case for all ancillary sensors, whose digital outputs are directly converted to physical units.

Assembling Data Files

The SIS, MOS and Fastie data acquisition programs produce independent files (one for each instrument) containing surface irradiances, upwelled radiance or downwelled irradiances at a number of depths. These instruments have different spectral resolution, and data acquisition from them is not done synchronously. This makes assembling and reducing the diverse data sets difficult.

Perhaps the most difficult problem is to provide a flexible system to merge the various data sets with the goal of determining water-leaving radiances and diffuse attenuation coefficients. The data acquisition programs produce files with file names that uniquely determine their contents (Appendix 4). Data from a single cruise or calibration experiment are contained in a single directory. The data merging procedure is outlined as follows:

1. The first step is to create lists of file names which constitute data for a single optical profile or for a group of stations to be processed in one session. This is done with the command "ALIAS", which is runs the DCL command file $MLML$DIR:ALIAS.COM. ALIAS is executed twice, first to assemble the MOS (and perhaps Fastie) files for a specific station and next to assemble the SIS files for that same station. The examples below result in two files: M.ALIAS and S.ALIAS, which are located in the user's logical directory ALIAS$DIR. The use of VMS wild-cards (*) limits the search to selected files. Familiarity with the VMS file naming conventions is essential to accomplish this process. The syntax for this is $ ALIAS input-files output-files, for example,

```
$ ALIAS  [DATA.MOCE_2.MOS.RAW]STN2*.MLDAT M
$ ALIAS             [DATA.MOCE_2.SIS.RAW]*.MLDAT S
```

   Examples of the ALIAS files are shown in Table 2.

2. The next step is to find the number of *PLOT Variables* and the time-span for each file. This is done by passing the M.ALIAS and S.ALIAS files to the NOAA_LIST_HEADERS program, which can be executed using the VMS symbol NLH, which is equivalent to $ RUN NOAA_LIST_HEADERS, from the NOAA$BIN directory. That program is invoked twice, once for MOS (or Fastie) files and again for SIS files. The syntax for this is $ NLH input-alias-file output-list-file, for example,

```
$ NLH                    ALIAS$DIR:M.ALIAS M.LIS
$ NLH                    ALIAS$DIR:S.ALIAS S.LIS
```

   Output from this procedure are the files, M.LIS and S.LIS, (Table 3) which contains header information from the selected MOS and SIS files.

3. The third step in merging files is to "group" the surface irradiance files (SIS) by time with the contemporaneous MOS files containing downwelled irradiance and upwelled radiance. This is done by use of the program NOAA_GROUP_FILES which can be run using the VMS symbol, NGF, equivalent to

```
$ RUN $NOAA$BIN:NOAA_GROUP_FILES
```

   The syntax to invoke the "grouping" program requires the ALIAS file names for the MOS and SIS file names followed by the name of the "merge" file, for example,

```
$ NGF                    M.LIS S.LIS MERGE.LIS;1
```

   Output from this procedure is shown in Table 4.

4. Up to this point, data reduction can be done more-or-less blindly, with the emphasis on "less blindly", because it is generally impossible to trap for all errors or exceptional circumstances that may occur aboard ship during data acquisition. Examples of exceptions might be erroneous latitude and longitude, erroneous system clock time or empty data files. Steps 1-3 are done outside of *PLOT*, from the VMS command line. The next step requires running *PLOT* and the *NOAA* programs to examine each E_d or L_u and E_s scan-set to determine which are suitable. This requires plotting each spectral scan and noting which are to be retained. The procedure is done inside *PLOT*. The syntax for doing this from the main *PLOT* prompt is to run the *NOAA* program and its subprogram *LOOK* followed by the merge listing file name, for example,

```
ML> NOAA LOOK                    MERGE.LIS;1
```

   While determining which files are to be combined, it is essential that a hardcopy of the MERGE.LIS;1 file is available on which to note the acceptable E_s, L_u, and E_d files. This procedure requires patience and practice.

   After the LOOK program has been run, the MERGE.LIS;1 file is manually edited to produce the file, MERGE.LIS:2, which contains the file names of only those scans which have passed scrutiny. The others are deleted by a text editor. The MERGE.LIS:2 file should be kept as a permanent record of data processing procedure.

Table 2. Example of MOS and SIS ALIAS Files used to group all Station 2 files before numerical processing.

```
    ALIAS$DIR:M.ALIAS
-------------------------------------------------------------------
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_11M_LU_05.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_ED_01.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_02.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_03.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_04.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_11M_08.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_11M_09.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_1M_18.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_6M_12.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_6M_13.MLDAT
    .
    .
    .
-------------------------------------------------------------------

    ALIAS$DIR:S.ALIAS
-------------------------------------------------------------------
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]ONLY_A_TEST.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180202.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180302.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180402.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180502.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180602.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180702.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180802.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180902.MLDAT
    _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_181002.MLDAT
    .
    .
    .
```

Table 3. Example of the M.LIS and S.LIS files formed by running the NOAA_LIST_HEADERS program.

```
M.LIS
------------------------------------------------------------------------------
M1  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_11M_LU_05.MLDAT #Var=10 31Mar93 19:45 to 31Mar93 19:50
M2  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_ED_01.MLDAT  #Var=14 31Mar93 18:55 to 31Mar93 19:02
M3  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_02.MLDAT  #Var=10 31Mar93 19:07 to 31Mar93 19:12
M4  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_03.MLDAT  #Var=19 31Mar93 19:07 to 31Mar93 19:18
M5  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_04.MLDAT  #Var=28 31Mar93 19:07 to 31Mar93 19:27
M6  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_11M_08.MLDAT #Var=10 31Mar93 20:35 to 31Mar93 20:39
M7  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_11M_09.MLDAT #Var=10 31Mar93 20:40 to 31Mar93 20:44
M8  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_1M_18.MLDAT  #Var=10 31Mar93 22:11 to 31Mar93 22:14
M9  _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_6M_12.MLDAT  #Var=10 31Mar93 21:34 to 31Mar93 21:38
M10 _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_6M_13.MLDAT  #Var=10 31Mar93 21:39 to 31Mar93 21:42
.
.

S.LIS
------------------------------------------------------------------------------
S1  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]ONLY_A_TEST.MLDAT          #Var=10 27Mar93 18:00 to 27Mar93 18:00
S2  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180202.MLDAT    #Var=10 27Mar93 18:02 to 27Mar93 18:02
S3  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180302.MLDAT    #Var=10 27Mar93 18:03 to 27Mar93 18:03
S4  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180402.MLDAT    #Var=10 27Mar93 18:04 to 27Mar93 18:04
S5  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180502.MLDAT    #Var=10 27Mar93 18:05 to 27Mar93 18:05
S6  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180602.MLDAT    #Var=10 27Mar93 18:06 to 27Mar93 18:06
S7  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180702.MLDAT    #Var=10 27Mar93 18:07 to 27Mar93 18:07
S8  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180802.MLDAT    #Var=10 27Mar93 18:08 to 27Mar93 18:08
S9  _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_180902.MLDAT    #Var=10 27Mar93 18:09 to 27Mar93 18:09
S10 _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930327_181002.MLDAT    #Var=10 27Mar93 18:10 to 27Mar93 18:10
.
.
```

Table 4. Example of a MERGE.LIS:1 file produced by the NOAA_GROUP_FILES program before running NOAA_LOOK. Notice that the ALIAS file names (M20, S797) precede the complete file names.

```
MERGE.LIS;1
--------------------------------------------------------------------------------------------------------------
M1     _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_11M_LU_05.MLDAT     #Var=10 31Mar93 19:45 to 31Mar93 19:50
S819   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_195129.MLDAT   #Var=10 31Mar93 19:51 to 31Mar93 19:51

M20    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_ED_01.MLDAT      #Var=14 31Mar93 18:55 to 31Mar93 19:02
S797   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185546.MLDAT   #Var=10 31Mar93 18:55 to 31Mar93 18:56
S798   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185646.MLDAT   #Var=10 31Mar93 18:56 to 31Mar93 18:57
S799   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185747.MLDAT   #Var=10 31Mar93 18:57 to 31Mar93 18:58
S800   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185846.MLDAT   #Var=10 31Mar93 18:58 to 31Mar93 18:59
S801   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185946.MLDAT   #Var=10 31Mar93 18:59 to 31Mar93 19:00

M2     _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_02.MLDAT      #Var=10 31Mar93 19:07 to 31Mar93 19:12
S801   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185946.MLDAT   #Var=10 31Mar93 18:59 to 31Mar93 19:00

M22    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_03.MLDAT      #Var=19 31Mar93 19:07 to 31Mar93 19:18
S801   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185946.MLDAT   #Var=10 31Mar93 18:59 to 31Mar93 19:00

M3     _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_04.MLDAT      #Var=28 31Mar93 19:07 to 31Mar93 19:27
S801   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185946.MLDAT   #Var=10 31Mar93 18:59 to 31Mar93 19:00

M4     _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_ED_11M_08.MLDAT     #Var=10 31Mar93 20:35 to 31Mar93 20:39
S863   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_203529.MLDAT   #Var=10 31Mar93 20:35 to 31Mar93 20:35
S864   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_203629.MLDAT   #Var=10 31Mar93 20:36 to 31Mar93 20:36
S865   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_203729.MLDAT   #Var=10 31Mar93 20:37 to 31Mar93 20:37
S866   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_203829.MLDAT   #Var=10 31Mar93 20:38 to 31Mar93 20:38
S867   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_203929.MLDAT   #Var=10 31Mar93 20:39 to 31Mar93 20:39
.
.
```

Table 5. Example of the edited MERGE.LIS file containing those files that passed scrutiny in the NOAA_LOOK program.

```
MERGE.LIS;2
------------------------------------------------------------------------------
!
! File: MOCE2_STN02_MERGE.LIS  22-Nov-1993 by M.Feinholz
! MOS/SIS data files processed for MOCE2 Stn02 Isla Santa Cruz
!

! Ed surface

M20    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_ED_01.MLDAT       #Var=14 31Mar93 18:55 to 31Mar93 19:02
S797   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185546.MLDAT    #Var=10 31Mar93 18:55 to 31Mar93 18:56
S798   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185646.MLDAT    #Var=10 31Mar93 18:56 to 31Mar93 18:57
S799   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185747.MLDAT    #Var=10 31Mar93 18:57 to 31Mar93 18:58
S800   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185846.MLDAT    #Var=10 31Mar93 18:58 to 31Mar93 18:59

! Lu surface

M22    _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_03.MLDAT       #Var=19 31Mar93 19:07 to 31Mar93 19:18
M3     _DUA1:[DATA.NOAA.MOCE_2.MOS.RAW]STN02_1M_LU_04.MLDAT       #Var=28 31Mar93 19:07 to 31Mar93 19:27
S801   _DUA1:[DATA.NOAA.MOCE_2.SIS.RAW]SIS_930331_185946.MLDAT    #Var=10 31Mar93 18:59 to 31Mar93 19:00
.
.
.
```

Table 6a. Schematic of MLML_DBASE Merged File Contents. Top, Mid and Bot refer to the sample depths.

```
MOCE2_STN02_MERGE.MLDAT
-------------------------------------------------------------------------------------------
Var #   Symbol          Var #      Symbol          Var #   Symbol        Var #   Symbol
-----   ------          -----      ------          -----   ------        -----   ------
 1      MOS lambda       3         Ed top           11     Ed mid         19     Ed bot
 2      SIS lambda       4         SNR              12     SNR            20     SNR
                         5         Es               13     Es             21     Es
                         6         SNR              14     SNR            22     SNR
                         7         Lu top           15     Lu mid         23     Lu bot
                         8         SNR              16     SNR            24     SNR
                         9         Es               17     Es             25     Es
                         10        SNR              18     SNR            26     SNR
```

Table 6b. Schematic of MLML_DBASE Derived File Contents. Attenuation coefficients between top and mid are designated K_1, between top and bot as K_2, and between mid and bot as K_3. Water-leaving radiances are designated by the surface-most upwelled radiance and the attenuation coefficient (1,2,3) used in the extrapolation.

```
MOCE2_STN02_DERIVE.MLDAT
-----------------------------------------------------------------------------------------
Var #   Symbol          Var #    Symbol      Var #   Symbol
-----   ------          -----    ------      -----   ------
 27      Ke_1            33       Lw t1       37      Lwn
 28      Kl_1            34       Lw t2       38      Lwn
 29      Ke_2            35       Lw m1       39      Lwn
 30      Kl_2            36       Lw b2       40      Lwn
 31      Ke_3                                 41      Fn
 32      Kl_3
```

The liberal use of comments, which are denoted by a leading exclamation point (!), is essential. An example of the edited MERGE.LIS;2 file is shown in Table 5.

5. The last step required to assemble scans before numerical processing can begin is to form *PLOT* data files containing the E_S, L_u, and E_d, data for the Top, Mid and Bot sampling depths. That is done within *PLOT* using the *NOAA LOOK* program which requires the name of the merge listing file, for example,

```
ML> NOAA MERGE                    MERGE.LIS;2
```

Notice that the second version number of the MERGE.LIS file is used.

Following preprocessing steps 1-5, the NOAA programs, NOAA_CONVERT, NOAA_DERIVE, NOAA_CLIP, NOAA_GRAPH, and NOAA_LIST can be run to produce calibrated radiances, attenuation coefficients and water-leaving radiances, as explained next. The second data processing phase involves numerical conversions and produces files containing a well-ordered set of radiometric values shown in Table 6.

1. Each raw MOS $L_u(z,\lambda)$, $E_d(z,\lambda)$ and SIS $E_s(z,\lambda)$ scan-set is converted from raw counts to radiometric units by applying the sensor's system response. Since E_d and L_u sensors are calibrated in air but are used to measure radiation underwater, an additional immersion correction factor, F_w, is applied.

2. For MOS data only, known "bad" pixels are replaced with a missing-data code, NaN.

3. For MOS data only, each scan is smoothed spectrally to reduce instrument noise.

4. Dark scans are averaged. Radiance or irradiance scans are averaged. Average dark count is subtracted from average radiance or irradiance. Percent errors are determined for each average, and Signal to Noise Ratio, SNR, is calculated.

These steps are repeated for each scan-set, with the resulting *Variables* recorded to *PLOT Archive* files in the following order (for example, using a SIS E_s scan-set):

Variable #
1. Corrected SIS Wavelength (nm)
2. Dark Scan # 1 (μW/cm^2/nm)
3. Dark Scan # 2 (μW/cm^2/nm)
4. E_s Scan # 1 (μW/cm^2/nm)
5. E_s Scan # 2 (μW/cm^2/nm)
6. E_s Scan # 3 (μW/cm^2/nm)
7. E_s Scan # 4 (μW/cm^2/nm)
8. E_s Scan # 5 (μW/cm^2/nm)
9. Dark Scan # 3 (μW/cm^2/nm)
10. Dark Scan # 4 (μW/cm^2/nm)
11. Mean Dark (μW/cm^2/nm)
12. Dark %RMSE
13. Mean E_s (μW/cm^2/nm)
14. E_s %RMSE
15. Mean E_s - Mean Dark (μW/cm^2/nm)
16. SNR

5. The dark-corrected radiance or irradiance and SNR (*Var#* 15 and 16 above) of several sets which represent a single depth or a single time are averaged. For example, several E_s sets may span the time interval of one L_u scan, and hence must be averaged together.

At this point, each set has been processed to a corrected and dark-adjusted radiance or irradiance spectra with SNR. Multiple scan-sets have been averaged if necessary. Each (average) E_d and L_u at a depth has been associated with an (average) E_s.

The final step is to combine SIS and MOS files, trim the scans to wavelengths having acceptable signal to noise, derive attenuation coefficients and water-leaving radiances and produce hard-copy reports.

6. Processed data files are merged into a single optical profile, containing E_d and L_u spectra at three depths along with corresponding E_s and SNR's. We use the terminology "Top" for the surface-most data; "Mid" for data obtained at the middle depth; "Bot" for data taken at the deepest or bottom depth. A merged profile contains 26 *Variables* in the following order:

1. Corrected MOS Wavelength (nm)
2. Corrected SIS Wavelength (nm)

3. Top E_d (μW/cm^2/nm)
4. SNR of Top E_d
5. E_i for Top E_d (μW/cm^2/nm)
6. SNR of E_s for Top E_d

7. Surface L_u (μW/cm^2/sr/nm)
8. SNR of Top L_u
9. E_i for Top L_u (μW/cm^2/nm)
10. SNR of E_s for Top L_u

11. Mid E_d (μW/cm^2/nm)
12. SNR of Mid E_d
13. E_i for Mid E_d (μW/cm^2/nm)
14. SNR of E_s for Mid E_d
15. Mid L_u (μW/cm^2/sr/nm)
16. SNR of Mid L_u
17. E_i for Mid L_u (μW/cm^2/nm)
18. SNR of E_s for Mid L_u

19. Bot E_d (μW/cm^2/nm)
20. SNR of Bot E_d
21. E_i for deep E_d (μW/cm^2/nm)
22. SNR of E_s for Bot E_d L_u(μW/cm^2/sr/nm)
23. Bot L_u (μW/cm^2/sr/nm)
24. SNR of Bot L_u
25. E_i for Bot L_u (μW/cm^2/nm)
26. SNR of E_s for Bot L_u

7. The SeaWiFS project group identifies a SNR of 100:1 as the minimum quality assurance level. Individual data *Elements* below this level can be removed, or clipped, from the merged *Variables*.

8. Diffuse attenuation coefficients and solar-normalized water-leaving radiances are calculated from *Variables* arranged in step 6 and clipped in step 7. SeaWiFS normalized responses are applied for the eight bands. PAR, FLH, solar altitude, and air mass are calculated and saved with processed spectral and analog data. This step derives the *Var#'s* 27 to 36. All 36 *Variables* are recorded in a single *Archive* file containing one optical profile. The file contents are summarized in Table 6.

27. Top to Mid K_E (m^{-1})
28. Top to Mid K_L (m^{-1})
29. Top to Bot K_E (m^{-1})
30. Top to Bot K_L (m^{-1})

31. Mid to Bot K_E (m^{-1})
32. Mid to Bot K_L (m^{-1})

33. L_W Top/1 (μW/cm^2/sr/nm)
34. L_W Top/2 (μW/cm^2/sr/nm)
35. L_W Mid/1 (μW/cm^2/sr/nm)
36. L_W Bot/2 (μW/cm^2/sr/nm)

37. L_{WN} Top/1 (μW/cm^2/sr/nm)
38. L_{WN} Top/2 (μW/cm^2/sr/nm)
39. L_{WN} Mid/1 (μW/cm^2/sr/nm)
40. L_{WN} Bot/2 (μW/cm^2/sr/nm)

41. F_N Solar normalizing factor

9. Two pages of X-Y line graphs formatted with three plots per page are produced (Figs. 1 and 2). These can be displayed to a terminal, PostScript printer or PostScript file. Plots are available in color or in black-and-white.

10. A data report listing is produced in tabular ASCII format and output to either a terminal, printer, or file (Figs 3 and 4). Graphical and tabular output are useful for archive and reference. The ASCII files generated here or more simple ASCII files generated by the *PLOT* program are used to distribute data to interested parties.

The above processing is implemented in 10 steps to allow flexibility in program sequencing, to accommodate exceptions, and to allow use of partially processed profiles. This is necessary, for example, while processing calibration data to generate system response, R(λ). In this situation, *CONVERT* is not applied and *DERIVE*d parameters are not calculated. Instead, sets are *EDIT*ed, *SMOOTH*ed, *ADJUST*ed and possibly *MERGE*d. System response is computed as the ratio of the calibrated lamp spectra and the processed MOS or SIS spectral counts.

The *CONVERT* step can be omitted if a valid system response is not available. This may be the case before post-cruise calibrations are performed. Scan-sets can be processed in raw units and later *CONVERT*ed to radiometric units. Indeed, diffuse attenuation coefficients are identical if *DERIVE*d from *CONVERT*ed or unconverted scan-sets.

Running Data Processing Programs

What follows illustrates use of the NOAA programs, which run under the MLML_DBASE program, generally called *PLOT*. *PLOT* **must** be run from the VMS command line as

```
$ PLOT 100 1000 4 4 2000
```

The four parameters passed to the *PLOT* program do the following: 100 indicates the number of *PLOT Variables*; 1000 indicates the number of data *Elements*;

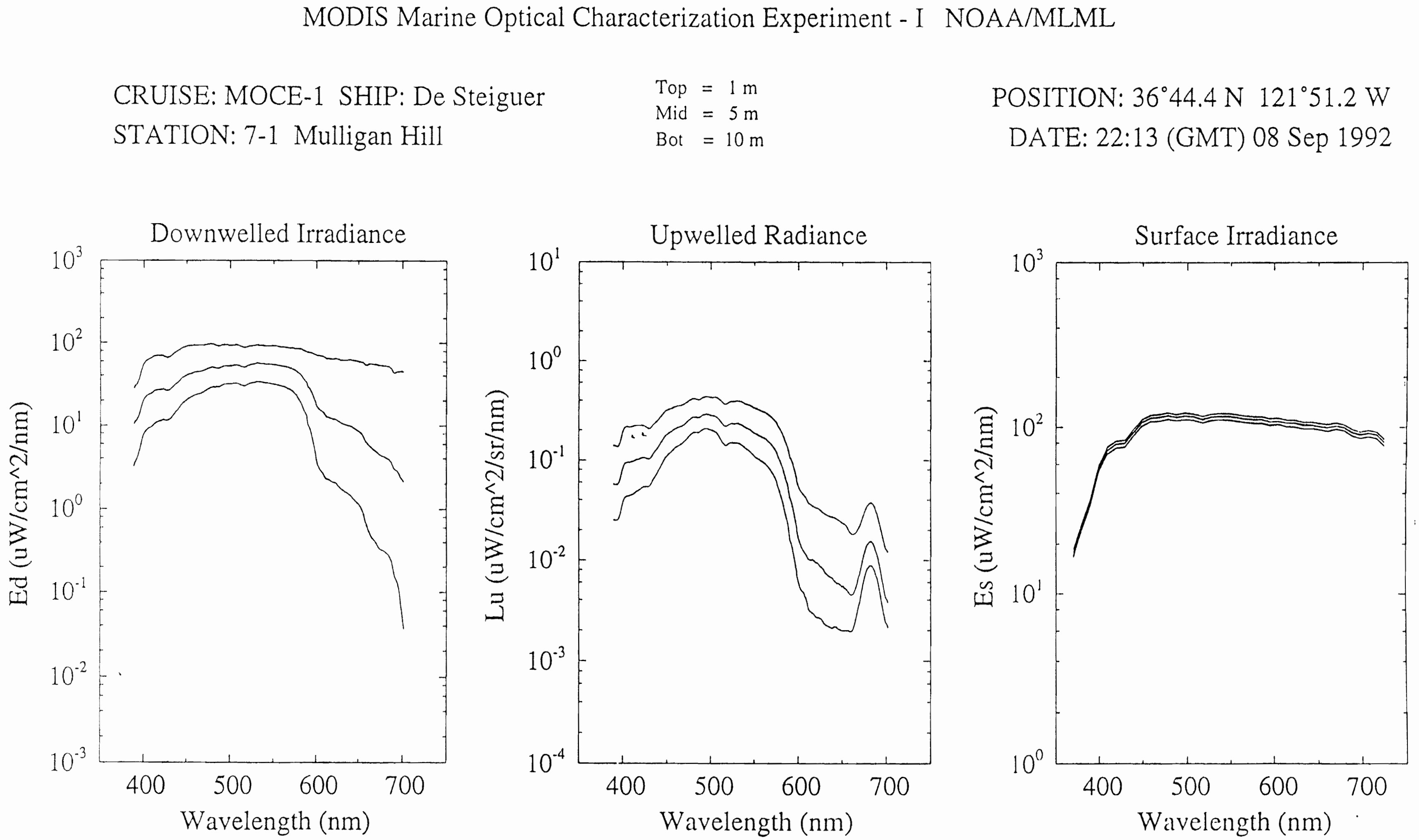


Figure 1. First page of figures, observed spectra, produced by NOAA_GRAPH.

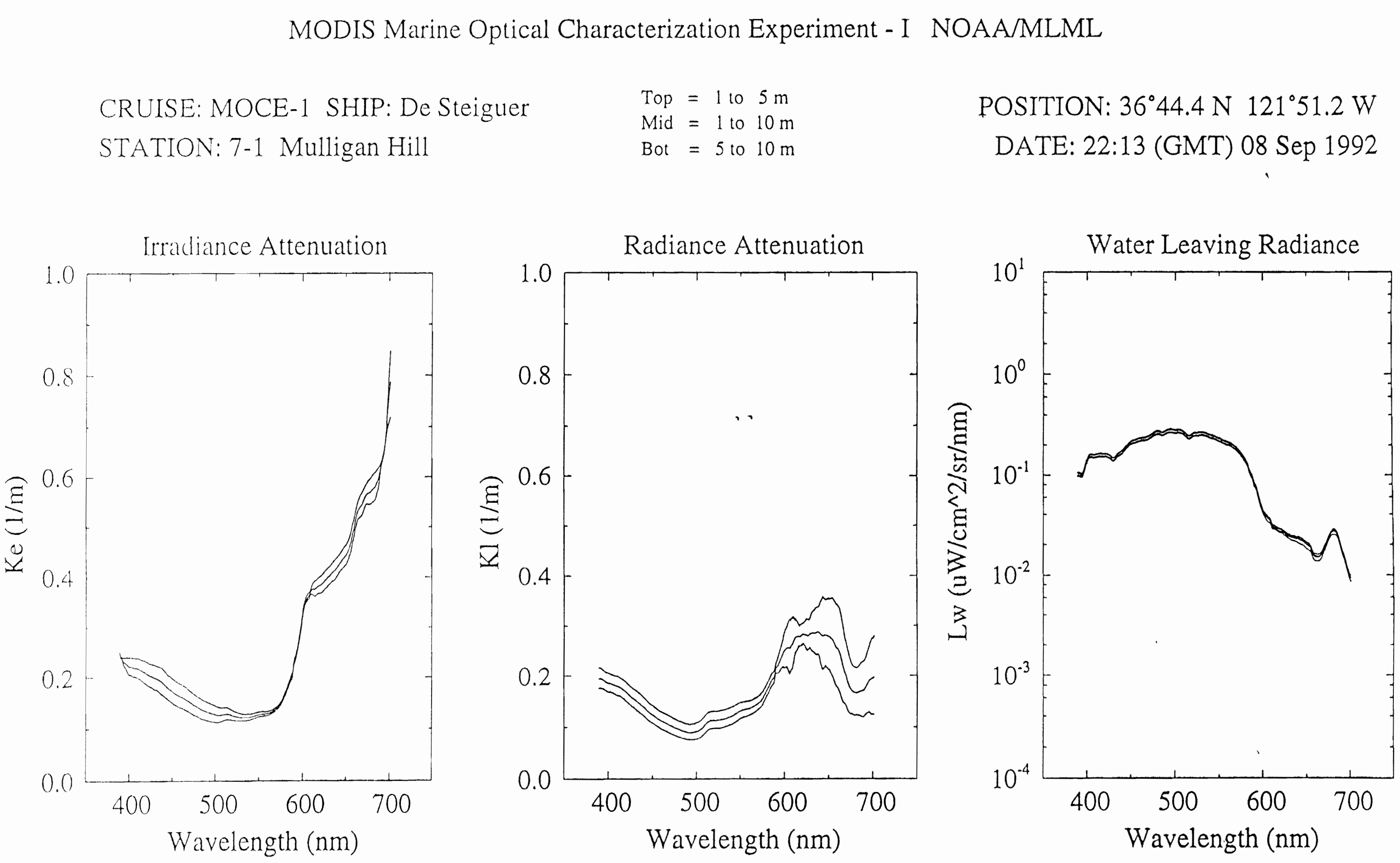
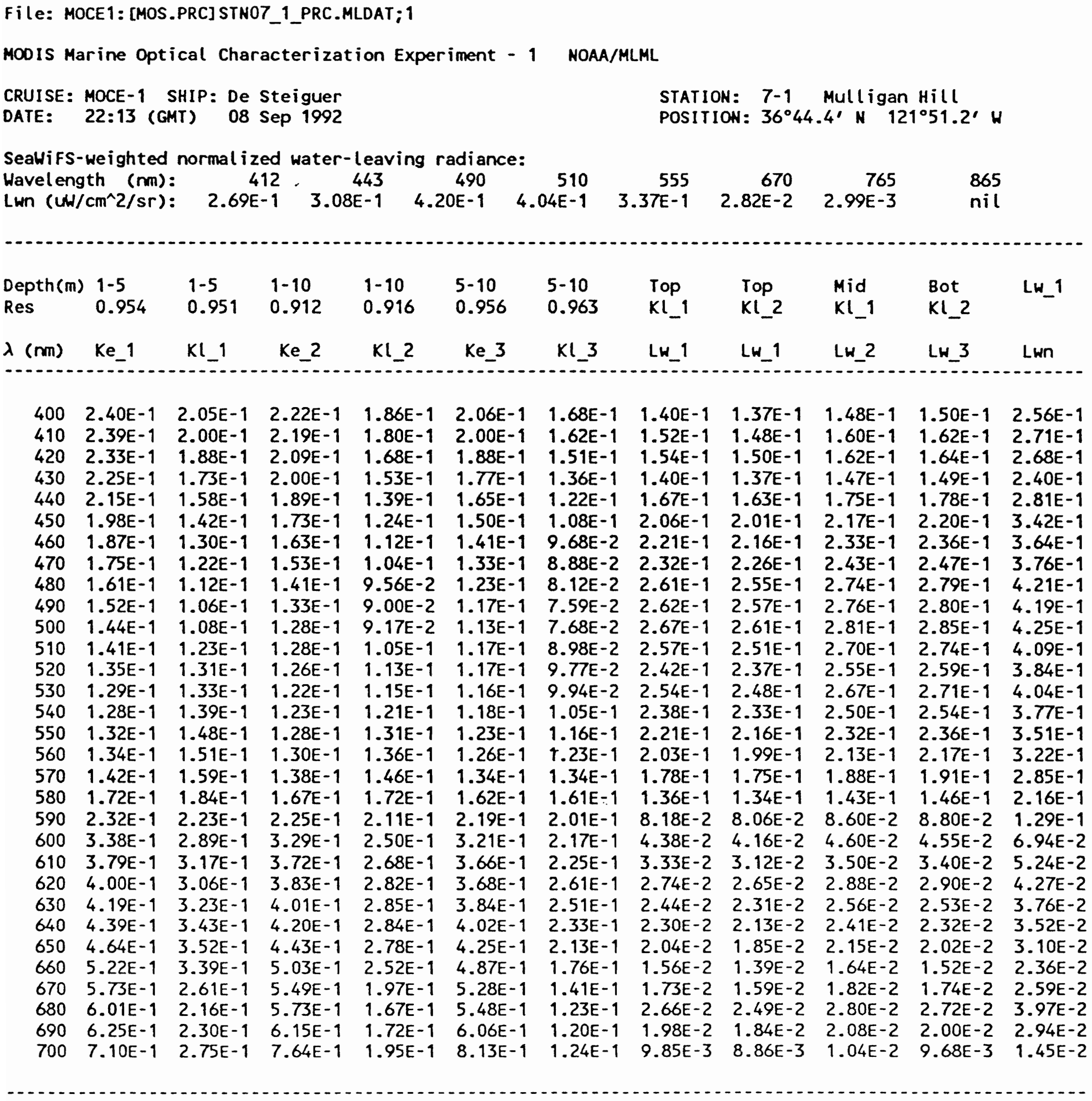


Figure 2. Second page of figures, attenuation coefficients and water-leaving radiances, produced by NOAA_GRAPH.

```
File: MOCE1:[MOS.PRC]STN07_1_PRC.MLDAT;1

MODIS Marine Optical Characterization Experiment - 1   NOAA/MLML

CRUISE: MOCE-1  SHIP: De Steiguer                          STATION:  7-1   Mulligan Hill
DATE:   22:13 (GMT)   08 Sep 1992                          POSITION: 36°44.4' N  121°51.2' W

SeaWiFS-weighted normalized water-leaving radiance:
Wavelength  (nm):        412       443       490       510       555       670       765       865
Lwn (uW/cm^2/sr):   2.69E-1   3.08E-1   4.20E-1   4.04E-1   3.37E-1   2.82E-2   2.99E-3      nil

----------------------------------------------------------------------------------------------------
                 Top                 Top                 Mid                 Mid                 Bot                  Bot
Depth (m)        0.6                 1.3                 5.0                 5.6                 9.8                 10.5
Time (GMT)     22:29               22:22               22:15               22:09               22:01                21:55

λ (nm)   Ed_1     Es_1     Lu_1     Es_1     Ed_2     Es_2     Lu_2     Es_2     Ed_3     Es_3     Lu_3     Es_3
----------------------------------------------------------------------------------------------------

   400  5.52E+1  5.34E+1  1.97E-1  5.40E+1  2.05E+1  5.63E+1  8.57E-2  5.70E+1  7.91E+0  5.90E+1  3.90E-2  5.97E+1
   410  6.60E+1  6.84E+1  2.15E-1  6.91E+1  2.47E+1  7.19E+1  9.56E-2  7.27E+1  9.78E+0  7.54E+1  4.49E-2  7.59E+1
   420  7.00E+1  7.43E+1  2.21E-1  7.51E+1  2.69E+1  7.81E+1  1.04E-1  7.91E+1  1.13E+1  8.18E+1  5.13E-2  8.23E+1
   430  6.69E+1  7.55E+1  2.06E-1  7.61E+1  2.66E+1  7.93E+1  1.03E-1  8.05E+1  1.18E+1  8.31E+1  5.48E-2  8.37E+1
   440  7.95E+1  8.77E+1  2.50E-1  8.86E+1  3.29E+1  9.22E+1  1.33E-1  9.33E+1  1.55E+1  9.65E+1  7.60E-2  9.71E+1
   450  9.05E+1  1.01E+2  3.15E-1  1.02E+2  4.04E+1  1.06E+2  1.80E-1  1.07E+2  2.04E+1  1.11E+2  1.10E-1  1.11E+2
   460  9.39E+1  1.07E+2  3.43E-1  1.08E+2  4.39E+1  1.12E+2  2.06E-1  1.14E+2  2.32E+1  1.17E+2  1.33E-1  1.18E+2
   470  9.38E+1  1.08E+2  3.63E-1  1.09E+2  4.62E+1  1.13E+2  2.26E-1  1.15E+2  2.53E+1  1.18E+2  1.52E-1  1.20E+2
   480  9.61E+1  1.11E+2  4.14E-1  1.12E+2  5.03E+1  1.16E+2  2.69E-1  1.18E+2  2.90E+1  1.21E+2  1.88E-1  1.22E+2
   490  9.38E+1  1.08E+2  4.20E-1  1.10E+2  5.11E+1  1.14E+2  2.80E-1  1.15E+2  3.04E+1  1.19E+2  2.00E-1  1.19E+2
   500  9.35E+1  1.11E+2  4.26E-1  1.11E+2  5.26E+1  1.16E+2  2.81E-1  1.17E+2  3.18E+1  1.21E+2  2.00E-1  1.22E+2
   510  9.32E+1  1.10E+2  4.03E-1  1.10E+2  5.31E+1  1.15E+2  2.49E-1  1.16E+2  3.16E+1  1.20E+2  1.67E-1  1.21E+2
   520  9.01E+1  1.06E+2  3.76E-1  1.07E+2  5.27E+1  1.11E+2  2.25E-1  1.12E+2  3.12E+1  1.16E+2  1.45E-1  1.16E+2
   530  9.43E+1  1.09E+2  3.93E-1  1.10E+2  5.66E+1  1.14E+2  2.33E-1  1.16E+2  3.38E+1  1.19E+2  1.49E-1  1.20E+2
   540  9.23E+1  1.10E+2  3.65E-1  1.12E+2  5.56E+1  1.15E+2  2.11E-1  1.17E+2  3.29E+1  1.21E+2  1.31E-1  1.21E+2
   550  9.26E+1  1.10E+2  3.35E-1  1.11E+2  5.48E+1  1.15E+2  1.87E-1  1.17E+2  3.16E+1  1.20E+2  1.10E-1  1.21E+2
   560  8.92E+1  1.08E+2  3.06E-1  1.09E+2  5.25E+1  1.13E+2  1.68E-1  1.15E+2  2.98E+1  1.19E+2  9.56E-2  1.19E+2
   570  8.70E+1  1.06E+2  2.66E-1  1.08E+2  4.95E+1  1.11E+2  1.41E-1  1.13E+2  2.70E+1  1.17E+2  7.61E-2  1.17E+2
   580  8.55E+1  1.05E+2  1.97E-1  1.06E+2  4.28E+1  1.10E+2  9.35E-2  1.12E+2  2.04E+1  1.15E+2  4.42E-2  1.16E+2
   590  7.77E+1  1.05E+2  1.12E-1  1.06E+2  3.00E+1  1.10E+2  4.53E-2  1.12E+2  1.09E+1  1.15E+2  1.77E-2  1.16E+2
   600  7.16E+1  1.02E+2  5.52E-2  1.03E+2  1.75E+1  1.07E+2  1.67E-2  1.08E+2  3.87E+0  1.12E+2  6.01E-3  1.13E+2
   610  6.68E+1  1.01E+2  4.03E-2  1.01E+2  1.37E+1  1.05E+2  1.08E-2  1.06E+2  2.43E+0  1.10E+2  3.75E-3  1.11E+2
   620  6.43E+1  9.98E+1  3.37E-2  1.01E+2  1.20E+1  1.05E+2  9.48E-3  1.06E+2  2.10E+0  1.09E+2  2.75E-3  1.10E+2
   630  6.23E+1  9.74E+1  2.93E-2  9.81E+1  1.07E+1  1.02E+2  7.65E-3  1.04E+2  1.74E+0  1.07E+2  2.32E-3  1.07E+2
   640  6.28E+1  9.77E+1  2.69E-2  9.85E+1  9.92E+0  1.02E+2  6.46E-3  1.04E+2  1.47E+0  1.07E+2  2.15E-3  1.07E+2
   650  5.97E+1  9.58E+1  2.37E-2  9.66E+1  8.49E+0  1.00E+2  5.46E-3  1.01E+2  1.13E+0  1.05E+2  1.99E-3  1.05E+2
   660  5.44E+1  9.44E+1  1.84E-2  9.50E+1  6.02E+0  9.87E+1  4.48E-3  9.96E+1  5.94E-1  1.03E+2  1.96E-3  1.04E+2
   670  5.50E+1  9.66E+1  2.26E-2  9.72E+1  4.89E+0  1.01E+2  7.71E-3  1.02E+2  3.94E-1  1.06E+2  4.03E-3  1.06E+2
   680  5.30E+1  9.45E+1  3.68E-2  9.51E+1  4.18E+0  9.89E+1  1.52E-2  9.97E+1  3.06E-1  1.03E+2  8.68E-3  1.04E+2
   690  4.41E+1  8.82E+1  2.70E-2  8.87E+1  3.13E+0  9.23E+1  1.05E-2  9.34E+1  1.74E-1  9.65E+1  6.07E-3  9.67E+1
   700  4.51E+1  8.54E+1  1.26E-2  8.57E+1  2.22E+0  8.93E+1  4.05E-3  9.05E+1  4.57E-2  9.35E+1  2.29E-3  9.35E+1

----------------------------------------------------------------------------------------------------
```

Figure 3. First page of the data report, observed spectra, produced by NOAA_LIST.



```
File: MOCE1:[MOS.PRC]STN07_1_PRC.MLDAT;1

MODIS Marine Optical Characterization Experiment - 1   NOAA/MLML

CRUISE: MOCE-1  SHIP: De Steiguer                          STATION:  7-1   Mulligan Hill
DATE:   22:13 (GMT)   08 Sep 1992                          POSITION: 36°44.4' N  121°51.2' W

SeaWiFS-weighted normalized water-leaving radiance:
Wavelength  (nm):        412       443       490       510       555       670       765       865
Lwn (uW/cm^2/sr):    2.69E-1   3.08E-1   4.20E-1   4.04E-1   3.37E-1   2.82E-2   2.99E-3       nil

-----------------------------------------------------------------------------------------------------

Depth(m) 1-5      1-5      1-10     1-10     5-10     5-10     Top      Top      Mid      Bot      Lw_1
Res      0.954    0.951    0.912    0.916    0.956    0.963    Kl_1     Kl_2     Kl_1     Kl_2

λ (nm)   Ke_1     Kl_1     Ke_2     Kl_2     Ke_3     Kl_3     Lw_1     Lw_1     Lw_2     Lw_3     Lwn
-----------------------------------------------------------------------------------------------------

   400 2.40E-1  2.05E-1  2.22E-1  1.86E-1  2.06E-1  1.68E-1  1.40E-1  1.37E-1  1.48E-1  1.50E-1  2.56E-1
   410 2.39E-1  2.00E-1  2.19E-1  1.80E-1  2.00E-1  1.62E-1  1.52E-1  1.48E-1  1.60E-1  1.62E-1  2.71E-1
   420 2.33E-1  1.88E-1  2.09E-1  1.68E-1  1.88E-1  1.51E-1  1.54E-1  1.50E-1  1.62E-1  1.64E-1  2.68E-1
   430 2.25E-1  1.73E-1  2.00E-1  1.53E-1  1.77E-1  1.36E-1  1.40E-1  1.37E-1  1.47E-1  1.49E-1  2.40E-1
   440 2.15E-1  1.58E-1  1.89E-1  1.39E-1  1.65E-1  1.22E-1  1.67E-1  1.63E-1  1.75E-1  1.78E-1  2.81E-1
   450 1.98E-1  1.42E-1  1.73E-1  1.24E-1  1.50E-1  1.08E-1  2.06E-1  2.01E-1  2.17E-1  2.20E-1  3.42E-1
   460 1.87E-1  1.30E-1  1.63E-1  1.12E-1  1.41E-1  9.68E-2  2.21E-1  2.16E-1  2.33E-1  2.36E-1  3.64E-1
   470 1.75E-1  1.22E-1  1.53E-1  1.04E-1  1.33E-1  8.88E-2  2.32E-1  2.26E-1  2.43E-1  2.47E-1  3.76E-1
   480 1.61E-1  1.12E-1  1.41E-1  9.56E-2  1.23E-1  8.12E-2  2.61E-1  2.55E-1  2.74E-1  2.79E-1  4.21E-1
   490 1.52E-1  1.06E-1  1.33E-1  9.00E-2  1.17E-1  7.59E-2  2.62E-1  2.57E-1  2.76E-1  2.80E-1  4.19E-1
   500 1.44E-1  1.08E-1  1.28E-1  9.17E-2  1.13E-1  7.68E-2  2.67E-1  2.61E-1  2.81E-1  2.85E-1  4.25E-1
   510 1.41E-1  1.23E-1  1.28E-1  1.05E-1  1.17E-1  8.98E-2  2.57E-1  2.51E-1  2.70E-1  2.74E-1  4.09E-1
   520 1.35E-1  1.31E-1  1.26E-1  1.13E-1  1.17E-1  9.77E-2  2.42E-1  2.37E-1  2.55E-1  2.59E-1  3.84E-1
   530 1.29E-1  1.33E-1  1.22E-1  1.15E-1  1.16E-1  9.94E-2  2.54E-1  2.48E-1  2.67E-1  2.71E-1  4.04E-1
   540 1.28E-1  1.39E-1  1.23E-1  1.21E-1  1.18E-1  1.05E-1  2.38E-1  2.33E-1  2.50E-1  2.54E-1  3.77E-1
   550 1.32E-1  1.48E-1  1.28E-1  1.31E-1  1.23E-1  1.16E-1  2.21E-1  2.16E-1  2.32E-1  2.36E-1  3.51E-1
   560 1.34E-1  1.51E-1  1.30E-1  1.36E-1  1.26E-1  1.23E-1  2.03E-1  1.99E-1  2.13E-1  2.17E-1  3.22E-1
   570 1.42E-1  1.59E-1  1.38E-1  1.46E-1  1.34E-1  1.34E-1  1.78E-1  1.75E-1  1.88E-1  1.91E-1  2.85E-1
   580 1.72E-1  1.84E-1  1.67E-1  1.72E-1  1.62E-1  1.61E-1  1.36E-1  1.34E-1  1.43E-1  1.46E-1  2.16E-1
   590 2.32E-1  2.23E-1  2.25E-1  2.11E-1  2.19E-1  2.01E-1  8.18E-2  8.06E-2  8.60E-2  8.80E-2  1.29E-1
   600 3.38E-1  2.89E-1  3.29E-1  2.50E-1  3.21E-1  2.17E-1  4.38E-2  4.16E-2  4.60E-2  4.55E-2  6.94E-2
   610 3.79E-1  3.17E-1  3.72E-1  2.68E-1  3.66E-1  2.25E-1  3.33E-2  3.12E-2  3.50E-2  3.40E-2  5.24E-2
   620 4.00E-1  3.06E-1  3.83E-1  2.82E-1  3.68E-1  2.61E-1  2.74E-2  2.65E-2  2.88E-2  2.90E-2  4.27E-2
   630 4.19E-1  3.23E-1  4.01E-1  2.85E-1  3.84E-1  2.51E-1  2.44E-2  2.31E-2  2.56E-2  2.53E-2  3.76E-2
   640 4.39E-1  3.43E-1  4.20E-1  2.84E-1  4.02E-1  2.33E-1  2.30E-2  2.13E-2  2.41E-2  2.32E-2  3.52E-2
   650 4.64E-1  3.52E-1  4.43E-1  2.78E-1  4.25E-1  2.13E-1  2.04E-2  1.85E-2  2.15E-2  2.02E-2  3.10E-2
   660 5.22E-1  3.39E-1  5.03E-1  2.52E-1  4.87E-1  1.76E-1  1.56E-2  1.39E-2  1.64E-2  1.52E-2  2.36E-2
   670 5.73E-1  2.61E-1  5.49E-1  1.97E-1  5.28E-1  1.41E-1  1.73E-2  1.59E-2  1.82E-2  1.74E-2  2.59E-2
   680 6.01E-1  2.16E-1  5.73E-1  1.67E-1  5.48E-1  1.23E-1  2.66E-2  2.49E-2  2.80E-2  2.72E-2  3.97E-2
   690 6.25E-1  2.30E-1  6.15E-1  1.72E-1  6.06E-1  1.20E-1  1.98E-2  1.84E-2  2.08E-2  2.00E-2  2.94E-2
   700 7.10E-1  2.75E-1  7.64E-1  1.95E-1  8.13E-1  1.24E-1  9.85E-3  8.86E-3  1.04E-2  9.68E-3  1.45E-2

-----------------------------------------------------------------------------------------------------
```

Figure 4. Second page of the data report, attenuation coefficients and water-leaving radiances, produced by NOAA_LIST.

which is sufficient for NOAA MOS or SIS spectra; 4 indicates use of MLML_DBASE DATA_TYPE 4, being REAL*4 values having about 7 significant digits; the second 4 indicates the DATA_ELEMENT_SIZE as 4 bytes; and 2000 sets the File Header Extension size to be 2000 bytes. The File Header Extension holds derived products,and Appendix 5 shows the details of the extension variables.

Two methods access the above programs from *PLOT*:

1. At the ML> prompt type "NOAA" to print a menu and display the NOAA> prompt.
2. At the ML> prompt type "NOAA" followed by the program name or number.

Typing EXIT or 0 at the NOAA> command line exits back to *PLOT* prompt, ML>, and entering an empty RETURN at NOAA> redisplays the menu shown below. As with the *PLOT* program, DCL commands can be run from the NOAA> prompt by preceding them with a $, or a DCL "shell" can be run by typing $ RETURN.

To display the main NOAA processing menu:

```
ML> NOAA
```

Notice that the prompt changes to NOAA, and that NOAA program names or numbers rather than the PLOT program names are in use.

```
NOAA:  NOAA/MLML Radiometric Data Processing
 rev:  24-May-1993

 #  Command       Description

 1  CONVERT       Apply Sys Resp, Immr Factor
 2  EDIT          Replace Erroneous Data with NaN
 3  SMOOTH        Apply N Point Running Mean Smooth
 4  ADJUST        Ave Rad & Drk,%Err,rad-drk,SNR
 5  AVERAGE       Average Spectral Mean & %Err
 6  MERGE         Collect Es, Ed, Lu's in one place
 7  CLIP          Replace SNR < 100:1 Data with NaN
 8  DERIVE        Ke,Kl,Lw,Lwn,SeaWiFS Weights,PAR
 9  GRAPH         Plot 2-Page, 3-Panel Graphs
10  LIST          Radiometric Data Report Listing

 0  EXIT
NOAA>
```

To exit from NOAA>:

```
NOAA> EXIT
```

or

```
NOAA> 0
ML>
```

To start the *SMOOTH* program, for example:

```
ML> NOAA SMOOTH
```

or

```
ML> NOAA 3
...
```

NOAA programs will prompt the user for necessary input. Typing CTRL Z in response to a prompt exits that program without processing data. Many prompts provide default values which can be accepted, modified or re-entered. Program input requests can be satisfied by passing parameters to the program when it is started. When passing parameters to a program, default inputs can be accepted by typing the wildcard * in place of the specific *Variable* or *Element* ranges. It is best to run a program through the interactive mode the first time to understand what input needs are required and what default values are provided. For example, *SMOOTH* prompts for the *Variable* list to be smoothed and the number of points to use for the smoothing window. *SMOOTH* provides 5 as the default window size. Input requests from *SMOOTH* can be answered in several ways:

1. Starting *SMOOTH* from the main NOAA> command line:

```
ML> NOAA
(— NOAA main menu printed here —)
NOAA> SMOOTH
NOAA_SMOOTH  Enter Range of Variable # to Smooth:
                                             2-10
NOAA_SMOOTH        Enter # of Elmts/Window (odd):
                                                5
Working...
Done.
```

2. Starting *SMOOTH* from the ML> command line:

```
ML> NOAA SMOOTH
NOAA_SMOOTH  Enter Range of Variable # to Smooth:
                                             2-10
NOAA_SMOOTH        Enter # of Elmts/Window (odd):
                                                5
Working...
Done.
```

3. Passing input to *SMOOTH*:

```
ML> NOAA
(— NOAA main menu printed here —)
NOAA> SMOOTH                                 2-10 7
```

```
Working...
Done.
```

or

```
ML> NOAA SMOOTH                          2-10 7
Working...
Done.
```

4. To use the default *SMOOTH* window size (5):

```
ML> NOAA SMOOTH                          2-10 *
Working...
Done.
```

The following paragraphs define the user interface and some details of processing algorithms and data handling for each of the *NOAA* programs.

MLML_NOAA

The main *NOAA* program provides an interface to the ten radiometric data processing programs. The tasks of *NOAA* are four:

1. *NOAA* displays the processing menu and the NOAA> prompt (see example above), reads and parses user commands.
2. *NOAA* handles any parameters passed from *PLOT*.
3. *NOAA* handles any parameters passed to subprograms.
4. *NOAA* runs its subprograms.

The menu contents and physical location of subprogram code is known to *NOAA* via the ASCII file NOAA_MAIN_MENU.DAT (see Appendix 4). This file contains three lines for each subprogram: line 1 = program name; line 2 = program description; line 3 = complete VMS filename of program. *NOAA* reads this file, prints the name and description information to the user's terminal in a menu format, and uses the VMS filename to run subprograms. NOAA_MAIN_MENU.DAT can be updated to add, delete, or change the name, description, or location of a NOAA subprogram.

Programming Details

A temporary disk file is used to pass parameters between separate programs because FORTRAN does not allow directly for passing arguments to a main program. The existence of the temporary parameter file is known to separate program units via the VMS logical MLML_DBASE_PARAMETER in a VMS logical table (Appendix 3). Managing parameter files constitutes most of *NOAA*'s work. If input is passed from *PLOT*, this information is extracted from the parameter file for interpretation by a subroutine. The name of the parameter file is retrieved from the VMS logical and saved, freeing the logical to be used, if necessary, to pass parameters to subprograms. Before exiting back to *PLOT*, the original parameter filename is replaced in the logical and returned to *PLOT*. If it is necessary for *NOAA* to pass parameters to a subprogram, it creates a temporary parameter file, writes information to the file, calls the subprogram, then deletes the file after the subprogram is finished.

If all the NOAA programs were coded as subroutines, *NOAA* would not have to pass parameters via external files. As separate programs, however, command line mode is enabled from both the ML> and NOAA> levels. This is convenient for an advanced user who may write batch mode command files from ML>, and for the novice user who runs the *NOAA* programs by passing parameters within the *NOAA* processing environment. As individual programs, the processing routines are also accessible to future high-level application programs, and the increased modularity facilitates program modification and maintenance.

NOAA_CONVERT

CONVERT applies a system response and/or immersion correction factor to SIS and MOS data. *CONVERT* has three prompts:

```
NOAA> CONVERT

NOAA_CONVERT:  Apply System Response
               rev:  22-Jul-1993

NOAA_CONVERT:                   Enter Response Filename:
                          [DATA:NOAA:MOCE_2]PRECAL

NOAA_CONVERT:              Enter Response Var # to Use:
                                                      2
NOAA_CONVERT:       Enter Range of Var #'s to Convert:
                                                    4-8
Working...
Done.
```

The system response, h(λ), is a spectral multiplier used to convert raw units of MOS or SIS radiance scans C(λ) and dark scans D(λ) (both in counts) to radiometric units of radiance L(λ) (μW/cm^2/sr/nm) or irradiance E(λ) (μW/cm^2/nm) for integration times, Δt. Multipliers are

$$L(\lambda) = \frac{C(\lambda) - D(\lambda)}{\Delta t} F_W(\lambda)\, h(\lambda) \tag{1}$$

determined via laboratory calibration of L_u, E_d and E_s sensors. The immersion factor, $F_W(\lambda)$, is a spectral multiplier necessary when the calibration situation is different from that of the field-measurement. When measuring L_u and E_d underwater, the difference between the indices of refraction for air and water is accounted for by $F_W(\lambda)$. Immersion factors are only applied to MOS data. The air-water $F_W(\lambda)$ for radiance is calculated from values for indices of refraction for fused quartz (MOS radiance port), with seawater salinity of 35 PSU and temperature of 16° C (Austin, 1976). The immersion factor for irradiance must be empirically determined; we use data from Tyler and Smith (1970) for the Scripps Spectroradiometer. The radiance immersion factors are listed in Appendix 4.

NOAA_EDIT

Erroneous data generated by "bad" pixels in a silicon diode array detector must be removed and replaced with a missing-data code, i.e. NaN "Not a Number". All other processing routines check for the presence of NaN and skip processing of such *Elements*. *EDIT* prompts the user for *Variable* and *Element* ranges to be replaced.

```
NOAA> EDIT

 NOAA_EDIT:  Replace Bad Data
     rev:  22-Jul-1993

NOAA_EDIT:                Enter Range of Var #'s to Edit:
                                                     2-10
NOAA_EDIT:            Enter Range of Element #s to Edit:
                                      406,415-419,483-502
Working...
Done.
```

Currently, MOS has three unusable areas on the Blue array and one on the Red array for a total of 25 bad pixels out of 1024. These known *Elements* are the default response to the second prompt. There is currently no need to *EDIT* SIS data. In the *Variable Header Extension*, NUM_PTS_EDITED is updated with the number of bad points edited (see Appendix 5 for SIS and MOS *Extension* structures.)

NOAA_SMOOTH

MOS's holographic diffraction grating disperses a bandwidth of approximately 300 nm onto a 512 diode array detector, giving a potential spectral resolution of 0.6 nm. However, to increase sensitivity, a 250 μm wide spectrograph entrance slit leads to a 2.6 nm or 4 pixel bandwidth. This allows the option to *SMOOTH* MOS data to reduce standard error without loss of spectral information. *SMOOTH* applies an N-point running-mean, even-weight smoothing function. The user is prompted to select which *Variable* to smooth and the number of points to use for window size.

```
NOAA> SMOOTH

 NOAA_SMOOTH:  N-Point Running Mean Smooth
     rev:  22-Jul-1993

NOAA_SMOOTH:Enter Range of Variable #'s to Smooth:
                                               2-8
NOAA_SMOOTH:        Enter # Points for Window (odd):
                                                 5
Working...
Done.
```

A five point window is the default and is typically used. *SMOOTH* skips the first and last N/2 points, takes N *Elements* centered around each point, replaces any NAN's with the mean of surrounding elements, and sums the weighted N data to replace the middle *Element*. SIS E_s spectra are not smoothed.

$$\overline{X} = \sum_{j=1}^{j=M} \frac{X(\lambda_j)}{M} \tag{2}$$

Applying a running mean smooth with a 5 point window does not change the first and last 2 data *Elements*. For example, a simple 5 point spectra smoothed with a 5 point window would only update the third point.

Before: N	L_w	After: L_w
1	2.47E-1	2.47E-1
2	2.45E-1	2.45E-1
3	2.45E-1	**2.44E-1**
4	2.42E-1	2.42E-1
5	2.39E-1	2.39E-1

NOAA_ADJUST

A typical SIS or MOS file or scan-set contains ten *Variables*: one wavelength, two dark scans, five radiance or irradiance scans, and two more dark scans. *ADJUST* averages and calculates the relative error of the four spectral dark *Variables*, averages and calculates relative error for radiance, subtracts average dark from average radiance, then calculates Signal to Noise Ratio, SNR. The user is prompted for *Var#'s* of wavelength, dark, and radiance data, and *Var#'s* to save the six output spectra (saving to *Var# 0* means do not save.)

```
NOAA> ADJUST

 NOAA_ADJUST: SIS/MOS Radiometer Data Processing
        rev: 22-Jul-1993

NOAA_ADJUST:              Enter Wavelength Variable #:
                                                     1
NOAA_ADJUST:           Enter Range of Radiance Var #'s:
                                                   4-8
NOAA_ADJUST:               Enter Range of Dark Var #'s:
                                              2,3,9,10
NOAA_ADJUST:  Enter Var #'s to Save: Avr.Rad, %Err,
                           Avr.Drk, %Err, Rad-Drk, SNR
                                                 11-16
NOAA_ADJUST: Divide by MOS Integration Time (Y/N):
                                                     Y
Working...
Done.
```

Relative error is calculated as the spectral quantity, root mean square error, RMSE:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{i=N} [X_i(\lambda) - X_m(\lambda)]^2}{N}}$$

$$X_m(\lambda) = \frac{\sum_{i=1}^{i=N} X(\lambda)}{N} \qquad (3)$$

where X(λ) represents radiances from the N scans For SNR, the *signal* equals the radiance less the dark counts, while *environmental* noise is given by the error in radiance:

$$SNR(\lambda) = \frac{L_M(\lambda) - L_D(\lambda)}{RMSE_L(\lambda)} \qquad (4)$$

where $L_M(\lambda)$ is the mean radiance or irradiance, $L_D(\lambda)$ is the mean radiance or irradiance dark count and $RMSE_L(\lambda)$ is the RMSE from Eq. 3. For MOS *Variables*, data are optionally divided by the integration time. The SIS integration time is constant.

The average percent errors in the eight SeaWiFS bands are saved in the *Variable Header Description* of each %RMSE spectra. These eight mean errors are used as an indicator of "goodness" for the radiance or dark data. Also updated are the *Variable Header Extensions*: all analog values are averaged and saved. This is necessary, for example, to record with the Rad-Drk *Variable* the average depth of a MOS scan-set or the average time of a SIS surface irradiance scan-set. Average depth is read from the *Extension* during the *DERIVE* step to calculate diffuse attenuation coefficients (below). *Variable Header* scale parameters are setup and saved to allow for easy plotting.

NOAA_AVERAGE

When more than one MOS scan-sets at a particular depth are to be used, or several surface irradiance SIS sets taken at different times need combining, data can be spectrally averaged via *AVERAGE*. This program prompts the user to enter the *Var#*s to be averaged and the *Var#s* to save the mean and %RMSE. These results will not be saved if *Var#* 0 is selected.

```
NOAA> AVERAGE

 NOAA_AVERAGE: Spectral Mean & %RMSE of Vars
   rev: 22-Jul-1993

NOAA_AVERAGE:             Enter Wavelength Var #:
                                                1
NOAA_AVERAGE:   Enter Range of Var #'s to Average:
                                       2-3,9-10
NOAA_AVERAGE:            Enter Var # to save Mean:
                                               11
NOAA_AVERAGE:          Enter Var # to save %RMSE:
                                               12
Working...
Done.
```

Averages are calculated across rows to preserve spectral information. Analog data in *Variable Header Extensions* are also averaged and saved with the mean

Variable's Extension. Again, eight mean %RMSE's corresponding to the SeaWiFS bands are calculated as a quality index and saved in the %RMSE *Variable Header Description*.

NOAA_MERGE

The *MERGE* program assists the user in combining processed *Archive* files containing L_u, E_d, and E_s data into *Workspace Variables* ready for the *DERIVE* step. The *MERGE*d *Variable* order is:

Variable #
1. MOS Corrected Wavelength
2. SIS Corrected Wavelength
3,4. MOS surface E_d and SNR
5,6. SIS E_s and SNR for Top E_d
7,8. MOS surface L_u and SNR
9,10. SIS E_s and SNR for Top L_u
11-18. Mid data as *Var#* 3-10
19-26. Bot data as *Var#* 3-10.

MOS *Variables* hold 1000 *Elements* (500 pixels from each of the two diode arrays) and SIS contain only 48 (38 scan channels plus 10 references). This is why both MOS and SIS wavelength *Vars* are needed. Merge works on the manually edited MERGE.LIS;2 file that was assembled during preprocessing (page 6).

```
NOAA> MERGE

 NOAA_MERGE: Load Radiometric Archive
      rev: 22-Jul-1993

NOAA_MERGE:                          Enter Filename:
                                         MERGE.LIS;1

Loading...
```

NOAA_CLIP

This program allows spectral data with a SNR less than 100:1 to be replaced with NaN. *CLIP* prompts the user for the *Variable* range to be clipped and the value of the SNR cutoff to be used.

```
NOAA> CLIP

 NOAA_CLIP: Replace Data if SNR < 100:1
      rev: 22-Jul-1993

NOAA_CLIP:               Enter Range of Var #'s to Clip:
                                              1-25:2
                                              2-26:2

NOAA_CLIP:                           Enter SNR cutoff:
                                                 100

Working...
Done.
```

NOAA_DERIVE

From L_u, E_d, and E_s *Variables* 1-26, *DERIVE* calculates diffuse attenuation coefficients K_L and K_E, solar-normalized water-leaving radiance, L_{WN}, SeaWiFS-weighted solar-normalized water-leaving radiances in eight SeaWiFS bands, and other products such as PAR and solar inclination. K's are calculated between depths for a pair of L_u or E_d's and are corrected for differences in associated E_s's. K's are calculated between the Top and Mid depths, between Top and Bot, and between Mid and Bot. Water-leaving radiance is obtained by attenuating L_u to just below the sea surface using a K_L, then propagating $L_{u,0-}$ across the water-air interface. Four such L_w's are calculated: using the L_{u_Top} with $K_{L\_Top\text{-}Mid}$ and $K_{L\_Top\text{-}Bot}$; using L_{u_Mid} with $K_{L\_Top\text{-}Mid}$; and the L_{u_Bot} with $K_{L\_Top\text{-}Bot}$.

Between observation depths, z_1 and z_2, irradiance is assumed to attenuate by a first-order absorption and scattering with a constant attenuation coefficient, K,

$$\frac{E_{z_2}}{E_{z_1}} = e^{-K(z_2-z_1)} \qquad (5)$$

The diffuse attenuation coefficient is calculated by Eq. 6, where K denotes either K_L or K_E; X denotes either L_u or E_d spectral data; Z are depths, and subscripts 2 and 1 indicate the deeper and shoaler depths, respectively. R_N (Eq. 7) is the incident irradiance normalization ratio determined from mean, spectrally- smoothed E_s, one (E_{s1}) for the shoaler E_d or L_u, the other (E_{s2}) for the deeper E_d or L_u. K cannot be derived if either of the two L_u or E_d scans or their corresponding surface irradiances E_s are missing. E_{sr} is the reference surface irradiance. This will normally be E_s taken for the surface-most (i.e. Top) scans.

$$K = -\frac{\ln\left(\frac{X_2 R_{N2}}{X_1 R_{N1}}\right)}{(z_2-z_1)} \qquad (6)$$

$$R_{N1} = \frac{E_{sr}}{E_{s1}} \qquad R_{N2} = \frac{E_{sr}}{E_{s2}} \tag{7}$$

The depths of L_u and E_d scans are retrieved from *Variable Header Extension* analog data, converted to pressure units (dbar), corrected for "deck" pressure offset, and corrected for pressure offset between the sensor and pressure transducer. E_s spectra are used to normalize L_u and E_d scans taken under potentially different sky conditions. L_u and E_d are normalized to the time of the surface-most E_s scan. Normalization factors, R_N, can be calculated as a mean ratio or spectral ratio. For mean normalization, E_s spectra are summed across wavelengths, divided by the number of *Elements*, then ratioed. A spectral ratio is cubic spline interpolated to MOS wavelengths. If a spectral R_N ratio is used, however, MOS wavelengths outside the E_s bandwidth cannot be normalized and are replaced with NaN's.

Water-leaving radiance, L_W, is calculated by extrapolating a radiance spectrum from one Evening: (observation depth to the surface:

$$L_w = 0.543\, L_u\, e^{K_L(z_2 - z_1)} \qquad 0.543 = \frac{(1 - R_F)}{n_w^2} \tag{8}$$

where R_F is water-air Fresnel reflectance and n_w is the index of refraction for salinity of 35 PSU. L_w cannot be calculated if any one of E_s, L_u or K_L is missing. L_W's can be solar normalized by the solar normalization factor, F_N, which is a function of

$$L_{WN} = \frac{L_W}{F_N} \tag{9}$$

atmospheric Rayleigh and ozone optical thicknesses, τ_R and τ_{oz}, solar zenith angle, θ_0, and earth-sun distance, r_{es} (Eqs. 9,10,11).

The normalized SeaWiFS response functions, Wt1...Wt8, (Appendix 6) are applied by their spectral multiplication with the solar-normalized water-leaving radiances.

$$F_N = \frac{t(\lambda,\theta_0)\,(1-\rho(\theta_0))\cos(\theta}{r_{es}^2} \tag{10}$$

$$t(\lambda,\theta_0) = \exp\left(-\frac{0.5\,\tau_R + \tau_{oz}}{\cos(\theta_0)}\right)$$

The earth-sun distance r_{es} in astronomical units is given approximately by Eq. 11, where D is the Julian day of the year, and the solar zenith angle θ_0 is

$$r_{es} = 1 + 0.0167\cos\left(\frac{2\pi(D-3)}{365}\right) \tag{11}$$

determined from time of the Top L_{WN}, station latitude and longitude from MLML_DBASE library procedures based on the solar ephemeris of Von Flanderan and Pulkkinen (1979).

The eight SeaWiFS-weighted solar-normalized water-leaving radiances along with the Photosynthetically active radiation, PAR (Eq. 12), the solar zenith angle, and earth-sun distance are saved in the MOS *File Header Extensions*.

$$PAR = \sum_{\lambda=400}^{\lambda=700} \frac{\lambda}{\hat{h}c} E(\lambda)\, d\lambda \tag{12}$$

All 41 *Variables* are setup with *Header* information and scale parameters tailored to the *Var* type and units. Default scale ranges are set for L_u, E_d, E_s and L_w's while K_L and K_E scales are adjusted for their ranges. Time of each E_s set is retrieved from *Var Header Extension*, converted, formatted, and saved in the *Var's* description. Converted and corrected depth of each L_u and E_d scan is saved in their *Var* descriptions. If average incident ratios were used, the R_N value is recorded with the diffuse attenuation *Var* description.

Because all variables have been formed by previous processing the *DERIVE* program requires only two input arguments and operates on the currently loaded data:

```
NOAA> DERIVE

 NOAA_DERIVE: Derived Radiometric Parameters:
       rev: 22-Jul-1993

 Var# 1-26: Lambda*2; Ed,SNR,Es,SNR,Lu,SNR,Es,SNR*3
 Derives Var# 27-41: Ke,Kl *3; Lw *4; Lwn *4

NOAA_DERIVE:    Enter Data Units 1=Raw 2=Cnvrted:
                                                1
NOAA_DERIVE:    Enter Ratio Type 1=Mean 2=Spctrl:
                                                1
Working...
Done.
```

NOAA_GRAPH

Graphical output of spectral data is provided via *GRAPH* (Figs 1 and 2). Plots can be sent to a graphics terminal or PostScript file or printer. Color or black-and-white plots are available. Two pages are produced, each with three X-Y plots. Page one shows E_d, L_u and E_s (Fig. 1), and page two shows K_E, K_L and L_w (Fig. 2). X-axis wavelength range is selectable as either full-scale, 300 to 900 nm, or clipped, 400 to 700 nm. Y-axis units are selectable between raw units (counts/sec) and (counts), or converted units ($\mu W/cm^2/nm$) and ($\mu W/cm^2/sr/nm$). Cruise and station name, position and date (found in *File Header* strings# 1 to 3) are labeled on each page, and the user can enter an optional page title and footer to be printed. *Vars* 1 to 36 are assumed to be in the order previously described, however empty *Vars* are acceptable and do not plot.

```
NOAA> GRAPH

 NOAA_GRAPH: 2-Page 3-Panel Radiometric X-Y Plots
      rev: 22-Jul-1993

NOAA_GRAPH: Enter Output Port
           (1=FALCO 2=$LASER: 3=$LJ4: 4=File):
                                             1
NOAA_GRAPH:Enter Data Units (1=Raw, 2=Cnvrted): 1
NOAA_GRAPH:                Enter Wavelength Range
                        (1=300-900, 2=350-750 nm):
                                             1
NOAA_GRAPH:                Enter Title for each page:
    MODIS Marine Optical Characterization Experiment 1
NOAA_GRAPH:               Enter Bottom Left Footer:
                                     MLML 23 Jul 93

NOAA_GRAPH:  Color Plot? (Y/N)                    N
Working...
Plotting data...
Done.
```

NOAA_LIST

Tabular output of spectral data is provided by *LIST*. The output device is selectable as either the user's terminal, a printer, or an ASCII file. *LIST* prints columns of user selectable E_d, L_u, E_s, K_E, K_L, L_{wsn} data and rows of wavelengths at user specified intervals. Two such tables are normally produced: the first showing observed radiance and irradiance spectra for the Top, Mid and Bot depths (Fig. 3); the other showing derived attenuation coefficient and water-leaving radiance spectra (Fig. 4). Cruise and station information is labeled at the top of each page along with Secchi disk depth, Munsell color, SeaWiFS-weighted solar-normalized water-leaving radiances, PAR, solar zenith angle, and an optional user-entered title and page footer.

```
NOAA> LIST

 NOAA_LIST: Radiometric Data Report Listing
      rev: 22-Jul-1993

NOAA_LIST:       Change Output Device or File? (Y/N):
                                                   N
NOAA_LIST:              Enter Range of Var #'s to List:
                                                  ??
NOAA_LIST:          Enter Wavelength Interval to List:
                                                  ??
NOAA_LIST:                   Enter Title for each page:
  MODIS Marine Optical Characterization Experiment 1  L

Working...
Done.
```

Batch Mode Processing

NOAA/MLML data processing may be done in batch-mode to automate repetitive steps. A text file is created containing keystrokes used to invoke the *NOAA* programs and respond to program prompts. For example, a raw MOS scan-set is loaded and the first four processing programs run sequentially by the following batch file:

```
! Load the raw scan-set from disk Archive file
load
!
! apply MOS system response to Var#'s 2-10
noaa convert mos_response 2 2-10
!
! apply MOS immersion factor to Var#'s 2-10
noaa convert mos_response 3 2-10
!
```

```
! throw out MOS bad data in Var#'s 2-10
noaa edit * *
!
! smooth w/ 5 pt running mean Var#'s 2-10
noaa smooth 2-10 *
!
! subtract dark counts, get %Error
noaa adjust * * * * *
!
! plot the results
graph
!
! record processed set
record
```

Other batch files can be created to process SIS sets, *AVERAGE* multiple sets, *MERGE* processed sets, and *DERIVE* radiometric quantities. If the above file's name is PROC1.MLCOM, it is run by typing:

```
ML> @PROC1.MLCOM
```

Any lines beginning with the exclamation mark in a batch file are comments and are not executed. When a *PLOT* or *NOAA* command is missing a parameter, or is supplied an improper parameter, the program will prompt the user for necessary input. In the above batch file, for example, the *LOAD* command will prompt the user for the filename and *Variable* range to load, and at which *Workspace Variable* to begin loading. Notice the use of asterisks (*) to use default values.

NOAA_PROCESS

Batch file processing can be automated for a set of file names by using the ALIAS command. If the ALIAS file SIS.ALIAS is created at the VMS command level,

```
$ ALIAS *SIS*.MLDAT SIS
```

then all the files referenced by SIS.ALIAS can be manipulated by NOAA_PROCESS program. The aliased files are referenced by an apostrophe followed by the alias file name, for example,

'SIS.ALIAS

The NOAA_PROCESS program can invoke all NOAA programs (Table 1), which derive much of their flexibility from their ability to operate on lists of files.

Acknowledgements

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Appendix 1. SeaWiFS standard radiometry symbols.

$E_d(z,\lambda)$	Downwelled spectral irradiance at depth = z ($\mu W/cm^2/nm$)
$E_u(z,\lambda)$	Upwelled spectral irradiance at depth = z ($\mu W/cm^2/nm$)
$L_u(z,\lambda)$	Upwelled spectral radiance at depth = z ($\mu W/cm^2/nm/sr$)
$E_s(\lambda)$	Surface spectral irradiance ($\mu W/cm^2/nm$) measured on ship well above the water
$E_s(t,\lambda)$	Surface spectral irradiance measured at time = t ($\mu W/cm^2/nm$)
$E_d(0^-,\lambda)$	Surface incident spectral irradiance ($\mu W/cm^2/nm$) in-water measurement at infinitesimal depth below surface ($z = 0^-$) extrapolated from $E_d(z,\lambda)$ estimated by propagating $E_s(\lambda)$ through the sea surface from a radiometer floated just below the surface ($z = z_r$) varies due to fluctuations in cloud cover and aerosols, and time of day
$L_u(0^-,\lambda)$	Upwelled spectral radiance ($\mu W/cm^2/nm/sr$) in-water measurement at infinitesimal depth below surface ($z = 0^-$) extrapolated from $L_u(z,\lambda)$
$K(z,\lambda)$	Spectral diffuse attenuation coefficient (1/m)
$K_E(z,\lambda)$	Spectral diffuse attenuation coefficient for downwelled irradiance (1/m) derived from $E_d(z,\lambda)$ measured over upper few optical depths
$K_L(z,\lambda)$	Spectral diffuse attenuation coefficient for upwelled radiance (1/m) derived from $L_u(z,\lambda)$ measured over upper few optical depths
$K_d(z,\lambda)$	Spectral diffuse attenuation coefficient for downwelled irradiance (1/m)
$K_u(z,\lambda)$	Spectral diffuse attenuation coefficient for upwelled irradiance (1/m)
$\tau(z,\lambda)$	Spectral optical depth integral of $K(z,\lambda)$ (for either radiance or irradiance depending on context) from the surface to a given depth z
τ_{oz}	Atmospheric ozone optical thickness
τ_R	Atmospheric Rayleigh optical thickness
$L_W(\lambda)$	Water-leaving radiance ($\mu W/cm^2/nm/sr$) "measured" via propagating $L_u(0^-,\lambda)$ upward through sea surface
$L_{WN}(\lambda)$	Normalized water-leaving radiance ($\mu W/cm^2/nm/sr$) derived for clear-sky zenith sun at mean earth-sun distance
$L_u(z,\theta,\phi)$	Submerged upwelled radiance distribution ($\mu W/cm^2/nm/sr$)
$R_L(z,\lambda)$	Remote sensing reflectance $L_U(z,\lambda)/E_d(z,\lambda)$
$F_i(\lambda)$	Immersion correction factor (for radiance or irradiance)

Appendix 1. (continued) SeaWiFS standard radiometry symbols.

$h(\lambda)$	Sensor response function
$n_w(\lambda)$	Spectral index of refraction of seawater
$T_a(\lambda)$	Spectral solar atmospheric transmission
$T_s(\lambda)$	Spectral transmittance through the surface
$T_w(\lambda)$	Spectral transmittance through a water path
$a(z,\lambda)$	Spectral absorption coefficient (inherent optical property, IOP)(1/m)
$b(z,\lambda)$	Total spectral scattering coefficient (IOP) (1/m)
$c(z,\lambda)$	Spectral beam attenuation coefficient (IOP) (1/m)
$b_b(z,\lambda)$	Spectral backscattering coefficient (IOP) (1/m)
$b_r(\lambda)$	Total Raman scattering coefficient (1/m)
$\beta(z,\lambda,\theta)$	Spectral volume scattering function (IOP) (1/m)
$Q(\lambda)$	$L_u(0^-,\lambda)$ to $E_d(0^-,\lambda)$ relation factor not well determined at present (theoretically equal to π) Assumed equal to 5 at all wavelengths and depths
θ_0	Solar zenith angle
$t(\lambda,\theta_0)$	Diffuse spectral atmospheric transmittance
r_{es}	Earth-sun distance (astronomical units)
$\rho(\theta_0)$	Fresnel reflectance for the air-water interface at incident angle θ_0

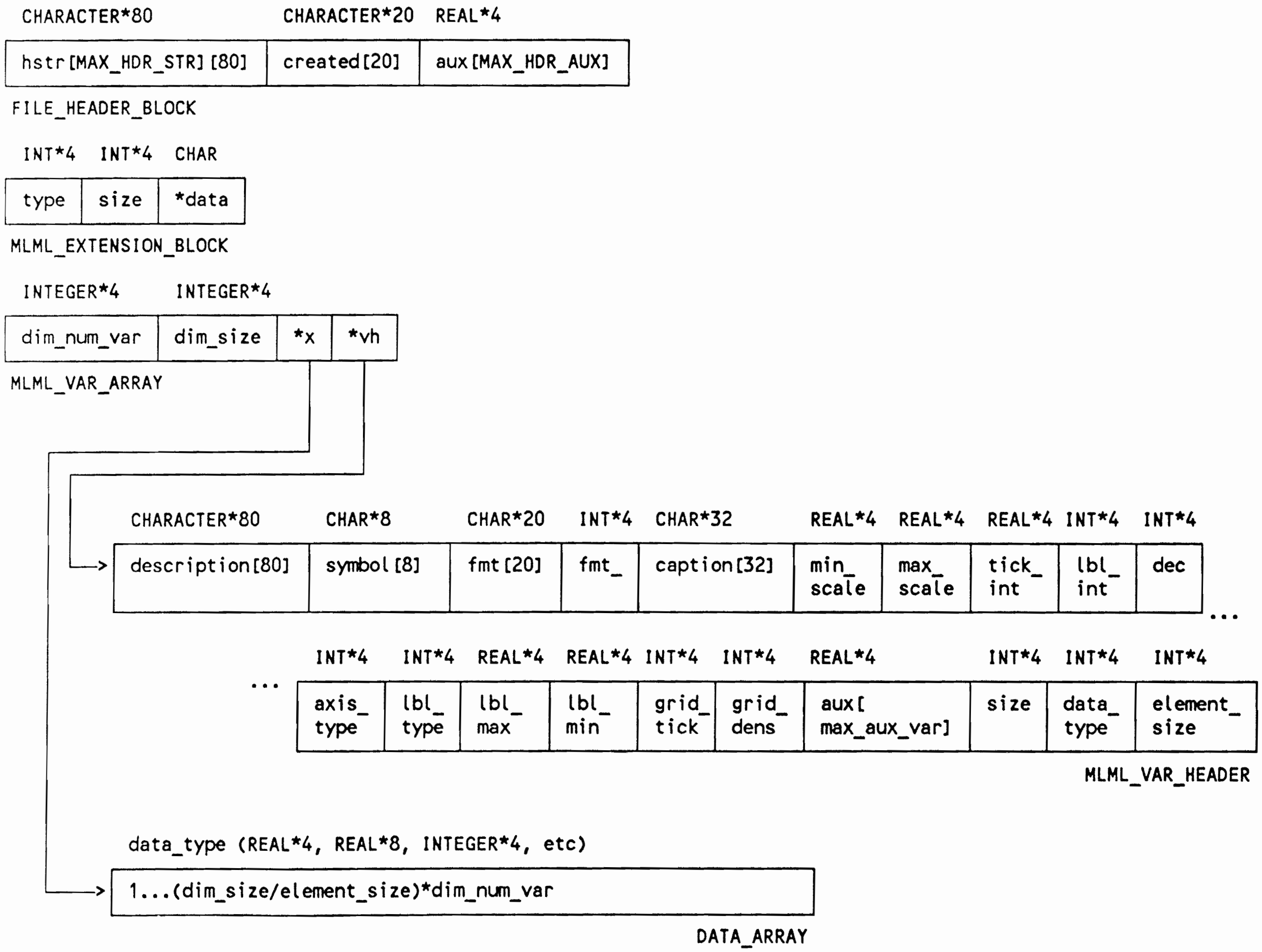
Adapted from Mueller, et al. 1991.

Appendix 2. Glossary of acronyms used in text.

Bot	Bottom or deepest sampling depth at a radiometer station
CTD	Conductivity, temperature and depth profiling instrument
CZCS	Costal Zone Color Scanner
FOV	Field-of-view
FLH	Fluorescent line height at 685 nm
FWHM	Full-width half-maximum
HPLC	High performance liquid chromatography
IOP	Inherent optical properties
IR	Infrared
Mid	Middle sampling depth at a radiometer station
MLML	Moss Landing Marine Laboratories
MOBY	Marine Optical Buoy
MOCE	Marine Optical Characterization Experiment
MOS	Marine Optical System
NAN	Not a Number, an IEEE standard value to represent missing data
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite Data Information Service
NOAA	National Oceanographic and Atmospheric Administration
PAR	Photosynthetically available radiation (400-700 nm)
SeaWiFS	Sea-viewing wide field-of-view spectrometer
SIS	Surface Irradiance Spectrometer
SNR	Signal-to-noise ratio
Top	Top sampling depth at a radiometer station
TSM	Total Suspended Material

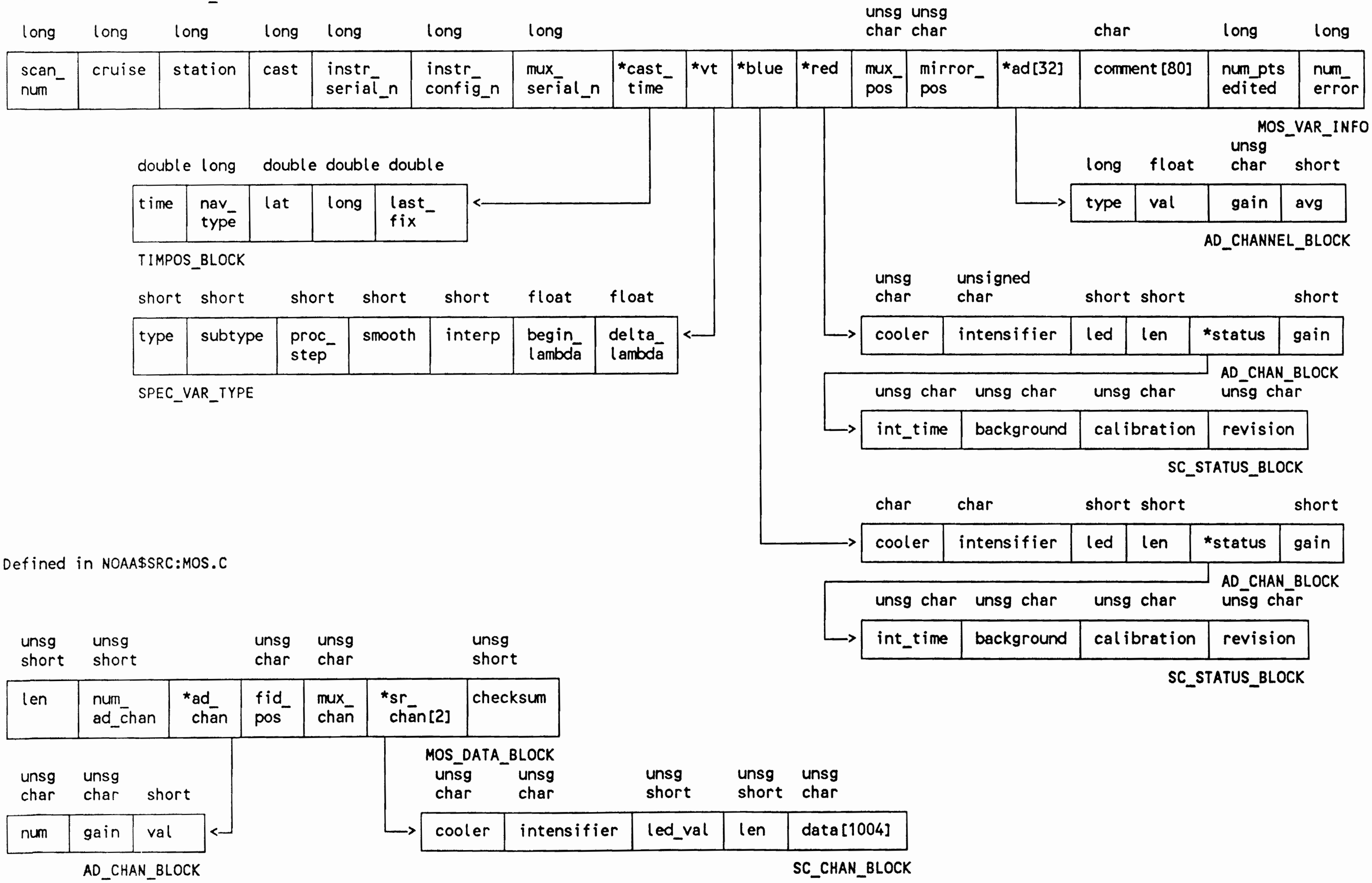
Appendix 3a. The MLML_DBASE data structure. Variable types use FORTRAN notation. Pointers to variable are shown by *.

Defined in [MLML_LIBRARY.MLCLIB]MLML_DBASE.H



Appendix 3b. Data Structures used with MOS. Variable types use C notation. Pointers to variables are shown by *. The structure, MOS_VAR_INFO, is an MLML_DBASE <u>File Header Extension</u>. The structure, MOS_DATA_BLOCK, is an MLML_DBASE <u>Variable Extension</u> and accompanies each SIS spectral <u>Variable</u>.

Defined in NOAA$DIR:MOS_TYPES.H



MOS_VAR_INFO

long	long	long	long	long	long	long					unsg char	unsg char		char	long	long
scan_num	cruise	station	cast	instr_serial_n	instr_config_n	mux_serial_n	*cast_time	*vt	*blue	*red	mux_pos	mirror_pos	*ad[32]	comment[80]	num_pts edited	num_error

TIMPOS_BLOCK

double	long	double	double	double
time	nav_type	lat	long	last_fix

SPEC_VAR_TYPE

short	short	short	short	short	float	float
type	subtype	proc_step	smooth	interp	begin_lambda	delta_lambda

AD_CHANNEL_BLOCK

long	float	unsg char	short
type	val	gain	avg

AD_CHAN_BLOCK

unsg char	unsigned char	short	short		short
cooler	intensifier	led	len	*status	gain

SC_STATUS_BLOCK

unsg char	unsg char	unsg char	unsg char
int_time	background	calibration	revision

AD_CHAN_BLOCK

char	char	short	short		short
cooler	intensifier	led	len	*status	gain

SC_STATUS_BLOCK

unsg char	unsg char	unsg char	unsg char
int_time	background	calibration	revision

Defined in NOAA$SRC:MOS.C

MOS_DATA_BLOCK

unsg short	unsg short		unsg char	unsg char		unsg short
len	num_ad_chan	*ad_chan	fid_pos	mux_chan	*sr_chan[2]	checksum

AD_CHAN_BLOCK

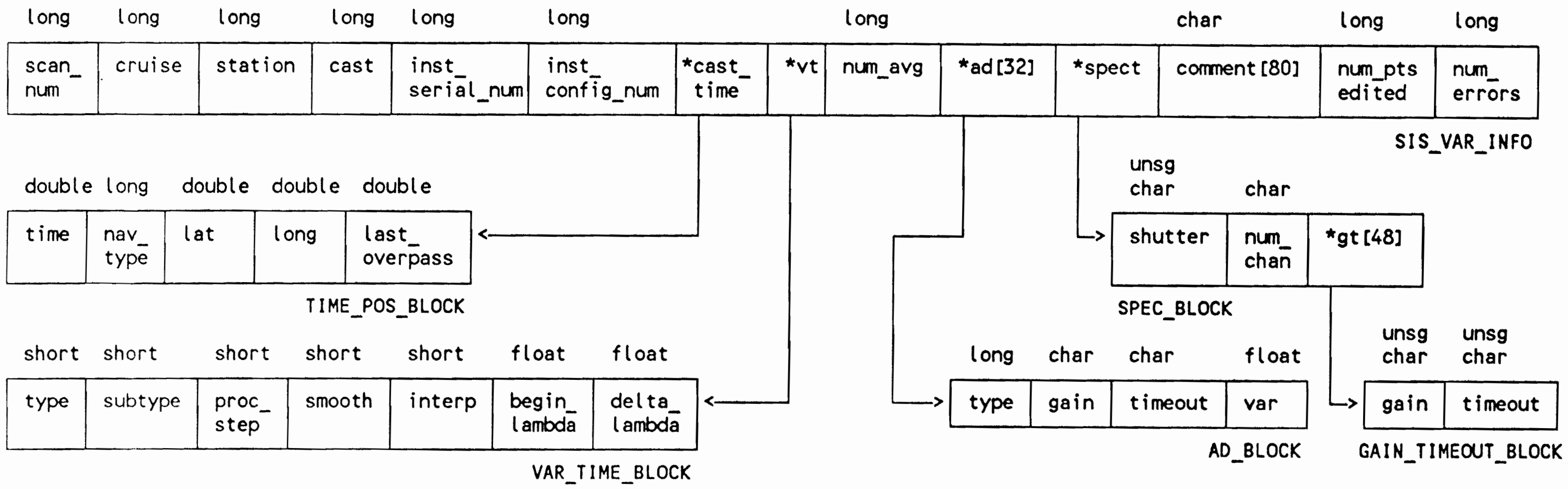
unsg char	unsg char	short
num	gain	val

SC_CHAN_BLOCK

unsg char	unsg char	unsg short	unsg short	unsg char
cooler	intensifier	led_val	len	data[1004]

Appendix 3c. Data Structures used with SIS. Variable types use C notation. Pointers to variables are shown by *. The structure, SIS_VAR_INFO, is an MLML_DBASE File Header Extension. The structure, SIS_DATA_BLOCK, is an MLML_DBASE Variable Extension and accompanies each SIS spectral Variable.

Defined in NOAA$INC:SIS_TYPES.H



long	long	long	long	long	long			long			char	long	long
scan_num	cruise	station	cast	inst_serial_num	inst_config_num	*cast_time	*vt	num_avg	*ad[32]	*spect	comment[80]	num_pts edited	num_errors

SIS_VAR_INFO

double	long	double	double	double
time	nav_type	lat	long	last_overpass

TIME_POS_BLOCK

unsg char	char	
shutter	num_chan	*gt[48]

SPEC_BLOCK

short	short	short	short	short	float	float
type	subtype	proc_step	smooth	interp	begin_lambda	delta_lambda

VAR_TIME_BLOCK

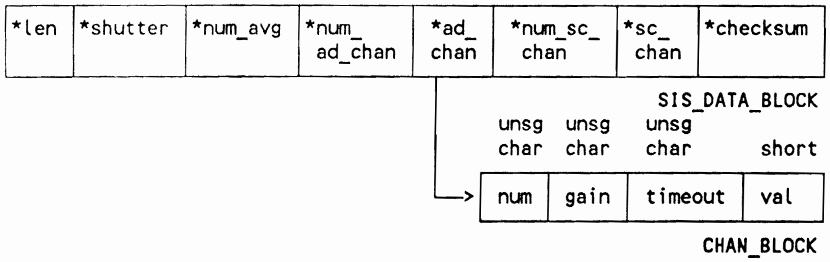
long	char	char	float
type	gain	timeout	var

AD_BLOCK

unsg char	unsg char
gain	timeout

GAIN_TIMEOUT_BLOCK

Defined in NOAA$SRC:SIS.C



*len	*shutter	*num_avg	*num_ad_chan	*ad_chan	*num_sc_chan	*sc_chan	*checksum

SIS_DATA_BLOCK

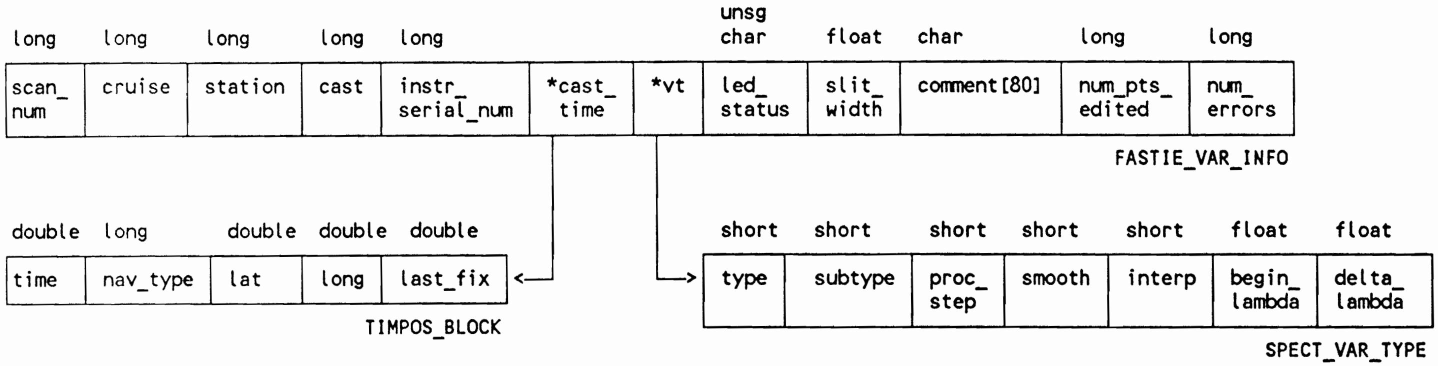
(Each pointer in SIS_DATA_BLOCK references a data element of type long that accompanies each SIS spectrum)

unsg char	unsg char	unsg char	short
num	gain	timeout	val

CHAN_BLOCK

Appendix 3d. Data structures used with Fastie. Variable types use C notation. Pointers to variables are indicated by *. The structure FASTIE_VAR_INFO is an MLML_DBASE <u>Variable Extension</u> and accompanies each <u>PLOT</u> <u>Variable</u> which contains the spectral data.

Defined in NOAA$INC:FASTIE_TYPES.H



long	long	long	long	long			unsg char	float	char	long	long
scan_num	cruise	station	cast	instr_serial_num	*cast_time	*vt	led_status	slit_width	comment[80]	num_pts_edited	num_errors

FASTIE_VAR_INFO

double	long	double	double	double
time	nav_type	lat	long	last_fix

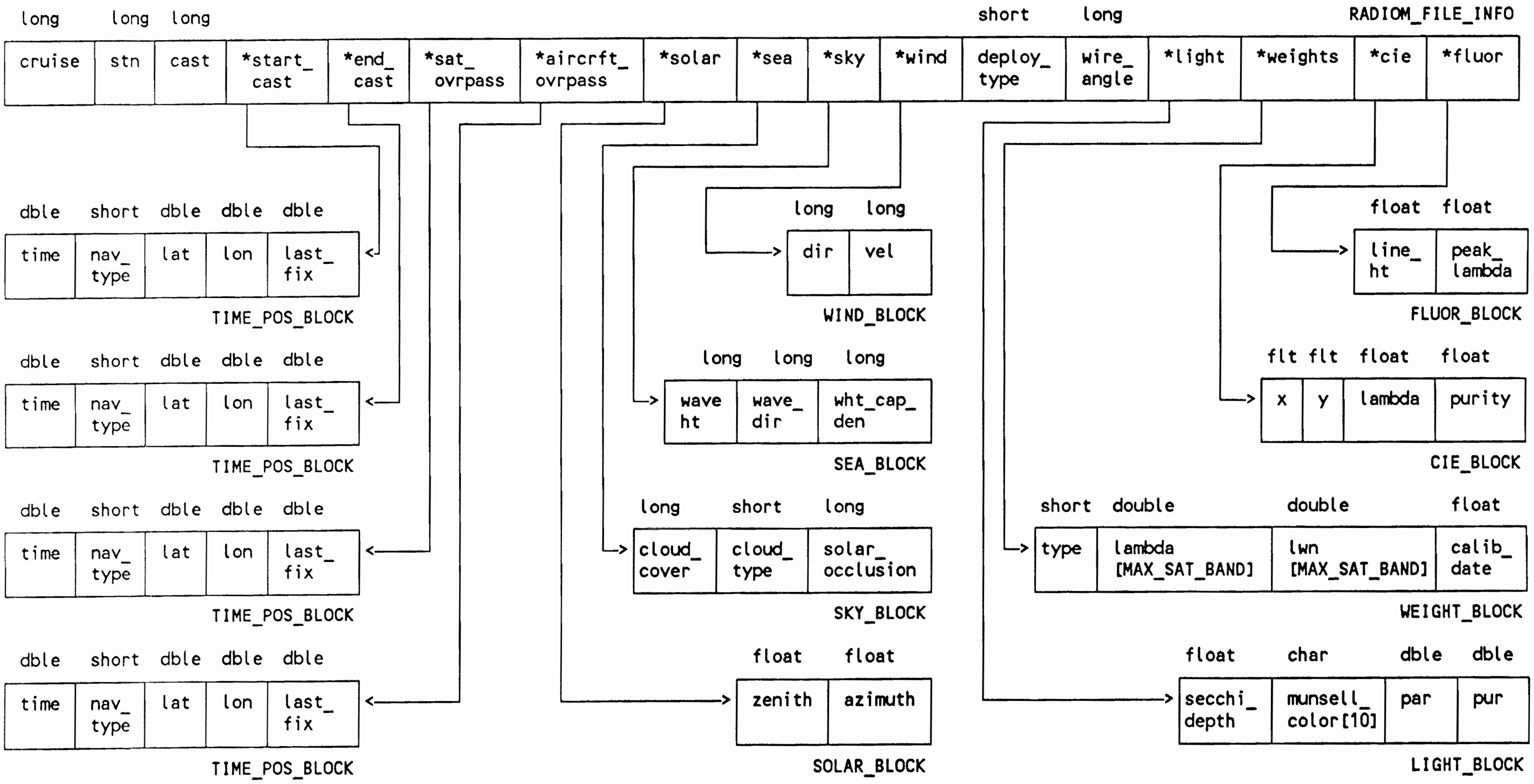
TIMPOS_BLOCK

short	short	short	short	short	float	float
type	subtype	proc_step	smooth	interp	begin_lambda	delta_lambda

SPECT_VAR_TYPE

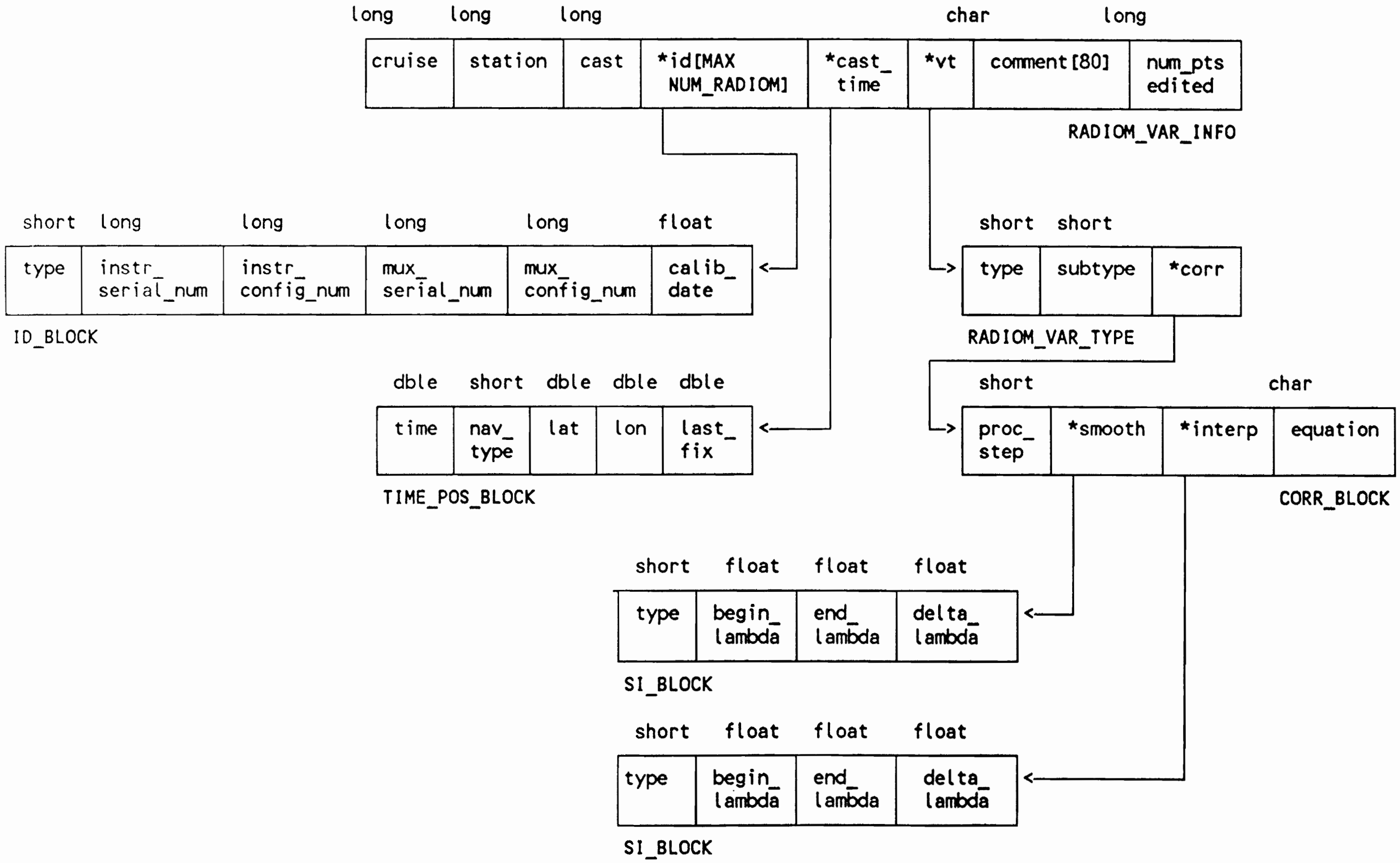
Appendix 3e. Data structures used with reduced NOAA radiometer files. Variable types use C notation. Pointers to variables are indicated by *. The structure, RADIOM_FILE_INFO, is an MLML_DBASE <u>File Header Extension</u> and accompanies each file. and accompanies each <u>PLOT</u> <u>Variable</u> which contains the spectral data.

Defined in NOAA$INC:RADIOM_TYPES.H



Appendix 3e. (continued) Data structures used with reduced NOAA radiometer files. Variable types use C notation. Pointers to variables are indicated by *. The structure, The structure, RADIOM_VAR_INFO, is an MLML_DBASE Variable Extension and accompanies each PLOT Variable which contains the spectral data.

Defined in NOAA$DIR:RADIOM_TYPES.H



long	long	long				char	long
cruise	station	cast	*id[MAX NUM_RADIOM]	*cast_time	*vt	comment[80]	num_pts edited

RADIOM_VAR_INFO

short	long	long	long	long	float
type	instr_serial_num	instr_config_num	mux_serial_num	mux_config_num	calib_date

ID_BLOCK

short	short	
type	subtype	*corr

RADIOM_VAR_TYPE

dble	short	dble	dble	dble
time	nav_type	lat	lon	last_fix

TIME_POS_BLOCK

short			char
proc_step	*smooth	*interp	equation

CORR_BLOCK

short	float	float	float
type	begin_lambda	end_lambda	delta_lambda

SI_BLOCK

short	float	float	float
type	begin_lambda	end_lambda	delta_lambda

SI_BLOCK

Appendix 4. Spectral quantities used in radiometer algorithms.

a) Air-water radiance immersion factors (Austin, 1976)

$$n = n_0 + \frac{C}{\lambda - \lambda_0}$$

$$F_w = n_w \frac{(n_w + n_g)^2}{(1 + n_g)^2}$$

Material	n_0	C	λ_0
Seawater 35 psu 16° C	1.32640	5.7689	159.0698
Plexiglass	1.47380	7.5	174.71
Borosilicate BK7	1.49891	7.61821	161.5089
Fused Quartz	1.44291	6.8244	149.724

Air-Water Radiance Factors

Wavelength	Plexiglass	BK7 Glass	Fused Quartz
360	1.765	1.761	1.771
380	1.759	1.755	1.766
400	1.754	1.750	1.761
420	1.750	1.746	1.756
440	1.746	1.742	1.753
460	1.743	1.739	1.749
480	1.740	1.736	1.746
500	1.738	1.734	1.744
520	1.736	1.732	1.742
540	1.734	1.730	1.740
560	1.732	1.728	1.738
580	1.731	1.727	1.736
600	1.729	1.725	1.735
620	1.728	1.724	1.734
640	1.727	1.723	1.732
660	1.726	1.722	1.731
680	1.725	1.721	1.730
700	1.724	1.720	1.729
720	1.723	1.719	1.728
740	1.722	1.718	1.728

Appendix 4. Spectral quantities used in radiometer algorithms.

b) SeaWiFS Normalized Response Functions as applied to the prototype MOS.

λ	Band 1	λ	Band 2	λ	Band 3	λ	Band 4	λ	Band 5	λ	Band 6	λ	Band 7	λ	Band 8
385.8	0.000E+0	409.7	0.000E+0	462.3	0.000E+0	480.2	0.000E+0	525.2	0.000E+0	639.8	0.000E+0	734.9	0.000E+0	835.0	0.000E+0
386.4	5.984E-5	410.4	6.218E-5	462.9	2.901E-6	480.8	8.531E-5	525.9	4.387E-5	640.5	1.032E-4	735.5	2.195E-3	835.6	1.266E-3
387.0	1.438E-4	411.0	3.572E-5	463.5	8.067E-7	481.4	9.029E-5	526.5	7.896E-5	641.1	1.287E-4	736.1	2.498E-3	836.2	1.400E-3
387.7	2.658E-4	411.6	5.409E-6	464.1	3.961E-8	482.0	1.139E-4	527.1	1.207E-4	641.8	1.387E-4	736.7	2.932E-3	836.8	1.575E-3
388.3	4.000E-4	412.3	4.374E-5	464.7	1.236E-9	482.6	1.585E-4	527.7	2.040E-4	642.4	2.833E-4	737.4	3.382E-3	837.4	1.739E-3
388.9	2.151E-4	412.9	1.503E-4	465.4	1.632E-0	483.3	7.972E-5	528.3	7.094E-5	643.1	3.211E-4	738.0	3.930E-3	838.0	1.997E-3
389.6	6.392E-5	413.5	9.511E-5	466.0	1.573E-1	483.9	1.426E-4	528.9	1.143E-4	643.7	3.114E-4	738.6	4.506E-3	838.5	2.317E-3
390.2	1.510E-4	414.1	9.856E-5	466.6	2.118E-2	484.5	1.904E-4	529.5	7.412E-5	644.4	3.176E-4	739.2	5.182E-3	839.1	2.710E-3
390.8	5.001E-4	414.8	1.086E-4	467.2	2.774E-3	485.1	1.273E-4	530.1	1.520E-4	645.0	3.712E-4	739.9	5.962E-3	839.7	3.051E-3
391.4	3.793E-4	415.4	1.981E-4	467.8	2.888E-4	485.7	2.166E-4	530.7	1.155E-4	645.7	4.726E-4	740.5	6.828E-3	840.3	3.550E-3
392.1	1.792E-4	416.0	3.044E-4	468.5	4.096E-5	486.3	2.780E-4	531.3	1.083E-4	646.3	5.157E-4	741.1	7.769E-3	840.9	4.076E-3
392.7	3.024E-5	416.7	1.551E-4	469.1	5.910E-6	486.9	3.870E-4	531.9	4.107E-5	647.0	5.256E-4	741.7	8.743E-3	841.5	4.730E-3
393.3	6.146E-4	417.3	1.522E-4	469.7	7.681E-7	487.6	4.407E-4	532.5	9.267E-5	647.6	5.545E-4	742.4	9.800E-3	842.0	5.466E-3
394.0	2.195E-4	417.9	1.142E-4	470.3	9.333E-8	488.2	5.430E-4	533.1	2.372E-4	648.3	6.268E-4	743.0	1.088E-2	842.6	6.222E-3
394.6	2.685E-4	418.5	1.730E-4	470.9	1.463E-9	488.8	5.847E-4	533.7	2.880E-4	648.9	6.061E-4	743.6	1.204E-2	843.2	7.068E-3
395.2	3.787E-4	419.2	2.615E-4	471.5	1.704E-0	489.4	7.364E-4	534.3	2.772E-4	649.6	7.475E-4	744.2	1.322E-2	843.8	8.068E-3
395.9	8.087E-4	419.8	3.048E-4	472.2	2.011E-1	490.0	9.789E-4	534.8	3.551E-4	650.2	8.270E-4	744.9	1.435E-2	844.4	9.139E-3
396.5	1.215E-3	420.4	2.346E-4	472.8	2.375E-2	490.6	1.182E-3	535.4	4.599E-4	650.9	9.871E-4	745.5	1.554E-2	844.9	1.035E-2
397.1	1.690E-3	421.1	2.940E-4	473.4	2.940E-3	491.2	1.484E-3	536.0	5.706E-4	651.5	1.142E-3	746.1	1.665E-2	845.5	1.164E-2
397.8	2.315E-3	421.7	3.464E-4	474.0	3.665E-4	491.9	1.832E-3	536.6	7.265E-4	652.2	1.340E-3	746.7	1.769E-2	846.1	1.292E-2
398.4	3.291E-3	422.3	3.843E-4	474.6	4.672E-5	492.5	2.333E-3	537.2	9.316E-4	652.8	1.626E-3	747.3	1.864E-2	846.7	1.424E-2
399.0	5.271E-3	422.9	6.227E-4	475.3	6.062E-6	493.1	2.837E-3	537.8	1.337E-3	653.5	2.032E-3	748.0	1.958E-2	847.3	1.554E-2
399.7	6.349E-3	423.6	6.052E-4	475.9	7.556E-7	493.7	3.642E-3	538.4	1.590E-3	654.1	2.665E-3	748.6	2.034E-2	847.8	1.677E-2
400.3	8.530E-3	424.2	7.762E-4	476.5	9.519E-8	494.3	4.555E-3	539.0	2.061E-3	654.8	3.430E-3	749.2	2.100E-2	848.4	1.802E-2
400.9	1.270E-2	424.8	1.114E-3	477.1	1.181E-9	494.9	5.678E-3	539.6	2.765E-3	655.4	4.615E-3	749.8	2.160E-2	849.0	1.917E-2
401.5	1.591E-2	425.5	1.458E-3	477.7	1.470E-0	495.5	7.184E-3	540.2	3.613E-3	656.1	6.368E-3	750.5	2.211E-2	849.6	2.004E-2
402.2	1.940E-2	426.1	1.628E-3	478.3	1.772E-1	496.1	9.063E-3	540.8	4.788E-3	656.7	8.924E-3	751.1	2.251E-2	850.1	2.095E-2
402.8	2.375E-2	426.7	2.050E-3	479.0	2.084E-2	496.7	1.114E-2	541.4	6.586E-3	657.4	1.244E-2	751.7	2.277E-2	850.7	2.172E-2
403.4	2.803E-2	427.3	2.751E-3	479.6	2.404E-3	497.4	1.380E-2	542.0	8.549E-3	658.0	1.692E-2	752.3	2.302E-2	851.3	2.230E-2
404.1	3.224E-2	428.0	3.557E-3	480.2	2.731E-4	498.0	1.655E-2	542.6	1.117E-2	658.7	2.226E-2	752.9	2.327E-2	851.9	2.281E-2
404.7	3.219E-2	428.6	4.534E-3	480.8	3.065E-5	498.6	1.947E-2	543.2	1.437E-2	659.3	2.803E-2	753.5	2.347E-2	852.4	2.316E-2
405.3	3.327E-2	429.2	5.857E-3	481.4	3.367E-6	499.2	2.279E-2	543.8	1.807E-2	660.0	3.393E-2	754.2	2.356E-2	853.0	2.354E-2
406.0	3.490E-2	429.8	7.478E-3	482.0	3.585E-7	499.8	2.593E-2	544.4	2.239E-2	660.6	3.943E-2	754.8	2.378E-2	853.6	2.372E-2
406.6	3.787E-2	430.5	9.405E-3	482.6	3.808E-8	500.4	2.900E-2	545.0	2.694E-2	661.3	4.364E-2	755.4	2.379E-2	854.2	2.391E-2
407.2	3.988E-2	431.1	1.163E-2	483.3	4.000E-9	501.0	3.208E-2	545.6	3.183E-2	661.9	4.636E-2	756.0	2.386E-2	854.7	2.404E-2
407.9	3.893E-2	431.7	1.425E-2	483.9	4.143E-0	501.6	3.527E-2	546.2	3.613E-2	662.6	4.764E-2	756.6	2.387E-2	855.3	2.420E-2
408.5	4.109E-2	432.3	1.720E-2	484.5	4.259E-1	502.2	3.772E-2	546.8	3.993E-2	663.2	4.755E-2	757.3	2.397E-2	855.9	2.430E-2
409.1	4.376E-2	433.0	2.031E-2	485.1	4.371E-2	502.8	3.897E-2	547.4	4.328E-2	663.9	4.697E-2	757.9	2.402E-2	856.5	2.436E-2
409.7	4.242E-2	433.6	2.374E-2	485.7	4.409E-3	503.5	4.033E-2	548.0	4.583E-2	664.5	4.627E-2	758.5	2.404E-2	857.0	2.447E-2
410.4	4.260E-2	434.2	2.708E-2	486.3	4.447E-4	504.1	4.120E-2	548.5	4.700E-2	665.2	4.564E-2	759.1	2.413E-2	857.6	2.456E-2
411.0	4.380E-2	434.9	2.978E-2	486.9	4.505E-5	504.7	4.144E-2	549.1	4.749E-2	665.8	4.534E-2	759.7	2.402E-2	858.2	2.468E-2
411.6	4.373E-2	435.5	3.242E-2	487.6	4.473E-6	505.3	4.152E-2	549.7	4.800E-2	666.5	4.538E-2	760.3	2.393E-2	858.7	2.467E-2
412.3	4.379E-2	436.1	3.450E-2	488.2	4.412E-7	505.9	4.141E-2	550.3	4.820E-2	667.1	4.576E-2	761.0	2.399E-2	859.3	2.470E-2
412.9	4.420E-2	436.7	3.601E-2	488.8	4.365E-8	506.5	4.112E-2	550.9	4.854E-2	667.8	4.594E-2	761.6	2.398E-2	859.9	2.479E-2

Appendix 4. Spectral quantities used in radiometer algorithms.
b) (continued) SeaWiFS Normalized Response Functions as applied to the prototype MOS.

λ	Band 1	λ	Band 2	λ	Band 3	λ	Band 4	λ	Band 5	λ	Band 6	λ	Band 7	λ	Band 8
413.5	4.658E-2	437.4	3.708E-2	489.4	4.333E-9	507.1	4.064E-2	551.5	4.828E-2	668.4	4.634E-2	762.2	2.392E-2	860.4	2.475E-2
414.1	4.840E-2	438.0	3.761E-2	490.0	4.319E-0	507.7	4.017E-2	552.1	4.814E-2	669.1	4.663E-2	762.8	2.384E-2	861.0	2.475E-2
414.8	5.012E-2	438.6	3.928E-2	490.6	4.312E-1	508.3	3.988E-2	552.7	4.826E-2	669.7	4.693E-2	763.4	2.381E-2	861.6	2.470E-2
415.4	5.015E-2	439.2	4.053E-2	491.2	4.293E-2	508.9	3.940E-2	553.3	4.854E-2	670.4	4.705E-2	764.0	2.375E-2	862.1	2.463E-2
416.0	4.948E-2	439.9	4.188E-2	491.9	4.287E-3	509.5	3.950E-2	553.9	4.894E-2	671.0	4.684E-2	764.7	2.375E-2	862.7	2.449E-2
416.7	4.895E-2	440.5	4.237E-2	492.5	4.286E-4	510.1	3.970E-2	554.5	4.925E-2	671.7	4.692E-2	765.3	2.371E-2	863.3	2.445E-2
417.3	4.850E-2	441.1	4.255E-2	493.1	4.309E-5	510.7	4.003E-2	555.1	4.954E-2	672.3	4.689E-2	765.9	2.371E-2	863.8	2.443E-2
417.9	4.824E-2	441.7	4.348E-2	493.7	4.317E-6	511.4	4.036E-2	555.6	4.962E-2	673.0	4.670E-2	766.5	2.370E-2	864.4	2.425E-2
418.5	4.820E-2	442.4	4.427E-2	494.3	4.329E-7	512.0	4.078E-2	556.2	4.993E-2	673.6	4.629E-2	767.1	2.369E-2	865.0	2.401E-2
419.2	4.767E-2	443.0	4.537E-2	494.9	4.283E-8	512.6	4.109E-2	556.8	5.044E-2	674.3	4.551E-2	767.7	2.367E-2	865.5	2.375E-2
419.8	4.601E-2	443.6	4.622E-2	495.5	4.317E-9	513.2	4.175E-2	557.4	5.064E-2	674.9	4.441E-2	768.3	2.370E-2	866.1	2.359E-2
420.4	4.390E-2	444.2	4.668E-2	496.1	4.339E-0	513.8	4.210E-2	558.0	5.049E-2	675.6	4.265E-2	769.0	2.367E-2	866.6	2.323E-2
421.1	4.095E-2	444.8	4.655E-2	496.7	4.252E-1	514.4	4.248E-2	558.6	4.985E-2	676.2	4.028E-2	769.6	2.378E-2	867.2	2.293E-2
421.7	3.817E-2	445.5	4.719E-2	497.4	4.137E-2	515.0	4.264E-2	559.2	4.890E-2	676.9	3.723E-2	770.2	2.381E-2	867.8	2.266E-2
422.3	3.483E-2	446.1	4.790E-2	498.0	3.953E-3	515.6	4.256E-2	559.8	4.750E-2	677.5	3.372E-2	770.8	2.381E-2	868.3	2.235E-2
422.9	3.150E-2	446.7	4.836E-2	498.6	3.710E-4	516.2	4.214E-2	560.4	4.568E-2	678.2	2.980E-2	771.4	2.381E-2	868.9	2.193E-2
423.6	2.761E-2	447.3	4.803E-2	499.2	3.449E-5	516.8	4.207E-2	560.9	4.318E-2	678.8	2.571E-2	772.0	2.381E-2	869.4	2.163E-2
424.2	2.369E-2	448.0	4.708E-2	499.8	3.120E-6	517.4	4.126E-2	561.5	4.047E-2	679.4	2.180E-2	772.6	2.384E-2	870.0	2.135E-2
424.8	1.964E-2	448.6	4.677E-2	500.4	2.770E-7	518.0	4.051E-2	562.1	3.743E-2	680.1	1.812E-2	773.2	2.383E-2	870.5	2.115E-2
425.5	1.613E-2	449.2	4.606E-2	501.0	2.397E-8	518.6	3.910E-2	562.7	3.390E-2	680.7	1.472E-2	773.9	2.371E-2	871.1	2.096E-2
426.1	1.300E-2	449.8	4.483E-2	501.6	2.051E-9	519.2	3.734E-2	563.3	3.008E-2	681.4	1.199E-2	774.5	2.360E-2	871.7	2.071E-2
426.7	9.702E-3	450.5	4.367E-2	502.2	1.703E-0	519.8	3.493E-2	563.9	2.632E-2	682.0	9.836E-3	775.1	2.353E-2	872.2	2.057E-2
427.3	7.157E-3	451.1	4.259E-2	502.8	1.360E-1	520.4	3.188E-2	564.5	2.280E-2	682.7	7.970E-3	775.7	2.333E-2	872.8	2.037E-2
428.0	5.213E-3	451.7	4.050E-2	503.5	1.076E-2	521.0	2.839E-2	565.0	1.926E-2	683.3	6.434E-3	776.3	2.309E-2	873.3	2.036E-2
428.6	3.971E-3	452.3	3.858E-2	504.1	8.465E-3	521.6	2.450E-2	565.6	1.596E-2	684.0	5.254E-3	776.9	2.281E-2	873.9	2.038E-2
429.2	2.811E-3	452.9	3.647E-2	504.7	6.570E-4	522.2	2.079E-2	566.2	1.316E-2	684.6	4.297E-3	777.5	2.242E-2	874.4	2.035E-2
429.8	2.133E-3	453.6	3.313E-2	505.3	5.049E-5	522.8	1.748E-2	566.8	1.073E-2	685.3	3.550E-3	778.1	2.190E-2	875.0	2.049E-2
430.5	1.576E-3	454.2	2.917E-2	505.9	3.950E-6	523.4	1.425E-2	567.4	8.655E-3	685.9	2.899E-3	778.7	2.130E-2	875.5	2.064E-2
431.1	1.202E-3	454.8	2.546E-2	506.5	3.075E-7	524.0	1.149E-2	568.0	6.934E-3	686.5	2.403E-3	779.3	2.060E-2	876.1	2.080E-2
431.7	9.717E-4	455.4	2.090E-2	507.1	2.409E-8	524.6	8.789E-3	568.6	5.623E-3	687.2	1.968E-3	780.0	1.982E-2	876.6	2.112E-2
432.3	7.927E-4	456.1	1.669E-2	507.7	1.947E-9	525.2	6.622E-3	569.1	4.589E-3	687.8	1.671E-3	780.6	1.898E-2	877.2	2.141E-2
433.0	6.997E-4	456.7	1.313E-2	508.3	1.471E-0	525.9	4.908E-3	569.7	3.745E-3	688.5	1.433E-3	781.2	1.795E-2	877.7	2.180E-2
433.6	5.828E-4	457.3	1.007E-2	508.9	1.197E-1	526.5	3.614E-3	570.3	3.071E-3	689.1	1.284E-3	781.8	1.690E-2	878.3	2.214E-2
434.2	5.340E-4	457.9	7.546E-3	509.5	9.784E-2	527.1	2.617E-3	570.9	2.544E-3	689.8	1.006E-3	782.4	1.587E-2	878.8	2.241E-2
434.9	4.667E-4	458.5	5.627E-3	510.1	8.496E-3	527.7	1.865E-3	571.5	2.152E-3	690.4	8.370E-4	783.0	1.484E-2	879.4	2.271E-2
435.5	4.279E-4	459.2	4.171E-3	510.7	6.774E-4	528.3	1.370E-3	572.1	1.846E-3	691.1	7.071E-4	783.6	1.383E-2	879.9	2.301E-2
436.1	3.887E-4	459.8	3.139E-3	511.4	5.680E-5	528.9	1.013E-3	572.6	1.630E-3	691.7	6.072E-4	784.2	1.284E-2	880.4	2.321E-2
436.7	3.526E-4	460.4	2.344E-3	512.0	4.486E-6	529.5	7.785E-4	573.2	1.466E-3	692.3	5.312E-4	784.8	1.182E-2	881.0	2.330E-2
437.4	2.925E-4	461.0	1.807E-3	512.6	4.029E-7	530.1	6.170E-4	573.8	1.180E-3	693.0	4.509E-4	785.4	1.076E-2	881.5	2.326E-2
438.0	2.495E-4	461.6	1.281E-3	513.2	3.507E-8	530.7	4.917E-4	574.4	1.042E-3	693.6	4.062E-4	786.0	9.749E-3	882.1	2.313E-2
438.6	2.360E-4	462.3	9.671E-4	513.8	2.813E-9	531.3	3.791E-4	575.0	8.951E-4	694.3	3.446E-4	786.6	8.899E-3	882.6	2.268E-2
439.2	2.354E-4	462.9	7.725E-4	514.4	2.566E-0	531.9	3.161E-4	575.6	6.720E-4	694.9	3.128E-4	787.3	8.061E-3	883.1	2.212E-2
439.9	2.273E-4	463.5	6.015E-4	515.0	2.275E-1	532.5	2.445E-4	576.1	7.904E-4	695.5	2.319E-4	787.9	7.254E-3	883.7	2.142E-2
440.5	0.000E+0	464.1	5.336E-4	515.6	1.800E-2	533.1	2.074E-4	576.7	6.373E-4	696.2	2.362E-4	788.5	6.524E-3	884.2	2.057E-2

Appendix 4. Spectral quantities used in radiometer algorithms.
b) (continued) SeaWiFS Normalized Response Functions as applied to the prototype MOS.

λ	Band 1	λ	Band 2	λ	Band 3	λ	Band 4	λ	Band 5	λ	Band 6	λ	Band 7	λ	Band 8
		464.7	3.528E-4	516.2	1.711E-3	533.7	1.438E-4	577.3	5.747E-4	696.8	1.910E-4	789.1	5.890E-3	884.8	1.952E-2
		465.4	2.790E-4	516.8	1.265E-4	534.3	1.041E-4	577.9	4.586E-4	697.5	2.004E-4	789.7	5.280E-3	885.3	1.816E-2
		466.0	2.707E-4	517.4	1.426E-5	534.8	7.188E-5	578.5	4.319E-4	698.1	1.520E-4	790.3	4.738E-3	885.8	1.676E-2
		466.6	1.785E-4	518.0	1.087E-6	535.4	5.647E-5	579.0	3.664E-4	698.8	1.791E-4	790.9	4.275E-3	886.4	1.531E-2
		467.2	7.003E-5	518.6	1.266E-7	536.0	3.891E-5	579.6	3.163E-4	699.4	1.256E-4	791.5	3.878E-3	886.9	1.393E-2
		467.8	5.464E-5	519.2	9.967E-8	536.6	3.544E-5	580.2	2.253E-4	700.0	1.034E-4	792.1	3.513E-3	887.4	1.253E-2
		468.5	4.399E-5	519.8	6.882E-9	537.2	3.812E-5	580.8	2.907E-4	700.7	0.000E+0	792.7	3.202E-3	888.0	1.108E-2
		469.1	8.728E-5	520.4	0.000E+0	537.8	9.822E-6	581.3	2.400E-4			793.3	2.862E-3	888.5	9.776E-3
		469.7	2.362E-5			538.4	1.447E-5	581.9	1.958E-4			793.9	2.629E-3	889.0	8.573E-3
		470.3	0.000E+0			539.0	1.497E-5	582.5	1.710E-4			794.5	2.404E-3	889.5	7.545E-3
						539.6	3.778E-5	583.1	1.656E-4			795.1	1.874E-3	890.1	6.629E-3
						540.2	0.000E+0	583.7	1.688E-4			795.7	0.000E+0	890.6	5.849E-3
														891.1	5.163E-3
														891.6	4.557E-3
														892.2	4.077E-3
														892.7	3.677E-3
														893.2	3.270E-3
														893.7	2.919E-3
														894.2	2.587E-3
														894.8	2.667E-3
														895.3	1.364E-3
														895.8	0.000E+0

Appendix 4. Spectral quantities used in radiometer algorithms.
c) Rayleigh and ozone atmospheric optical thicknesses. τ_{oz} from Howard Gordon (personal communication).

λ (nm)	τ_R	τ_{oz}
340	0.7062	0.0188
345	0.6653	0.0070
350	0.6273	0.0032
355	0.5919	0.0007
360	0.5590	0.0000
365	0.5283	0.0000
370	0.4997	0.0000
375	0.4730	0.0000
380	0.4480	0.0000
385	0.4247	0.0000
390	0.4029	0.0000
395	0.3824	0.0000
400	0.3632	0.0000
405	0.3452	0.0000
410	0.3283	0.0000
415	0.3124	0.0000
420	0.2975	0.0000
425	0.2834	0.0000
430	0.2702	0.0003
435	0.2577	0.0007
440	0.2459	0.0010
445	0.2348	0.0010
450	0.2243	0.0010
455	0.2144	0.0018
460	0.2050	0.0029
465	0.1962	0.0029
470	0.1878	0.0025
475	0.1798	0.0043
480	0.1723	0.0065
485	0.1651	0.0072
490	0.1583	0.0065
495	0.1519	0.0079
500	0.1458	0.0101
505	0.1399	0.0137
510	0.1344	0.0145
515	0.1292	0.0137
520	0.1241	0.0163
525	0.1194	0.0195
530	0.1148	0.0228
535	0.1105	0.0254
540	0.1064	0.0261
545	0.1024	0.0279
550	0.0987	0.0304
555	0.0951	0.0323
560	0.0917	0.0348
565	0.0884	0.0388
570	0.0853	0.0421
575	0.0823	0.0431
580	0.0794	0.0424
585	0.0767	0.0402
590	0.0740	0.0392
595	0.0715	0.0417
600	0.0691	0.0450
605	0.0668	0.0450
610	0.0646	0.0428
615	0.0625	0.0402
620	0.0604	0.0377
625	0.0585	0.0352
630	0.0566	0.0326
635	0.0548	0.0301
640	0.0531	0.0279
645	0.0514	0.0254
650	0.0498	0.0232
655	0.0483	0.0214
660	0.0468	0.0199
665	0.0454	0.0185
670	0.0440	0.0166
675	0.0427	0.0152
680	0.0414	0.0137
685	0.0402	0.0123
690	0.0390	0.0108
695	0.0379	0.0090
700	0.0368	0.0079
705	0.0357	0.0075
710	0.0347	0.0064
715	0.0337	0.0057
720	0.0328	0.0052
725	0.0318	0.0047
730	0.0310	0.0042
735	0.0301	0.0038
740	0.0293	0.0034
745	0.0285	0.0031
750	0.0277	0.0028
755	0.0270	0.0025
760	0.0263	0.0022
765	0.0256	0.0020
770	0.0249	0.0018
775	0.0242	0.0016
780	0.0236	0.0015
785	0.0230	0.0013
790	0.0224	0.0012
795	0.0218	0.0011
800	0.0213	0.0009
805	0.0207	0.0008
810	0.0202	0.0008
815	0.0197	0.0007
820	0.0192	0.0006
825	0.0188	0.0005
830	0.0183	0.0005
835	0.0178	0.0004
840	0.0174	0.0004
845	0.0170	0.0003
850	0.0166	0.0003
855	0.0162	0.0003
860	0.0158	0.0002
865	0.0154	0.0002
870	0.0151	0.0002
875	0.0147	0.0002
880	0.0144	0.0001
885	0.0141	0.0001
890	0.0137	0.0001
895	0.0134	0.0001
900	0.0131	0.0001

Appendix 5. File Naming Conventions and Directory Structures.

Device Names for Program and Data Directories:

```
  NSF::DUA1:                 ! VAX 4000 Model 300        System Device = _DUA0:
HYDRA::DKA300:               ! VAXstation 4000 model 60  System Device = _DKA300:
SISSR::DKA100:               ! VAXstation 4000 model 60  System Device = _DKA300:
```

Data Directories:

```
[DATA]
  [DATA.COM]                     ! Data directory         eg. SETUP.COM
  [DATA.COLLATED]                ! Collated data          eg. CZCS_RESPONSES.MLDAT LW_SN_CZCS_PIGS.MLDAT
  [DATA.cruise]                  ! Cruise subdirectory    eg. MOCE_1 MOBY_2
    [DATA.cruise.DOC]            ! Cruise documentation   eg. STATION_LOG.TXT DATA_PROCESSING_SUMMARY.TXT
    [DATA.cruise.MOS]
      [DATA.cruise.MOS.CAL]      ! Calibration data       eg. OPT420_S3W6D40_00CM_025SEC_01.MLDAT
      [DATA.cruise.MOS.RAW]      ! Raw cruise data        eg. STN01_01M_ED_01.MLDAT
      [DATA.cruise.MOS.PRC]      ! Processed data         eg. STN01_01M_ED_01_PROC.MLDAT
    [DATA.cruise.SIS]
      [DATA.cruise.SIS.CAL]      ! Calibration data       eg. FEL_50CM_100AVG_01.MLDAT
      [DATA.cruise.SIS.RAW]      ! Raw cruise data        eg. STN01_WMOS_01M_ED_01.MLDAT
      [DATA.cruise.SIS.PRC]      ! Processed data         eg. STN01_WMOS_01M_ED_01_PROC.MLDAT
    [DATA.cruise.FASTIE]
      [DATA.cruise.FASTIE.CAL]   ! Calibration data       eg. OPT420_S3W6D40_03CM_1000V_01.MLDAT
      [DATA.cruise.FASTIE.RAW]   ! Raw cruise data        eg. STN01_01M_1KV_01SEC_01.MLDAT
      [DATA.cruise.FASTIE.PRC]   ! Processed data         eg. STN01_01M_1KV_01SEC_01_PROC.MLDAT
    [DATA.cruise.CTD]
      [DATA.cruise.CTD.CAL]      ! Calibration data       eg. CTD_CALIB.TXT
      [DATA.cruise.CTD.RAW]      ! Raw cruise data        eg. CTD_5000A_RAW.MLDAT
      [DATA.cruise.CTD.PRC]      ! Processed data         eg. ROSETTE_BOTTLE_DATA.MLDAT
      [DATA.cruise.CTD.TMP]      ! Temporary data         eg. CTD_BUF_01SEP92_1720.DAT
    [DATA.cruise.TRANS]
      [DATA.cruise.TRANS.CAL]    ! Calibration data
      [DATA.cruise.TRANS.RAW]    ! Raw cruise data
      [DATA.cruise.TRANS.PRC]    ! Processed data
    [DATA.cruise.SPECTROM]       ! Spectrophotometer
    [DATA.cruise.LONGTRACK]      ! Horizontal profiling   eg. STN01_TURNER.MLDAT
    [DATA.cruise.STATION]        ! Ancillary data         eg. STN01_PUMP_CHL.MLDAT
    [DATA.cruise.RADIOMETRIC]    ! Final processed        eg. MOCE01_STN01.MLDAT
    [DATA.cruise.ETC]            ! Misc.
```

MLML_DBASE Directories

```
[MLDBASE]
  [MLDBASE.BIN]                  ! Executable files       eg. MLML_ENTER.EXE
  [MLDBASE.COM]                  ! VMS Command files
  [MLDBASE.DOC]                  ! Documentation      eg. MLML_DBASE_INTRO.WP5
  [MLDBASE.ETC]                  ! Misc.                  eg. TIDE_STATIONS.MLDAT
  [MLDBASE.INC]                  ! Include files          eg. MLML_DBASE.H MLML_DBASE.FOR
  [MLDBASE.LIB]                  ! Library files
  [MLDBASE.SRC]                  ! Source code files      eg. MLML_ENTER.FOR
  [MLDBASE.TMP]                  ! Temporary files        eg. ?
```

Appendix 5. (continued) File Naming Conventions and Data Directory Structure.

Program Directories:

```
[MLLIBRARY]
  [MLLIBRARY.BIN]                ! Executable files      eg. HPL.EXE
  [MLLIBRARY.DOC]                ! Documentation
  [MLLIBRARY.LIB]                ! Library files         eg. MLCLIB.TLB MLLIB.OLB
  [MLLIBRARY.INC]                ! Include files
  [MLLIBRARY.SRC]                ! Source code files     eg. C_FILES.C UNESCO_83.FOR


[NOAA]                           ! Login directory       eg. LOGIN.COM DECW*.*
  [NOAA.BIN]                     ! Executable files      eg. MOS.EXE SIS.EXE
  [NOAA.COM]                     ! VMS Command files     eg. MOS.COM SIS.COM
  [NOAA.DOC]                     ! Documentation         eg. DATA_PROCESSING.TXT MOS_SETUP.WP5
  [NOAA.ETC]                     ! Misc.
  [NOAA.INC]                     ! Include files         eg. MOS_TYPES.H
  [NOAA.LIB]                     ! Library files
  [NOAA.SRC]                     ! Source code files     eg. MOS.C SIS.C
  [NOAA.TMP]                     ! Temporary files       eg. ?
  [NOAA.DATA_FLEX]               ! DATAFLEX files        eg. EQUIPMENT.FRM .FLX .DAT
  [NOAA.FORTH]                   ! FORTH code files      eg. MOS.SCR

[CTD]                            ! Login directory       eg. LOGIN.COM DECW*.*
  [CTD.BIN]                      ! Executable files      eg. MLML_CTD_ACQ.EXE
  [CTD.COM]                      ! VMS Command files     eg. START_CTD.COM
  [CTD.DOC]                      ! Doccumentation        eg. CTD_SETUP.WP5
  [CTD.ETC]                      ! Misc.
  [CTD.INC]                      ! Include files         eg. CTD_TYPES.H
  [CTD.LIB]                      ! Library files         eg.
  [CTD.SRC]                      ! Source code files     eg. MLML_CTD_ACQ.C
  [CTD.TMP]                      ! Temporary files       eg. ?
```

Appendix 5. (continued) Logical Name Table used in NOAA data processing programs.

VMS Logicals:

```
Setup by SYS$MANAGER:SETUP_NOAA_LOGICALS.COM:

$ DEFINE/EXEC/SYS    NOAA$ROOT        USER$DEV:[NOAA.]
$ DEFINE/EXEC/SYS    NOAA$DIR         USER$DEV:[NOAA]
$ DEFINE/EXEC/SYS    NOAA$SRC         NOAA$ROOT:[SRC]
$ DEFINE/EXEC/SYS    NOAA$BIN         NOAA$ROOT:[BIN]
$ DEFINE/EXEC/SYS    NOAA$COM         NOAA$ROOT:[COM]
$ DEFINE/EXEC/SYS    NOAA$LIB         NOAA$ROOT:[LIB]
$ DEFINE/EXEC/SYS    NOAA$INC         NOAA$ROOT:[INC]
$ DEFINE/EXEC/SYS    NOAA$DOC         NOAA$ROOT:[DOC]
$ DEFINE/EXEC/SYS    NOAA$ETC         NOAA$ROOT:[ETC]
$ DEFINE/EXEC/SYS    NOAA$TMP         NOAA$ROOT:[TMP]
$ DEFINE/EXEC/SYS    NOAA$FORTH       NOAA$ROOT:[FORTH]
$ DEFINE/EXEC/SYS    NOAA$SCRATCH     NOAA$TMP

Setup by SYS$MANAGER:SETUP_CTD_LOGICALS.COM:

$ DEFINE/EXEC/SYS    CTD$ROOT         USER$DEV:[CTD.]
$ DEFINE/EXEC/SYS    CTD$DIR          USER$DEV:[CTD]
$ DEFINE/EXEC/SYS    CTD$SRC          CTD$ROOT:[SRC]
$ DEFINE/EXEC/SYS    CTD$BIN          CTD$ROOT:[BIN]
$ DEFINE/EXEC/SYS    CTD$COM          CTD$ROOT:[COM]
$ DEFINE/EXEC/SYS    CTD$LIB          CTD$ROOT:[LIB]
$ DEFINE/EXEC/SYS    CTD$INC          CTD$ROOT:[INC]
$ DEFINE/EXEC/SYS    CTD$DOC          CTD$ROOT:[DOC]
$ DEFINE/EXEC/SYS    CTD$ETC          CTD$ROOT:[ETC]
$ DEFINE/EXEC/SYS    CTD$TMP          CTD$ROOT:[TMP]
$ DEFINE/EXEC/SYS    CTD$SCRATCH      CTD$TMP

Setup by USER$DEV:[DATA.COM]SETUP.COM:

$ DEFINE/EXEC/SYS    DATA             USER$DEV:[DATA.cruise.]
```

VMS Symbols:

```
Setup by USER$DEV:[NOAA]LOGIN.COM:

$ MOS        :== @NOAA$COM:MOS
$ SIS        :== @NOAA$COM:SIS
$ FASTIE     :== @NOAA$COM:FASTIE
$ GPS        :== SUBMIT/LOG=DATA:[STATION]GPS.LOG/NAME=GPS_LOGGER NOAA$COM:START_GPS

Setup by USER$DEV:[CTD]LOGIN.COM:

$ CTD        :== @CTD$COM:START_CTD_ACQ
$ GPS        :== SUBMIT/LOG=DATA:[STATION]GPS.LOG/NAME=GPS_LOGGER NOAA$COM:START_GPS
```

```
Setup by USER$DEV:[CTD]LOGIN.COM:

$ CTD        :== @CTD$COM:START_CTD_ACQ
$ GPS        :== SUBMIT/LOG=DATA:[STATION]GPS.LOG/NAME=GPS_LOGGER NOAA$COM:START_GPS
```