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MODIS Team Member -Quarterly Report
Marine Optical Characterizations
July-September 1995

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NOAA/NESDIS

SUMMARY

During the past three months, the MOCE Team conducted two field experiments in Mill Creek,Chesapeake Bay, from July 24 to August 4, and at the MOBY operations site at Snug Harbor, Honolulu, Hawaii, from August 15-30, prepared two technical memoranda, and continued MOCE-2 and MOCE-3 data reduction. The primary purposes of the experiments were to test the SeaWiFS "remote sensing reflectance" protocol, obtain turbid water data for ocean color satellite algorithm development, perform calibration for both NIR and Visible Rainbow Spectrometer system, continue assembling the operational Marine Optical Buoy, and to test the MOBY cellular phone communications link at the Lanai mooring site.

MOCE/TURBID 3 EXPERIMENTS

A series of measurements were conducted at Mill Creek, (a northwestern Chesapeake Bay tributary) to verify the "remote sensing reflectance" protocols and examine the polarization effects, which are not presently considered by the protocol. Sky, water, and plaque polarization were measured using a linear polarizer and a photodiode at zenith angle of 20 degrees and azimuth angles of 90, 95, 100, 105, 120, and 135 degrees relative to the sun (Figure 1). Visible and NIR casts were performed with 1 mm bare fiber and the Collector Head from the surface down to a depth of 50 cm in very turbid waters to provide data for the atmospheric correction algorithm (Figure 2). Coincident phytoplankton pigment concentrations, total suspended material, and particle absorption water samples were collected.

The following personnel participated:

NOAA - Dennis Clark, Yuntao Ge, Phil Hovey, Ed King, Eric Stengel, Marilyn Yuen, Larisa Koval
CHORS - Chuck Trees

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MOBY-L10/TURBID-4 EXPERIMENT

The MOCE team was in Hawaii, from August 15-30, to continue assembling the Marine Optical Buoy (MOBY) and to obtain additional turbid water data for ocean color satellite algorithm development. Radiance and irradiance data in the visible (380-730 nm) and near IR (560-1100 nm) regions were collected to quantify measurement fluctuations due to wave focusing and water molecule backscattering, instrument self-shading effects, and sky polarization effects. Turbid water profiles were obtained using both the Rainbow Spectrometer system and a turbid water profiling system (fluorescence, beam attenuation, and depth) to provide data for the atmospheric correction algorithm.

The following personnel participated:

NOAA - Dennis Clark, Yuntao Ge, Phil Hovey, Ed King, Eric Stengel,
Marilyn Yuen, Larisa Koval
CHORS - Chuck Trees
MLML - Mark Yarbrough, Yong-Sung Kim

Wavelength calibration was carried out for both the NIR and Visible Rainbow Spectrometer systems using Krypton, Mercury, and Neon lamps. It was found that both systems have a linear wavelength-pixel relationship.

NIR system:
- o left channel: wavelength=1127.53-4.16867*pixel
- o right channel: wavelength=38.6112+4.13781*pixel

Visible system:
- o left channel: wavelength=715.914-2.74262*pixel
- o right channel: wavelength=41.5030+2.73912*pixel

The accuracy of this calibration was verified by using a He-Ne laser emitting at 543.5 nm and a photo-diode laser emitting at 670 nm.

Radiance calibration was carried out for both the NIR and Visible Rainbow Spectrometer systems using the Optronic 420M integrating sphere. The following configurations were calibrated:

- o 1 mm fiber with radiance collector head
- o 1 mm bare fiber
- o 1 mm bare fiber with a field-of-view limiter

Irradiance calibration was performed for both Rainbow Systems using the standard lamp GS922. System response for the NIR and Visible Rainbow Spectrometer Systems is illustrated in Figures 3 and 4. The long term stability of both Rainbow

Systems will be monitored using an RS-10 reference lamp. The following configurations were calibrated:

- o Irradiance head with 200 micron fiber
- o Radiance head with 200 micron fiber
- o 1 mm bare fiber

A submersible platform was built to hold the Sea-Tech transmissometer, Wet Labs fluorometer, and a depth transducer in order to provide high sensitivity bio-optics within the first several meters of water depth (Turbid Water Profiling System) (Figure 5). This new system was used with the Visible Rainbow system to obtain turbid water profile data.

A set of observations was performed in an effort to quantify the effects of sky polarization and self-shading. To simulate the self-shading of the in-water optical instruments, several disks of different diameter were used (Figure 6). The results are being evaluated.

Remote sensing reflectance was measured according to the SeaWiFS protocol and technique used by Ken Carder. The effect of solar zenith angle on the remote sensing reflectance is shown in Figure 7 and illustrates that the large errors exist due to polarization. Improvement in the protocol is being recommended based on these data.

MOCE INSTRUMENTATION

Instrumentation Hardware Status

As shown in Table 1, the majority of the MOCE instrumentation is fully functional. Exceptions to this are the MOS-2, Martec transmissometer, HHCRM, and NIST radiometer, which are in the testing and evaluation stage. The AC-9, VLST, scattering meter, photosynthetron, sky camera, air temperature and relative humidity sensors, towed paravane system, and diver calibration lamps, are either being modified or refurbished.

The two new mobile labs were delivered to Moss Landing Marine Laboratories and will be shipped to Hawaii.

Instrumentation Software Status

With the exception of MOS-2, all of the data acquisition software is fully functional (Table 2). No progress has been made on MOS-2 software since the last report. When the new spectrographs from American Holographics have been installed, the final stages of software testing will begin. The majority of the data processing routines are fully functional with modifications being implemented into AC-9 and HP spectrophotometer processing software, and with the scattering meter, particle counter, and sky camera processing software in development and testing.

MARINE OPTICAL BUOY

Software development

Updating window software from UIS windows to Xwindows version 11 (also called DECwindows) was completed. Three types of window software required modification: text, menu, and graphics. The text window is used to display data in a simple text form and includes scrolling. The menu window displays choices to control execution of a data acquisition (or any) program, for example, the graphics window plots data from instruments.

The reasons for this conversion are several: (1) to increase speed, (2) to make the software compatible with machines running Xwindows, (3) UIS is proprietary software of DEC and is not supported across other manufacturer's machines, (4) to allow Xwindows to be displayed on different machines that have an X11 server, and (5) UIS does not support colors, while Xwindows allows up to 256 colors to distinguish plotted data.

The UIS routines required driver software to emulate Xwindows which consume CPU time. An increased speed, by a factor of five, is realized for the next window. No change is observed in the menu window. The graph window, however, is slower by a factor between one and three. The major cause of this time consumption is that text rotation transposes a text image bit by bit. A second cause might be that Xwindows uses protocol language between the client and server so windows can be displayed across networked machines.

Low level Xwindows routines (XLIB) are used to replace the UIS routines. Although the details between XLIB and UIS routines differ somewhat, the basic graphic concepts are identical so the conversion was accomplished with minimum difficulty. The major difficulty was that Xwindows does not support text scaling and rotation.

Commercially available PC software is being evaluated for data acquisition and data processing capabilities. The software chosen includes LabView, HP VEE, HP BASIC, MATLAB and IDL. This is the first step towards moving data acquisition and data processing from the VAXstation to DOS machines to simplify our computer requirements.

Hardware development

MOS

All of the internal modification parts for MOS have been fabricated and anodized. Little more can be done in assembling MOS until the spectrographs arrive from American Holographics. Mounting locations for the power supplies, coolant pump, and flow sensor have not been determined. The work is continuing on the mechanical elements of the cooling system and on the MOS wiring harnesses.

MOBY PROTOTYPE

The MOBY test controller (previously deployed at the MOBY site) was recovered. The controller ran properly the entire time on its backup battery. It was impossible to contact the controller by cell phone because the modem had failed. Destructive testing of the controller and modem on Oahu isolated the problem to overheating of the modem. The temperatures inside the unshaded controller box can be in excess of 60°C which appears to be the temperature where the modems are damaged. In order to avoid this condition, the modems were heat sinked and the controller unit shaded. Shading reduced the controller temperature by about 20°C. Even though the modem appears to function well under these conditions, its use during midday hours will be avoided as an added precaution.

An attempt was made to redeploy the MOBY test controller at the Lanai site. This attempt was thwarted due to poor sea conditions and failure of the MOBY cell phone transceiver. The cell transceiver was damaged during reassembly of the controller. The cell transceiver was later repaired and the controller is functional. The MOBY test controller is currently on Maui island.

Some communications tests were performed from California with the unit on shore in Maui. This testing demonstrated that the MOBY files (250 kb) must be broken into smaller files for reliable transmission. Presently, 150 kb file transfers to the MOBY site in Hawaii and 30 kb file transfer to Moss Landing Marine Labs in California are possible. File transfers are limited by the length of the time the modems can stay connected. To eliminate the possibility of the MOBY controller receiving potentially system-crashing characters, the modems must be configured for a "high reliability only" mode of operation. This operating mode requires a minimum level of signal quality between the modems. The modems disconnect when signal quality drops to this base signal level. Signal degradation caused by the cell phone connection and the long distance connections is additive and results in shorter connection periods between the modems.

The solution is to support partial file transfers from MOBY. This change is currently implementing in the MOBY system. In the operational mode the files will be dumped scan by scan from MOBY to the VAX machine at Snug Harbor and then Internet the files from Hawaii to California. This will allow us to eliminate the poor quality long distance connection from the already marginal cell phone link to MOBY. It will also save money by eliminating the toll charge for the Hawaii to California transfer.

MOBY-2

The RSI fiber-optic collector heads, GFO fibers, and fiber feedthroughs were delivered to Hawaii. Some of the mechanical assembly tasks on MOBY-2 and MOBY-3 were completed during the Hawaii trip. The new collector heads were fitted to the arms and the battery cables were assembled. The access hatches were added to the lower instrument bay and the parts were made to adjust the position of the solar panels to fit the new electrical boxes. The electrical assembly of the solar panels was finished and each unit has been load tested.

DATA REDUCTION

MOCE-2

The reconstruction of MOCE-2 data sets is continuing. VLST vertical data set is not finished because of the trouble with the depth register utility. A system of extracting the data through a series of hand operations using spread sheets has been developed. This data set will be completed and checked. Scanning of MOCE-2 skycam data is completed. The movies and still pictures were created and digitized.

MOCE-3

The work is continuing on processing radiometric data from the MOCE-3 cruise. During the previous MOCE cruises it became apparent that there was a problem matching processed spectra from the blue and red spectrographs where their wavelength ranges overlapped. The size and "direction" of this overlap offset changes between consecutive scan sets and throughout the cruise. Possible explanations for this discrepancy include:

- o Array temperature variations may effect system response.
- o Instrument temperature variations may effect dichroic transmission spectra.
- o Instrument temperature variations may effect dichroic wavelength response.
- o Pixel shifts from spectrographs may offset wavelengths.
- o Wavelength calibration may not match in overlap region.
- o System response may not be linear with integration time.
- o Integration times may not be exact.
- o Dark current may drift during the course of a scan set.
- o System and/or environmental noise may shift blue signal relative to red.

- o Data processing step(s) may create/increase the offset.
- o Surface wave focusing may not be being averaged out.

After conducting many exploratory tests on the data base, the preliminary conclusion is that the offsets are produced by a combination of inexact integration time and high environmental noise level. Integration time is selected from seven values (0.25, 0.5, 1, 2, 4, 8, 16 sec) and is set by the SC controller. If one integration time is not exactly a factor of two different from the next time, system response (expressed in ADU counts per second) will not be exactly valid. This was found to be the case when a system response derived from a radiance calibration at 1/1 sec blue/red integration time was applied to a 1/0.5 sec radiance scan of the same source and the blue/red overlap did not exactly match (Figure 8). The photometrics CCD controller in MOS-2 provides increased user control of integration time, so this contribution to the overlap problem may be solved on MOS-2.

In the 78 processed scan-sets from MOCE-3, there were 25 instances where the overlap offset relative to the signal at 609 nm was greater than 1/SNR from the blue array at 609 nm. Of the 25 cases, 6 had overlap offsets more than a few percent greater than the total blue and red environmental noise. This indicates that the size of the overlap offset is comparable to the environmental noise level (Table 3). Again, MOS-2 should solve this problem with increased SNR by lowering dark counts and allowing longer integration times. A test of this hypothesis would be to collect many scans to average and reduce environmental noise, the size of the overlap offset should thus be reduced.

Alternatively, environmental noise due to periodic fluctuations of the underwater light field (caused by surface wave focusing) may be aliased by the integration times. Collecting more observations, either by increasing integration time per scan or by increasing the number of scans, should decrease this effect.

For the MOCE-3 experiments, the blue and red spectrographs were modified in an attempt to account for drifting dark count levels during a scan-set by "masking" a series of pixels at the far end of each diode array. The masked pixels' level during a "lite" scan can be compared to levels during a "dark" scan and any offset applied to all unmasked "lite" pixel levels. We modified the dark-adjust software to process masked pixel information. Table 4 shows these offsets for one MOCE-3 station. Masked pixel offsets during both calibration and field scans appeared random, and processing with masked pixel offsets in system response and field scans did not reduce the overlap offset (Tables 3, 4). The temperature of the cooled array seemed not to correlate with the size or direction of the overlap offset. Masked pixel offsets also showed no relationship to array temperatures. It is not yet clear if internal instrument temperature is related to these offsets (via response of the dichroic mirror).

Occasionally, the output from the spectrographs is randomly shifted by +/- 1 pixel. The source of this problem is in the SC controller. This random shift could affect the wavelength fit in the overlap but probably not affect the intensity offset. The new spectrographs in MOS-2 should eliminate this problem. Wavelength calibration of blue and red arrays in the overlap region may not exactly match because different equations are used for the two spectrographs to fit the line source calibration points.

Based on the preliminary conclusion that the overlap offset was "in the noise," field data were reprocessed by subtracting the offset at 609 nm from the blue array data before deriving attenuation coefficients and water-leaving radiances. System response was derived without processing masked-pixel offsets. This effectively reduced the spiking when scans were ratioed to calculate attenuation coefficients. The magnitude of the offsets for each scan set is given in Table 3.

New beta corrections for spectral photometric particle absorption measurements were developed and applied to the MOCE-3 data.

The MOCE-3 VLST vertical data set is not finished, again due to trouble with the depth register utility.

A database program was designed and created to manage the MOCE team's photographic database.

DOCUMENTATION

Moss Landing Marine Laboratories personnel have prepared two technical memoranda:

Feinholz, M.E. (1995) File structure for Marine Optical Buoy and Marine Optics System data. MLML Technical Memorandum 95-2. 25 pp.

Gashler, J.A., W.W.Broenkow, and M.E.Feinholz (1995) MOBY pressure and inclination 26 February to 22 March 1994. MLML Technical Memorandum 95-3. 15 pp.

SeaWiFS Review

A SeaWiFS prelaunch review took place at NASA/GSFC, 8-10 August 1995. D. Clark presented progress made by the MOCE team since last December, and Dr. W. Broenkow from Moss Landing Marine Laboratories presented the status of the upgraded MOBY.

SUPPORTING GRANTS AND INTERAGENCY ACTIONS

The Research and Data Systems (RDS) Corporation science support contract has been initiated.

A one year site support contract to the University of Hawaii has been initiated.

Funds were transferred to NSF UNOLS for University of Hawaii ship time support.

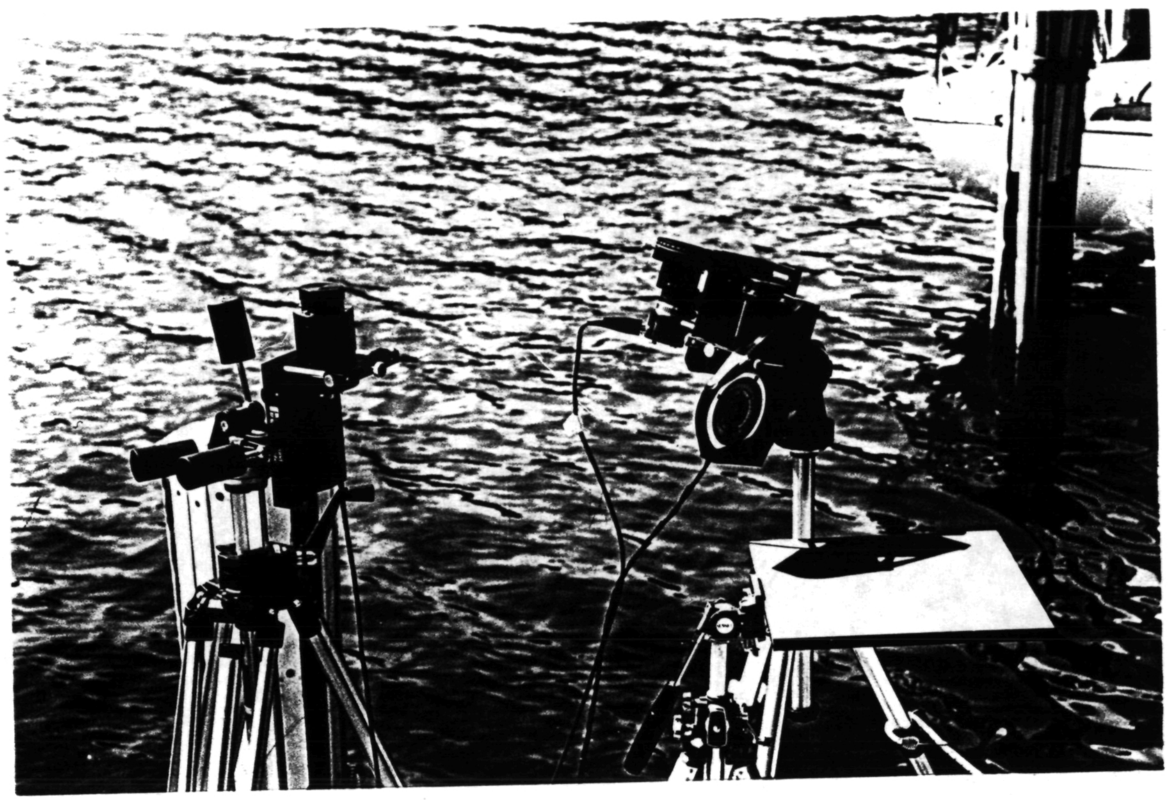


FIGURE 1.

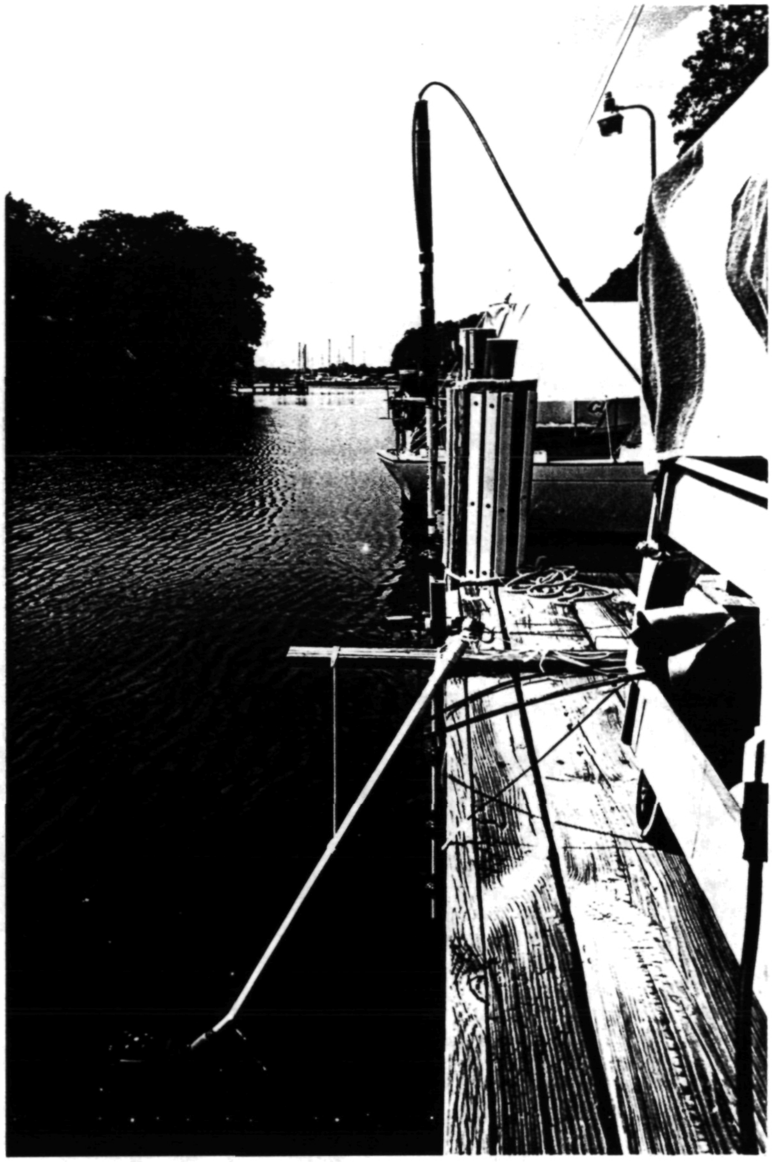


FIGURE 2.

@

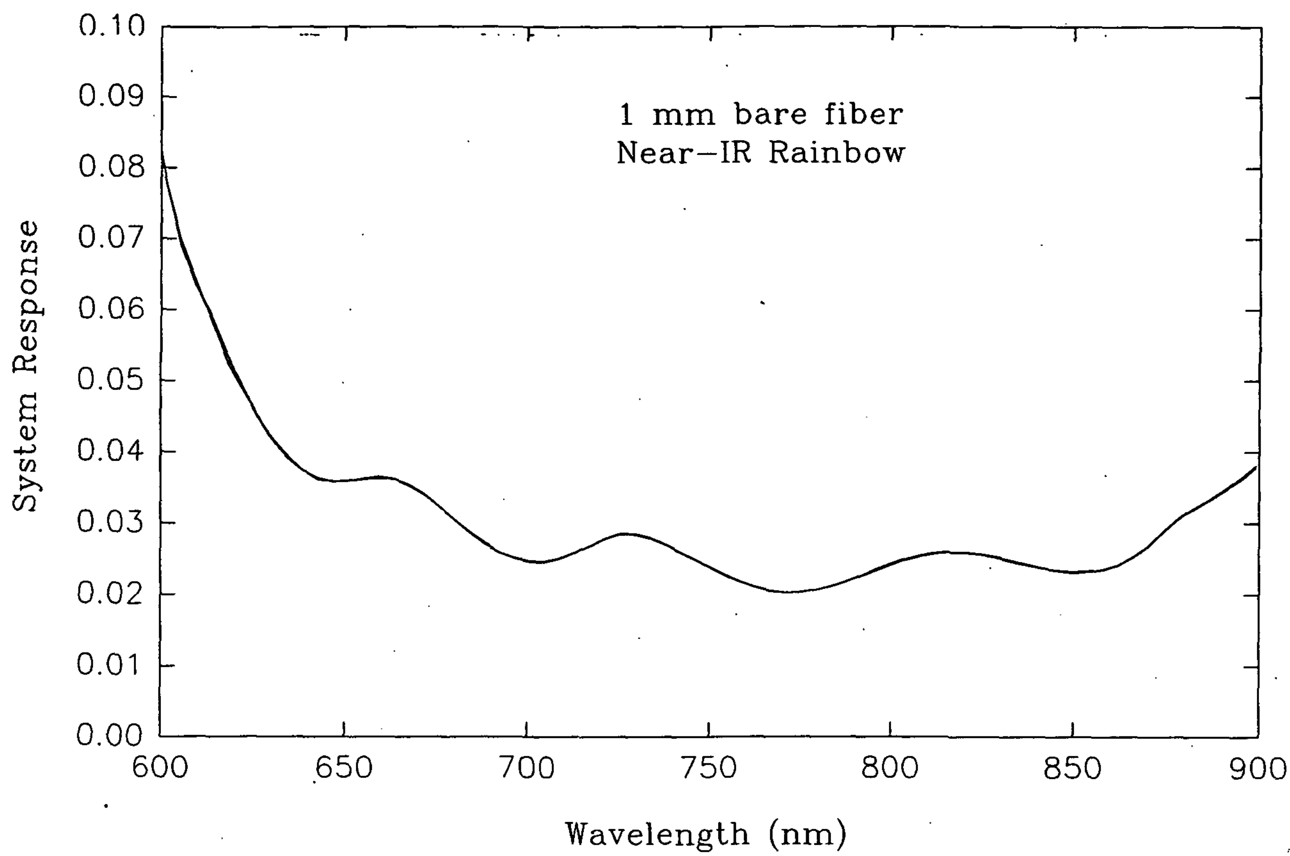

1 mm bare fiber
Near-IR Rainbow
System Response
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
600
650
700
750
800
850
900
Wavelength (nm)

FIGURE 3.

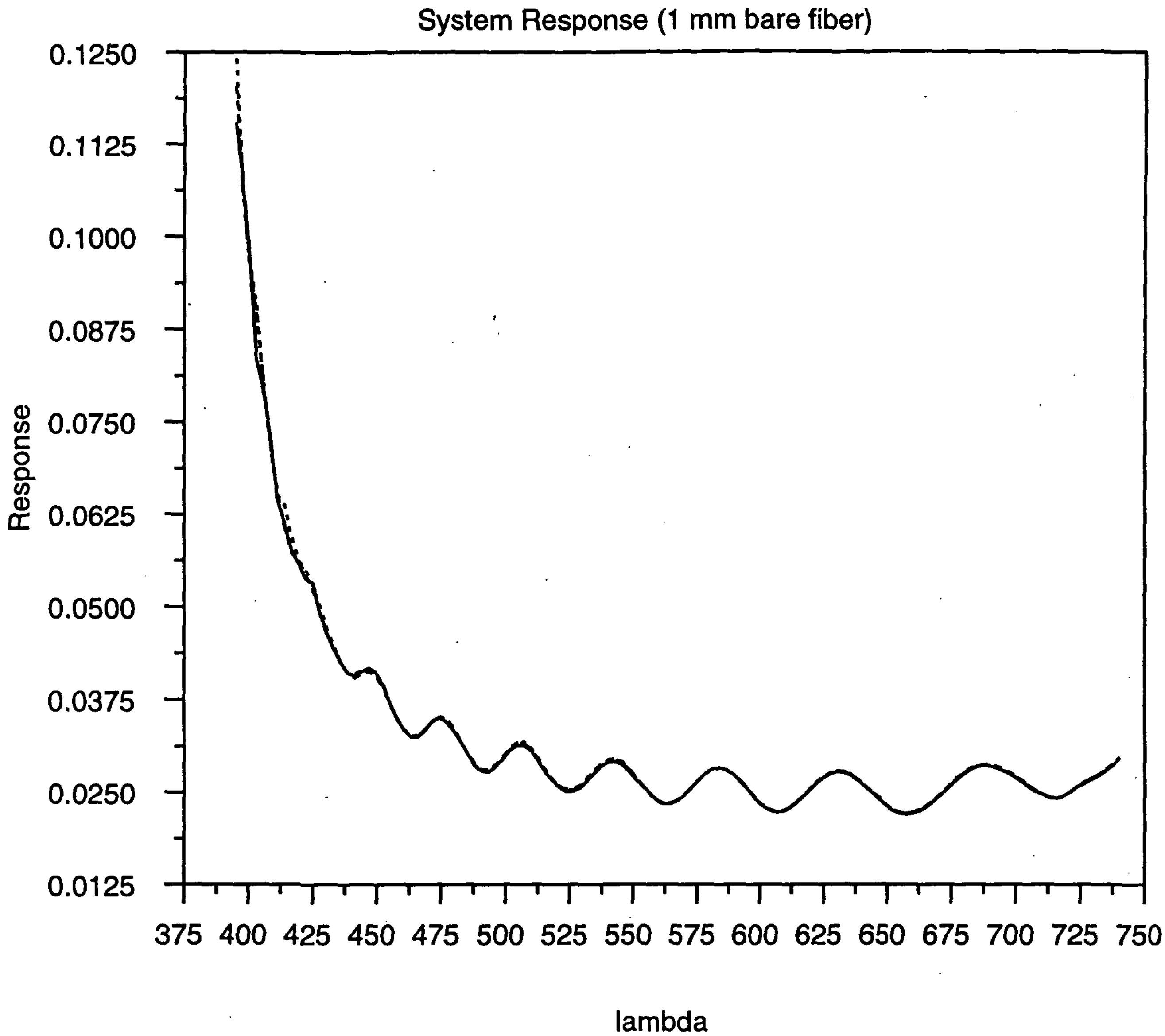

System Response (1 mm bare fiber)
Response
0.1250
0.1125
0.1000
0.0875
0.0750
0.0625
0.0500
0.0375
0.0250
0.0125
375 400 425 450 475 500 525 550 575 600 625 650 675 700 725 750
lambda

FIGURE 4.

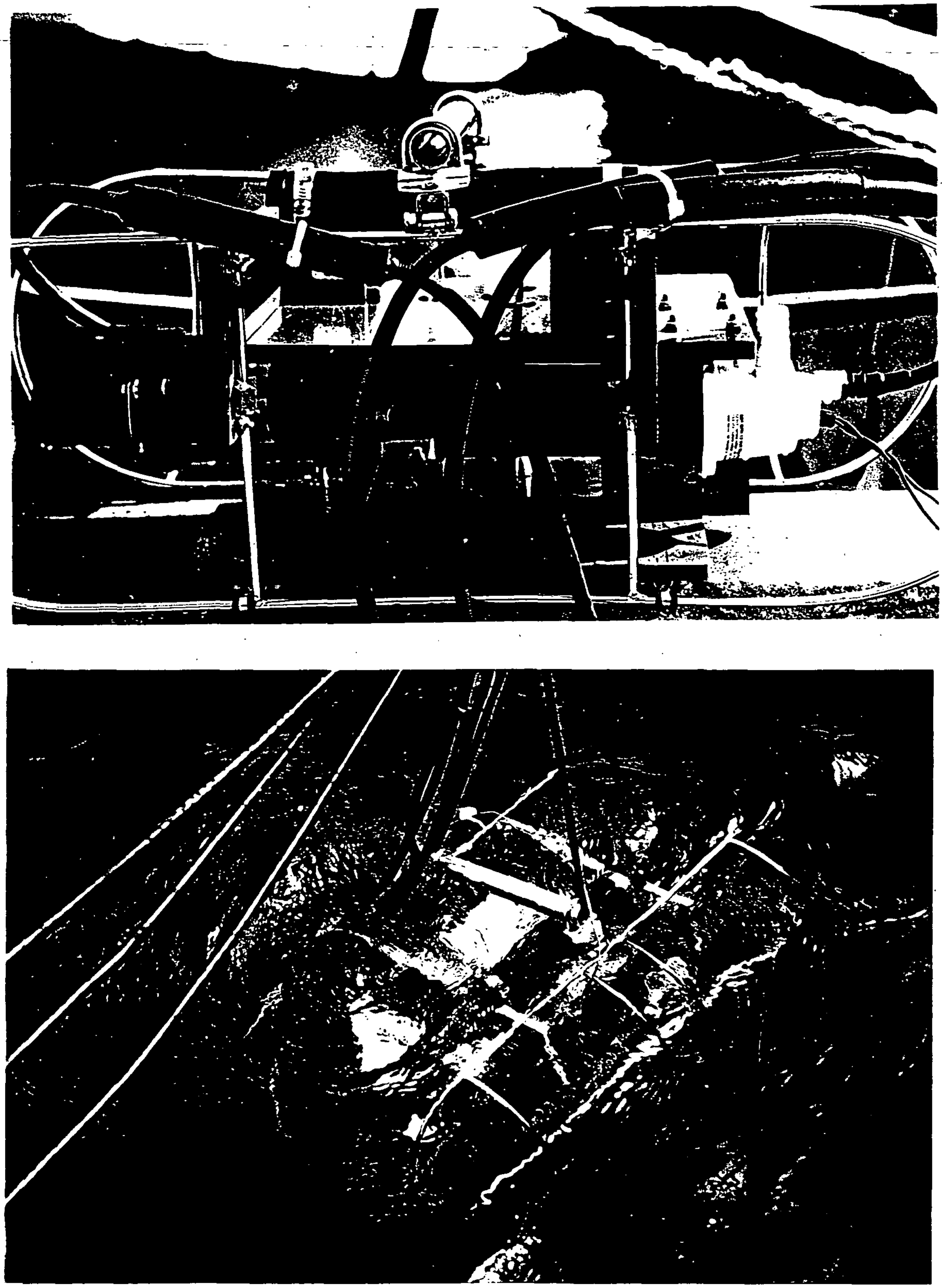
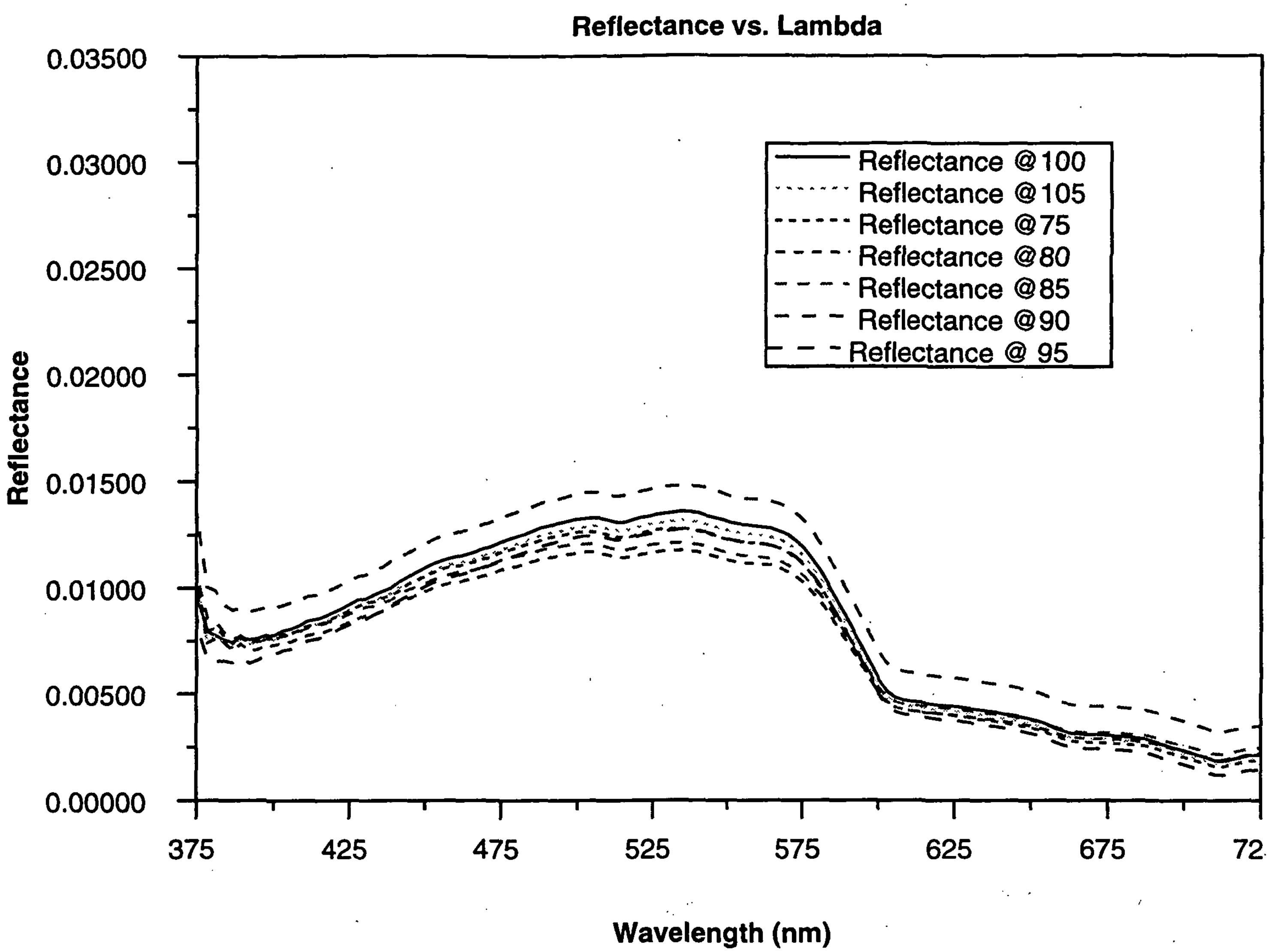


FIGURE 5.

FIGURE 6.



Reflectance vs. Lambda
0.03500
0.03000
0.02500
0.02000
0.01500
0.01000
0.00500
0.00000
Reflectance
Reflectance @100
Reflectance @105
Reflectance @75
Reflectance @80
Reflectance @85
Reflectance @90
Reflectance @ 95
375
425
475
525
575
625
675
72
Wavelength (nm)

FIGURE 7.

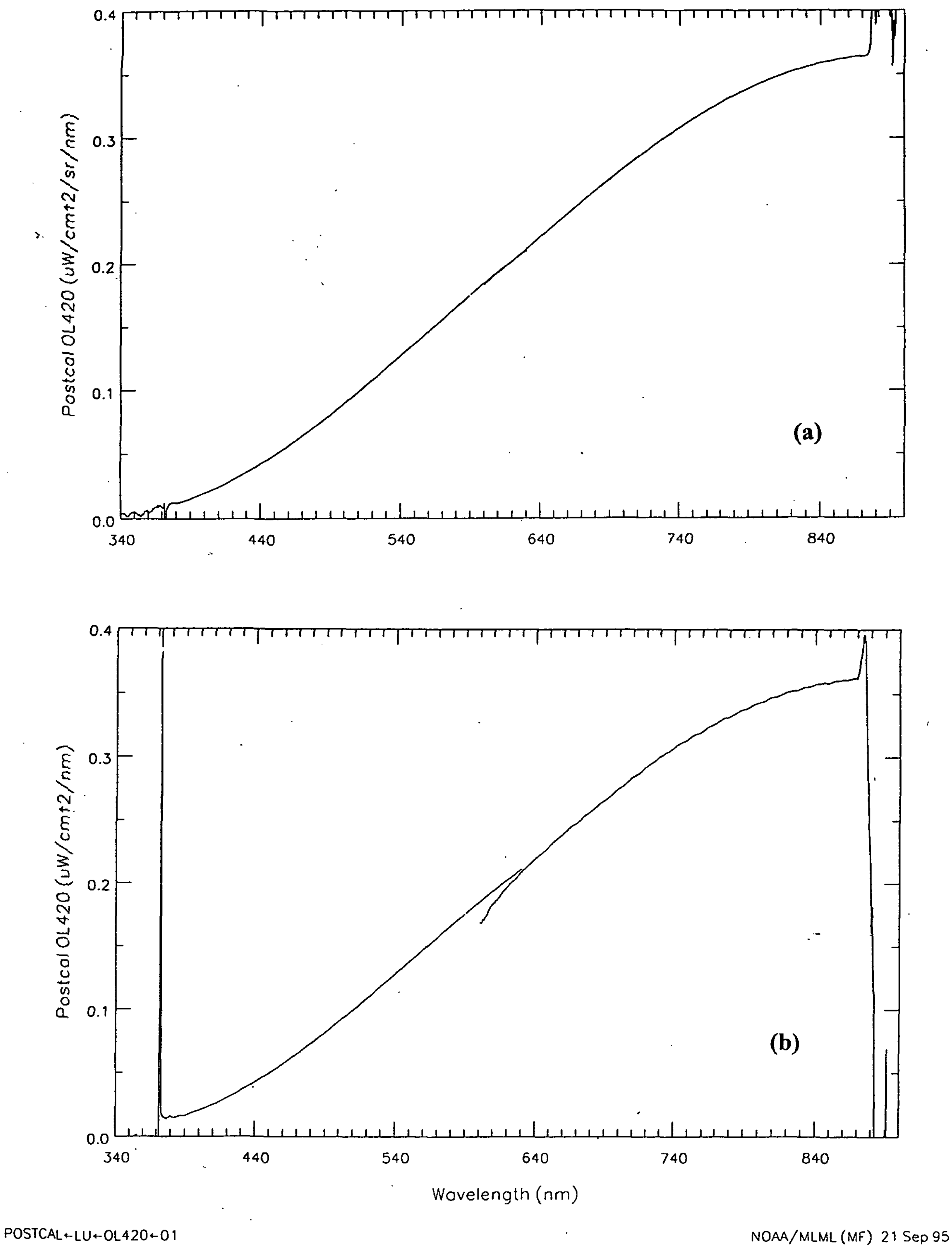


FIGURE 8. MOS Lu response derived from 1/1 sec blue/red integrations.
(a) 1/1 sec scans converted with 1/1 sec response.
(b) 1/0.5 sec scans converted with 1/1 sec response.

MOCE Instrumentation Software Status

Instrument	Acquisition			Processing		
	Fully Func	Mod/ Refurb	Develop & Test	Fully Func	Mod/ Refurb	Develop & Test
OPTICAL						
MOS 1	X			X		
MOS 2			X		X	
SIS	X			X		
MER	X			X		
Fastie	X			X		
BIO-OPTICAL						
Transmissometer						
AC-9	O				O	X
Martek	X			X		
SeaTech	X			X		
VLST	X			X		
Scattering Meter	O					X
Fluorometer						
Chelsea	X			X		
MLML	X			X		
Turner (3)	X			X		
Galai Particle Counter	X					X
HP Spectrophotometer	X				O	
Microscope Video System	X			X		
Photosynthetron	X			X		
ANCILLARY						
Sky Camera	X					X
HHCRM	X			X		
Barometer	X			X		
Air Temperature	X			X		
% Relative Humdity	X			X		
Wind	X			X		
Compass	X			X		
GPS Navigation						
Trak (Time)	X			X		
Trimble (Position)	X			X		
Profiling CTDO2	X			X		
Alongtrack CT	X				X	O
CALIBRATION						
System Responses						
Irradiance	X			X		
Radiance	X			X		

X --> As of 12/94
O --> As of 8/95

TABLE 1

MOCE Instrumentation Hardware Status

Instrument	Fully Functional	Modification/ Refurbishment	Test & Evaluate
OPTICAL			
MOS 1	X		
MOS 2			X
SIS	X		
MER	X		
Fastie	X		
BIO-OPTICAL			
Transmissometer			
AC-9		O	X
Martek			O
SeaTech	X		
VLST		X	
Scattering Meter		O	X
Fluorometer			
Chelsea	X		
MLML	X		
Turner (3)	X		
Galai Particle Counter	X		
HP Spectrophotometer	X		
Microscope Video System	X		
Photosynthetron		O	
ANCILLARY			
Sky Camera		X	
HHCRM		X	O
Barometer	X		
Air Temperature		O	
% Relative Humdity		O	
Wind	X		
Compass	X	O	
GPS Navigation			
Trak (Time)	O		
Trimble (Position)	X		
Profiling CTDO2	X		
Alongtrack CT	X		
Towed Paravane System		X	
CALIBRATION			
Optronix	X		
EG&G Gamma 5000	X		
Line Sources	X		
Portable Reference Lamps	X		
Diver Calibration Lamps		O	X
NIST Radiometer			O

X --> As of 12/94
O --> As of 8/95

TABLE 2

file: moce3:[mos.prc]overlap_summary.txt (rev 28Sep95 MF)

From MOCE-3 MOS Ed and Lu underwater spectra (depth = Top, Mid, Bot), examine the difference between the blue and red spectrographs in the overlap region (between ~ 598 and 626 nm) at 609 nm. All MOS spectra were edited, smoothed, dark-adjusted and converted to radiometric units. Blue spectrum Element # 451 corresponds to 608.8 nm, red spectrum Element #520 corresponds to 608.9 nm. The blue/red overlap at 609 nm is calculated as Element# 451 minus Element# 520. Overlap is calculated from spectra without and with masked pixel offsets applied. Blue array Element# 10-30 and red array Element# 985-1000 are used for mased pixel offsets. ('*' when red counts convert to negative watts.)

Summary: The size of the blue/red overlap changed between the 'without' and the 'with' masked-pixel-offset processing the following number of times in the folowing 'directions':

			-- SIGN CHANGE ---	
INCREASE	DECREASE	SAME	INCREASE	DECREASE
33	25	4	8	3

			Without masked pixel offsets			With masked pixel offsets		
	#Lite Scans	B/R Int Time	%Overlap Blue-Red	% 1/SNR Blue	Red	%Overlap Blue-Red	% 1/SNR Blue	Red
Stn 02								
Ed Top	10	0.5/0.5	- 10	14	11	- 11	14	11
Ed Mid	MISSING							
Ed Bot	5	1/16	3	12	4	3	6	2
Lu Top	5	0.25/16	4	11	2	9	18	11
Lu Mid	MISSING							
Lu Bot	5	0.5/16	- 7	45	31	- 0.3	7	14
Stn 03								
Ed Top	15	0.5/1	- 8	17	11	- 9	18	11
Ed Mid	5	0.5/4	- 3	4	3	- 4	4	3
Ed Bot	5	1/16	13	9	1	9	9	2
Lu Top	15	0.25/16	- 8	15	4	- 10	6	3
Lu Mid	10	0.25/16	6	15	2	8	8	2
Lu Bot	5	0.25/16	- 15	22	9	22	8	3
Stn 04								
Ed Top	5	0.5/1	- 14	9	8	- 15	9	7
Ed Mid	10	1/4	- 3	6	4	- 5	5	4
Ed Bot	5	2/16	34	45	11	- 33	12	7
Lu Top	10	0.25/16	- 10	14	4	- 17	10	4
Lu Mid	10	0.25/16	2	29	7	2	23	5
Lu Bot	5	0.5/16	- 64	71	17	- 10	18	8
Stn 05								
Ed Top	5	1/2	- 12	4	6	32	4	5
Ed Mid	5	2/8	2	8	8	41	7	6
Ed Bot	MISSING							
Lu Top	5	0.5/16	1	7	4	48	10	3
Lu Mid	5	0.5/16	18	20	10	50	7	5
Lu Bot	MISSING							
Stn 06								
Ed Top	5	1/2	- 10	18	19	- 11	18	19
Ed Mid	10	4/16	3	5	7	0.1	4	6
Ed Bot	10	8/16	182	50	159	- 113	6	39
Lu Top	5	0.5/16	- 14	8	12	- 20	5	12
Lu Mid	10	1/16	- 4	18	38	- 6	10	17
Lu Bot	10	2.16	- 50	85	92	- 128	20	35
Stn 08								
Ed Top	10	0.5/1	16	13	12	15	13	13
Ed Mid	10	1/8	19	29	25	18	29	25
Ed Bot	10	4/16	- 140	115	25	- 80	18	16
Lu Top	10	0.25/16	49	8	7	34	10	6
Lu Mid	10	0.5/16	39	12	4	53	11	2

TABLE 3 **MOS blue/red overlap offset at 609 nm from MOCE-3.**

Lu Bot	10	1/16	-29	58	6	40	26	6
Stn 09								
Ed Top	MISSING							
Ed Mid	5	8/16	132	20	60	84	11	20
Ed Bot	5	4/16	*	1196	50	-52	11	31
Lu Top	MISSING							
Lu Mid	5	2/16	-13	13	20	24	13	26
Lu Bot	5	2/16	201	18	10270	55	28	20
Stn 10								
Ed Top	5	1/8	-7	19	7	-8	20	6
Ed Mid	5	1/8	12	14	8	13	15	5
Ed Bot	5	2/16	*	86	96	46	30	43
Lu Top	5	0.25/16	47	42	17	23	47	16
Lu Mid	5	0.25/16	49	23	13	10	15	7
Lu Bot	5	0.5/16	95	41	16	-11	29	7
Stn 11								
Ed Top	5	1/4	8	20	9	9	20	10
Ed Mid	10	0.5/2	-14	11	6	-15	10	6
Ed Bot	5	1/16	41	44	16	-56	86	5
Lu Top	10	0.25/16	22	24	8	9	19	9
Lu Mid	10	0.25/16	30	23	7	7	17	6
Lu Bot	5	0.5/16	11	91	8	13	19	5
Stn 12								
Ed Top	5	0.5/1	1	13	9	1	13	9
Ed Mid	5	1/4	8	8	4	5	9	2
Ed Bot	5	1/16	10	5	2	9	5	2
Lu Top	10	0.25/16	19	8	9	13	7	8
Lu Mid	5	0.25/16	4	16	6	28	12	8
Lu Bot	5	0.25/16	29	42	4	19	9	5
Stn 13								
Ed Top	5	1/2	-2	28	25	-3	28	25
Ed Mid	5	1/4	-16	9	10	-17	9	9
Ed Bot	5	1/16	*	36	103	13	7	22
Lu Top	5	0.25/16	27	9	11	3	12	10
Lu Mid	5	0.25/16	26	28	5	16	22	5
Lu Bot	15	0.5/16	-10	25	5	14	20	2
Stn 14								
Ed Top	10	2/8	2	8	5	2	8	3
Ed Mid	5	0.5/4	-9	15	11	-8	14	10
Ed Bot	5	1/16	3	61	18	-29	35	12
Lu Top	10	0.5/16	23	30	11	29	30	9
Lu Mid	5	0.25/16	15	26	16	13	19	15
Lu Bot	5	0.5/16	8	42	11	-41	65	10
Stn 15								
Ed Top	5	0.5/1	-7	7	9	-8	7	9
Ed Mid	5	2/8	5	4	6	4	5	6
Ed Bot	5	2/16	-1	3	6	-2	3	4
Lu Top	5	0.25/16	2	15	16	1	15	16
Lu Mid	10	0.5/16	14	6	3	18	5	3
Lu Bot	5	1/16	25	10	6	33	5	2
Stn 16								
Ed Top	5	0.5/1	-7	26	13	-8	26	12
Ed Mid	5	1/16	20	12	13	-14	21	11
Ed Bot	5	2/16	*	34	79	235	16	96
Lu Top	10	0.25/16	18	4	3	16	7	3
Lu Mid	10	0.5/16	25	37	6	35	16	13
Lu Bot	5	1/16	19	17	46	71	24	39

Offsets applied to converted Ed and Lu scans (without masked pixel offsets) to eliminate blue/red overlap mismatch at 609 nm. Values for Ed are in uW/cm^2/nm, values for Lu are in uW/cm^2/sr/nm. Offsets were subtracted from the blue array data (Element # 1-500, ~ 334 to 636 nm).

Stn 02	Ed Top	-7.066E+0	Stn 08	Ed Top	7.099E+0	Stn 13	Ed Top	-4.342E-1
	Ed Mid	MISSING		Ed Mid	1.271E+0		Ed Mid	-1.963E+0
	Ed Bot	3.734E-2		Ed Bot	-9.413E-2		Ed Bot	*

TABLE 3 **MOS blue/red overlap offset at 609 nm from MOCE-3.**

	Lu Top	6.404E-4
	Lu Mid	MISSING
	Lu Bot	-1.515E-4
Stn 03	Ed Top	-5.868E+0
	Ed Mid	-5.975E-1
	Ed Bot	5.799E-1
	Lu Top	-1.932E-3
	Lu Mid	7.053E-4
	Lu Bot	-9.596E-4
Stn 04	Ed Top	-1.039E+1
	Ed Mid	-4.088E-1
	Ed Bot	4.597E-2
	Lu Top	-2.605E-3
	Lu Mid	1.624E-4
	Lu Bot	-1.058E-3
Stn 05	Ed Top	-3.912E+0
	Ed Mid	1.266E-1
	Ed Bot	MISSING
	Lu Top	8.040E-5
	Lu Mid	7.105E-4
	Lu Bot	MISSING
Stn 06	Ed Top	-4.334E+0
	Ed Mid	1.002E-1
	Ed Bot	3.918E-2
	Lu Top	-1.025E-3
	Lu Mid	-8.114E-5
	Lu Bot	-2.481E-4
	Lu Top	9.325E-3
	Lu Mid	1.638E-3
	Lu Bot	-3.901E-4
Stn 09	Ed Top	MISSING
	Ed Mid	2.030E-1
	Ed Bot	*
	Lu Top	MISSING
	Lu Mid	-1.762E-4
	Lu Bot	9.033E-4
Stn 10	Ed Top	-7.485E-1
	Ed Mid	7.685E-1
	Ed Bot	*
	Lu Top	6.807E-3
	Lu Mid	3.814E-3
	Lu Bot	2.315E-3
Stn 11	Ed Top	1.169E+0
	Ed Mid	-1.918E+0
	Ed Bot	7.612E-2
	Lu Top	3.144E-3
	Lu Mid	2.978E-3
	Lu Bot	2.980E-4
Stn 12	Ed Top	6.820E-1
	Ed Mid	1.086E+0
	Ed Bot	2.906E-1
	Lu Top	6.882E-3
	Lu Mid	3.419E-4
	Lu Bot	1.536E-3
	Lu Top	5.118E-3
	Lu Mid	3.043E-3
	Lu Bot	-2.964E-4
Stn 14	Ed Top	1.646E-1
	Ed Mid	-9.182E-1
	Ed Bot	2.946E-3
	Lu Top	1.731E-3
	Lu Mid	1.470E-3
	Lu Bot	1.452E-4
Stn 15	Ed Top	-2.043E+0
	Ed Mid	2.107E-1
	Ed Bot	-1.648E-2
	Lu Top	1.282E-3
	Lu Mid	2.558E-3
	Lu Bot	1.122E-3
Stn 16	Ed Top	-5.509E+0
	Ed Mid	1.999E-1
	Ed Bot	*
	Lu Top	4.804E-3
	Lu Mid	5.940E-4
	Lu Bot	1.624E-4

TABLE 3 **MOS blue/red overlap offset at 609 nm from MOCE-3.**

MOCE3:[MOS.RAW]STN03_SFC_ED_01.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1405.5	27.2	1343.7	1454.1	21
3805.1	21.0	3764.0	3832.5	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

120.9	36.7	48.5	190.1	21	9
58.3	122.7	-98.6	307.3	21	4
-21.3	33.9	-71.7	64.9	21	-2
-14.6	39.0	-69.5	86.5	21	-1
-98.6	37.8	-162.5	0.0	21	-7
-49.6	17.6	-89.5	0.0	16	-1
-5.4	31.6	-113.5	41.5	16	-0.1
-9.1	21.2	-40.9	49.5	16	-0.2
-33.9	20.0	-77.5	3.6	16	-0.9
-108.2	17.6	-150.5	0.0	16	-3

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-67.3	30.3	-120.7	11.3	21	-5
-44.5	16.2	-72.2	0.0	16	-1

MOCE3:[MOS.RAW]STN03_SFC_ED_02.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1312.7	12.8	1293.6	1337.5	21
3810.0	29.1	3764.4	3856.7	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

138.1	21.1	100.4	179.0	21	11
99.0	16.4	70.8	131.5	21	8
-5.4	18.9	-42.1	26.9	21	-0.4
70.6	11.4	53.5	87.3	21	5
61.6	15.4	36.2	97.4	21	5
-52.9	44.9	-198.0	28.0	16	-1
21.4	22.6	-13.0	61.9	16	0.6
77.5	29.0	-8.0	118.5	16	2
-99.8	22.3	-166.0	0.0	16	-3
51.1	25.6	-16.0	85.7	16	1

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

10.3	15.1	-16.5	34.5	21	0.8
-105.7	15.9	-136.4	0.0	16	-3

MOCE3:[MOS.RAW]STN03_SFC_ED_03.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1349.9	13.1	1325.2	1378.9	21
3808.6	27.7	3761.6	3875.5	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

105.0	72.5	1.1	209.5	21	8
67.5	18.6	37.9	99.7	21	5
-42.6	19.4	-73.8	0.0	21	-3
-33.7	20.2	-67.1	5.7	21	-3
72.2	17.6	23.3	96.1	21	5
-6.7	33.6	-92.5	89.5	16	-0.2
-101.7	25.1	-172.5	0.0	16	-3
91.4	28.5	19.5	173.5	16	2
67.1	18.2	35.5	107.5	16	2
19.3	52.0	-110.5	172.5	16	0.5

TABLE 4 MOS masked pixel offsets at Station 03 during MOCE-3.

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

1.5	14.3	-29.8	34.2	21	0.1
-11.8	18.2	-65.0	28.0	16	-0.3

MOCE3:[MOS.RAW]STN03_SFC_LU_01.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1243.6	11.2	1220.3	1262.4	21
43827.8	369.8	43268.4	44479.0	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-16.6	18.1	-49.5	23.2	21	-1
-192.7	17.6	-231.1	0.0	21	-15
-104.1	16.1	-130.3	0.0	21	-8
-106.5	15.1	-130.8	0.0	21	-9
-33.2	24.8	-88.4	0.0	21	-3
30.7	44.7	-56.6	132.0	16	0.07
-142.5	34.6	-234.0	0.0	16	-0.3
-100.5	44.6	-205.0	0.0	16	-0.2
-284.6	45.3	-407.0	0.0	16	-0.6
-81.1	41.3	-166.4	0.0	16	-0.2

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-181.7	26.4	-243.6	0.0	21	-15
-77.8	32.2	-130.3	0.0	16	-0.2

MOCE3:[MOS.RAW]STN03_SFC_LU_02.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1197.9	11.7	1174.9	1221.5	21
43959.2	377.4	43334.6	44573.0	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

16.5	23.3	-11.7	62.9	21	1
70.4	166.4	-59.3	506.9	21	6
-67.0	17.6	-114.7	0.0	21	-6
17.2	21.1	-33.3	42.2	21	1
-165.8	12.5	-186.7	0.0	21	-14
-82.3	63.6	-195.5	46.8	16	-0.2
-60.3	14.3	-77.2	0.0	16	-0.1
-113.8	63.0	-219.7	13.8	16	-0.3
-235.0	62.2	-350.3	0.0	16	-0.5
-136.6	17.1	-191.0	0.0	16	-0.3

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-6.0	60.4	-104.5	101.1	21	-0.5
-141.9	33.7	-200.0	0.0	16	-0.3

MOCE3:[MOS.RAW]STN03_SFC_LU_03.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1222.9	9.3	1206.1	1236.2	21
43945.0	362.2	43404.1	44581.5	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

10.2	22.9	-39.3	53.0	21	0.8
-107.5	20.0	-143.5	0.0	21	-9
-53.1	19.8	-87.0	0.0	21	-4
-228.6	87.6	-411.1	0.0	21	-19
-193.6	16.6	-219.4	0.0	21	-16

TABLE 4 **MOS masked pixel offsets at Station 03 during MOCE-3.**

68.8	54.0	-45.5	154.0	16	0.2
-37.0	62.6	-153.5	64.5	16	-0.08
-44.5	55.9	-155.5	55.2	16	-0.1
-145.4	64.8	-272.3	0.0	16	-0.3
-211.5	18.9	-241.5	0.0	16	-0.5

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-158.0	12.7	-189.4	0.0	21	-13
-163.5	37.1	-230.5	0.0	16	-0.4

MOCE3:[MOS.RAW]STN03_MID_ED_02.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1477.2	9.4	1461.6	1496.2	21
12109.6	95.9	11956.2	12290.0	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-35.4	24.7	-64.6	23.4	21	-2
80.3	21.4	40.4	121.4	21	5
87.2	17.7	53.8	113.9	21	6
96.9	14.9	71.3	126.5	21	7
77.8	14.7	57.9	112.0	21	5
0.6	11.3	-21.5	22.3	16	0.005
-89.4	23.1	-135.9	0.0	16	-0.7
1.0	31.7	-105.0	64.5	16	0.008
-3.4	25.4	-41.5	40.0	16	-0.03
19.0	29.6	-36.0	85.5	16	0.2

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

35.4	19.6	7.5	80.4	21	2
-50.5	25.7	-141.0	0.0	16	-0.4

MOCE3:[MOS.RAW]STN03_MID_LU_01.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1161.0	10.6	1136.1	1178.1	21
43727.2	372.3	43152.2	44350.5	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-54.9	18.1	-90.3	0.0	21	-5
2.2	16.7	-17.9	40.1	21	0.2
-144.8	36.7	-204.7	0.0	21	-12
-142.6	16.2	-178.5	0.0	21	-12
-17.2	18.2	-40.9	37.5	21	-1
-42.5	29.3	-88.1	26.5	16	-0.10
-264.3	37.1	-316.2	0.0	16	-0.6
-257.9	39.4	-308.8	0.0	16	-0.6
-223.7	25.5	-258.1	0.0	16	-0.5
-151.4	40.7	-246.5	0.0	16	-0.3

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-18.6	10.4	-32.2	0.4	21	-2
-130.8	38.6	-236.0	0.0	16	-0.3

MOCE3:[MOS.RAW]STN03_MID_LU_02.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1126.2	13.4	1100.9	1147.8	21
43694.1	365.1	43099.1	44262.0	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

TABLE 4 MOS masked pixel offsets at Station 03 during MOCE-3.

-32.3	141.9	-241.8	178.3	21	-3
7.7	17.3	-19.6	40.1	21	0.7
-36.7	13.4	-51.3	0.7	21	-3
26.9	21.0	-15.6	57.1	21	2
76.9	14.2	45.6	97.8	21	7
-31.4	63.6	-132.0	82.5	16	-0.07
-159.5	71.7	-281.0	0.0	16	-0.4
-144.5	34.1	-196.0	0.0	16	-0.3
-108.7	47.0	-217.0	37.5	16	-0.2
-140.3	20.2	-165.5	0.0	16	-0.3

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-17.7	18.5	-45.0	17.7	21	-2
-223.0	41.0	-286.0	0.0	16	-0.5

MOCE3:[MOS.RAW]STN03_BTM_ED_01.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

2159.6	29.9	2112.4	2222.1	21
43717.7	379.4	43096.5	44361.0	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

12.5	15.0	-16.6	47.4	21	0.6
-35.1	15.1	-74.4	0.0	21	-2
-50.2	9.7	-73.6	0.0	21	-2
-67.8	16.0	-98.6	0.0	21	-3
-71.8	21.2	-115.3	0.0	21	-3
-19.0	51.2	-111.0	152.5	16	-0.04
-117.0	27.7	-213.0	0.0	16	-0.3
-117.1	30.6	-216.0	0.0	16	-0.3
-78.6	30.6	-185.0	0.0	16	-0.2
-28.5	46.3	-133.0	117.5	16	-0.07

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-89.5	13.6	-114.7	0.0	21	-4
-106.1	57.9	-177.0	13.2	16	-0.2

MOCE3:[MOS.RAW]STN03_BTM_LU_01.MLDAT;1
Offsets (BlueElmt=10-30 Red=985-1000 Dk Lt Dk Vlist=2,3 4-8 9,10)

Dark Blue & Red masked Element mean,RMSE,min,max,N

1232.3	84.3	1084.0	1376.1	21
43729.5	359.7	43167.0	44333.5	16

Lite Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-106.0	84.9	-222.1	91.2	21	-9
-161.8	86.9	-324.3	0.0	21	-13
-155.8	88.9	-310.9	0.0	21	-13
-141.9	92.2	-312.5	23.6	21	-12
-154.9	83.1	-288.3	5.4	21	-13
-20.9	54.4	-137.5	124.5	16	-0.05
-68.6	33.5	-128.4	31.5	16	-0.2
-266.2	33.5	-334.4	0.0	16	-0.6
-226.6	43.1	-292.8	0.0	16	-0.5
-289.2	33.3	-338.5	0.0	16	-0.7

Dark Var Blue & Red Offset: mean, RMSE, min, max, N, %Offset

-166.0	78.3	-303.7	0.0	21	-13
-408.9	41.0	-487.1	0.0	16	-0.9

TABLE 4 **MOS masked pixel offsets at Station 03 during MOCE-3.**