TERRA Data Validation Plan for Oceans

MODIS Oceans Group

May 5, 1999

1.0 Introduction

MODIS will measure radiance in visible, near-IR, and thermal IR bands that will be used to derive ocean bio-optical and thermal properties. This derivation is subject to uncertainties resulting from the instrument, the atmospheric effects of scattering and absorption, and the relations used to estimate ocean properties from ocean reflectance or emittance in the MODIS spectral bands. The influence of these sources of uncertainty is expected to have considerable spatial and temporal variability, and as such, a continuing validation effort throughout the mission lifetime is required. Within the MODIS Oceans Group (MOCEAN) a capability has been developed to perform a core set of validation studies, consisting of modeling efforts, internal consistency checks, collection of a limited set of *in situ* observations from ships, buoys, drifters, and aircraft, and a processing system for timely comparison of these data with MODIS products. However, due to the immensity of the oceans, the scales of variability, and limited resources, the MOCEAN global validation effort must leave many areas, regions and times unsampled. Uncertainties will have to be assigned to a large fraction of the global ocean from the areas where they have been rigorously determined. Fortunately, there are strong at-sea activities by a number of other NASA projects, US agency programs, and international efforts that will also provide observations useful for validation of the products, and will greatly strengthen this effort.

The initial plans for algorithm validation and data product validation were developed at a time when a SeaWiFS launch was expected in 1993. A close coordination of SeaWiFS Project and MOCEAN (especially for the bio-optical products) was developed under the guidance of NASA HQ. Thus, the MODIS activities relied heavily upon the SeaWiFS Calibration-Validation (Cal/Val) effort. Components of the joint SeaWiFS Cal/Val and MODIS validation effort that are especially important are the development of protocols for making *in situ* measurements (Mueller and Austin 1995) and the instrument calibration round-robin intercomparison effort (Mueller *et al*., 1996) for those MODIS products sharing a common heritage with SeaWiFS.

2.0 Summary Revisions

This is a summary of the post-launch field activities of the MODIS Instrument Team for oceans. It represents an update and revision of our earlier plans. The approach

for initialization of MODIS water leaving radiance algorithm has been described by Clark et al., (1997), and relies upon the MOBY time series and a related initialization cruise. This was successfully implemented for SeaWiFS in February, 1998 using a cruise in the vicinity of Hawaii.

The overall schedule for at-sea activities which are led by, or involve participation by MODIS Ocean Team members is shown in Figure 1. More detailed schedules and descriptions of individual efforts are found on Team Member web pages:

Activity	URL
MOBY/MOCE	http://orbit20i.nesdis.noaa.gov/~marilyn/index.html
In Situ Data & Fluorescence	http://picasso.oce.orst.edu/users/jasmine/ORSOO/
SST & MAERI	http://www.rsmas.miami.edu/ir/MAERI99.html

2.1 MOBY

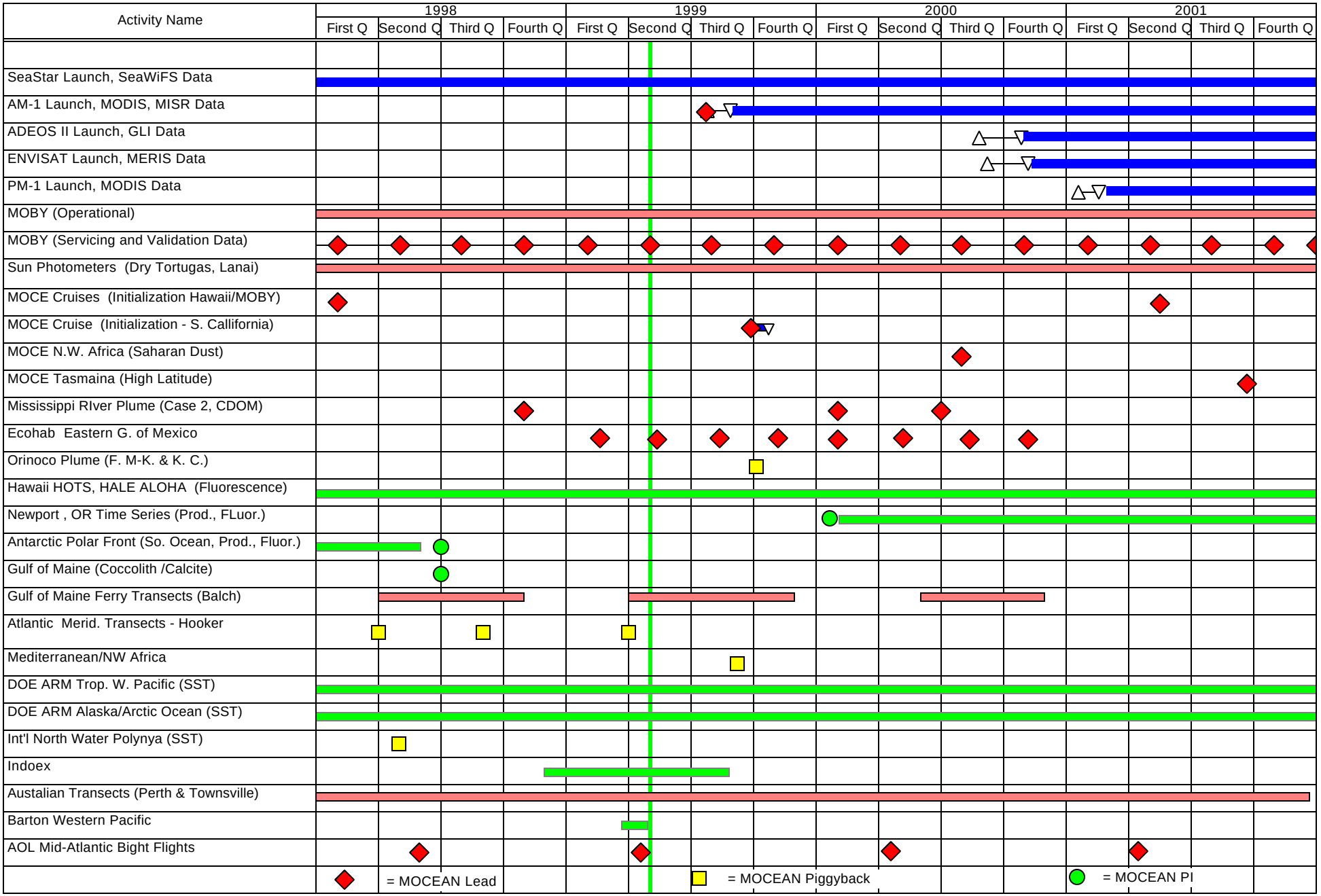
The MOBY optical buoy will be exchanged in August, 1999 with a refurbished and recalibrated buoy as part of the quarterly swap out. The buoy currently collects data at both 10:30 am and noon local time, in preparation for MODIS PFM and continued support of SeaWIFS. The MOBY observations have formed the mainstay of the vicarious calibration effort for SeaWiFS, and are expected to be invaluable for MODIS. Clark's group has found that MOBY operations are highly reliable and stabilty is on the order of a few percent.

The MOBY servicing cruise planned for November will be augmented to obtain additional in-water optical measurements in support of initialization and validation. Due to the buoy servicing activities and limited ship time, it will not cover the full suite of activities of the MOCE effort, however.

2.2 INITIALIZATION CRUISE

Given the excellent MOBY performance, the MOCE and MODIS Ocean Group determined in Spring, 1998 that we would rely upon MOBY and the MOBY services cruises to provide data in the clearest waters, and conduct the initialization cruise in high chlorophyll waters in order to improve the dynamic range of the initialization data.. The MOCE group conducted a survey of ship availability, reviewed weather data for cloud probability and the seasonality of chlorophyll concentrations from CZCS and SeaWiFS, and examined cruise support logistics. For MODIS, a cruise from San Diego on the R/V Melville for the first three weeks in October, 1999 to waters off Southern California and Baja was selected as providing the best probability for success. A Cruise Prospectus which provides full information on the scientific crew and schedule of activities is attached as Appendix A.

MODIS OCEAN VALIDATION SCHEDULE



In addition to the MOCE core activity, other team members will also participate directly or indirectly, in the Melville cruise. These include fluorescence work by Abbott's group, primary production photosynthesis/light experiments, a ship-board phycoerythrin laser system from Frank Hoge, and above water measurements of spectral reflectance by Carder's group. Brown and Minnett's group will perform M-AERI measurements in support of SST.

A complete suite of bio-optical measurements (including the water-leaving radiances) will be carried out on the Melville cruise, along with measurements needed to characterize the columnar properties of the atmosphere, i.e., atmospheric transmission, whole-sky radiance and polarization, solar aureole, and micro pulse lidar. The resulting atmospheric measurements will be used as input to a radiative transfer code to predict the MODIS radiances at the top of the atmosphere (Gordon and Zhang 1996). These will be used to adjust the radiometric calibration of the MODIS ocean bands (8-16).

2.3 CASE 2 ALGORITHMS

Carder's group will conduct a series of cruises in the Gulf of Mexico oriented toward case 2 algorithms with high Dissolved Organic material. He will also participate in a series of ECOHAB cruises, and a cruise in the Orinoco plume with F. Muller-Karger. Field studies are planned to initialize the Chlorophyll *a* and CDOM algorithms for both Case 1 and Case 2 waters (Gulf of Mexico and Sargasso Sea), and to examine MODIS near-field scatter problem. The scattering assessment will use imagery and measurements from the Tongue of the Ocean (TOTO) in the Bahamas where there is high contrast between the white beach sands and the deep off shore waters. A detailed shedule is given as Appendix B.

2.4 FLUORESCENCE STUDIES

Abbott's group will continue to collect in-water fluorescence data from the HALE ALOHA site off Hawaii, and will begin a time series station off Oregon early in 2000.

Data from past deployments can be found on the www at http://picasso.oce.orst.edu/users/jasmine/ORSOO/

2.5 SST – M-AERI Cruises.

Measurements of sea surface brightness temperature with the M-AERI instruments by the Brown/Minnett group forms the research backbone of the SST at-sea validation effort. A listing of cruises which have been conducted, and which are planned for 1999-2000 is given in Appendix C.

Details of intercomparison and calibration round robin data can be found on the web site at http://www.rsmas.miami.edu/ir/

2.6 COCCOLITH and FERRY TRANSECTS

W. Balch will continue his MODIS/SEAWIFS/SIMBIOS sampling of the Gulf of Maine making use of the Portland/Yarmouth ferry. These data are useful for validation of several of the ocean color algorithms.

2.7 ATLANTIC MERIDIONAL TRANSECTS / PROSOPE

S. Hooker will complete his participation in the AMT cruises this spring, and will then focus on participation in the PROSOPE cruise (4 September through 10 October) with Andre Morel and Herve Claustre. The cruise is separated into long (all day) and short (5 hour) stations in the NW African upwelling (UPW),the oligotrophic Eastern Mediterranean (MIO), and a buoy site off of France (DYF). If MODIS is launched in July as planned, we should be well situated to provide high and low calibration vicarious calibration data (the pigments will be determined using HPLC).

2.8 SIMBIOS ACTIVITIES

The NASA SIMBIOS Program provides a tremendous increase in the geographical and temporal extent of validation activities in support of ocean color mission. SIMBIOS maintains a current listing of at sea validation activities which encompass the entire NASA Ocean Color Program in support of SeaWiFS, OCTS, MODIS, OCI, GLI, etc, available via the www at http://simbios.gsfc.nasa.gov/

3. Scientific Objectives

The scientific objectives of the validation effort are to provide data necessary for the initialization of some product algorithms, and for an ongoing effort to describe the uncertainty fields of the standard MODIS Level 2 and 3 ocean products. This information will be used to identify and remove systematic biases in the data products resulting from the instrument, the algorithms, and data production.

The specific products that require validation are:

- Fundamental radiance products (water-leaving radiance in the visible and surface emittance in the thermal infrared).

- Products relating to the physical and bio-optical state of the water (sea-surface temperature, phytoplankton pigment concentration, chlorophyll *a* concentration, phytoplankton fluorescence, photosynthetically active radiation, suspended solids concentration, organic matter concentration, coccolith/calcite concentration, ocean

water attenuation coefficient, total absorption coefficient, gelbstoffe absorption coefficient, aerosol optical thickness, and phycoerythrin concentration).

- Higher-level products (ocean primary productivity, chlorophyll fluorescence efficiency).

Detailed descriptions of the of the algorithms used to produce these products are provided in the Algorithm Theoretical Basis Documents (ATBD's) available on World Wide Web

3.1 Validation Requirements

The overall approach and requirements have been discussed in detail by Clark et al., 1997. Several fundamentally different, but complementary, data sets are necessary to provide an adequate sampling of the marine atmospheric conditions, oceanic bio-optical state, and sea-surface temperature (SST), needed to validate the MODIS Ocean Products. Our validation strategy is multi-fold: Highly-focused field expeditions using state-of-the-art calibrated in-water and surface spectral radiometers, supported by extensive instrument suites to determine the state of the atmosphere, are utilized to understand the atmospheric and oceanic processes that limit the accuracy of the derived bio-optical properties and the SST. A permanent buoy-based oceanic optical station is maintained to continuously monitor the performance of the MODIS system (sensor *plus* algorithms). Long-time period, global-scale data sets are obtained to provide a monitoring capability for revealing calibration drift and the consequences of sudden or extreme atmospheric events, such as volcanic eruptions, transoceanic transport of terrestrial aerosols, cold-air outbreaks, etc., on the global products. These data sets will enable MOCEAN to define the uncertainties in products under a variety of conditions as well as providing the information required to fine-tune the algorithms described in the ATBD's.

3.2 Satellite Missions

The validation activities of the MOCEAN are keyed to the EOS platforms, MODIS AM-1 and MODIS PM-1. The *in situ* observations have been developed with the recognition of their relevance to missions of similar ocean sensors, i.e., SeaWiFS, OCTS, MISR, GLI, MERIS, POLDER, GOES-8, GOES-9, AVHRR, ATSR, and the MOS instruments on PIRODA and IRS.

4.0 Validation Approach

4.1 Overall Approach

The approach to validation of the MODIS Ocean Products is to compare surface- or *in situ* -measured values with MODIS-retrieved values. The comparisons will be completed

for a variety of situations ranging from those for which the performance of the individual algorithm is expected to be excellent to situations for which the performance is expected to be severely degraded.

For the visible products (bio-optical products and water-leaving radiance), the validation begins with initialization of the sensor, i.e., the process of carrying out on-orbit calibration for a newly-launched sensor, prompted by the fact that it is reasonable to expect that the stresses associated with launch may alter radiometric calibration, using a prediction of the radiance expected at the sensor, based on a rigorous set of *in situ* atmospheric measurements and radiative transfer computations. On this basis, the sensor calibration is revised to provide agreement with the predictions.

The validation will be carried out at various ocean test sites, principally the MOBY site off Hawaii, the initialization cruise off Southern California and Baja, and other cruises. The role of Ocean Test Sites encompasses the somewhat conflicting needs for intensive validation and initialization data collection, oceanic process studies, time series stations, as well as providing for stratified global observations. Data collected at the time series sites are necessary to validate trends detected in satellite data, and to monitor the response of marine ecosystems and SST to climate change. By including physical and biogeochemical observations, the sites will provide insight on the mechanisms of coupling between biological and physical systems. Data collected at the test sites will be of value to MODIS, MISR, ASTER, and CERES on the EOS AM-1 Platform, as well as other missions (SeaWiFS, ADEOS I, II, TPF, and ENVISAT).

4.2 Measurement Needs at Calibration/Validation Sites

In order to validate the MODIS Ocean Products in the visible, it is necessary to obtain measurements of several environmental parameters in addition to the product being validated, e.g., in the case of atmospheric correction (water-leaving radiance) it is necessary to make a suite of measurements aimed at understanding the state to the atmosphere at the time of the retrievals. The Tier 1 MOCEAN at-sea validation effort consists of the MOCE campaigns. A listing of the quantities to be measured on these cruises is provided in the following table.

Measurement Suite for Typical MOCE Campaigns	
Incident Spectral Irradiance	Downwelled Spectral Irradiance
Upwelled Spectral Irradiance	Upwelled Spectral Radiance
Upwelled Spectral Radiance Distribution	Sky Radiance & Polarization Distribution
Aerosol Vertical Distribution (MPL)	TIR Radiance (M-AERI) (Occasional)
Whitecap Spectral Reflectance Aug.	Spectral Solar Atmospheric Transmission
Water-Leaving Radiance	Attenuation Coff. of Upwelled Irradiance
Downwelling Irradiance Attenuatuion	Attenuation Cofficients Radiance
Spectral Reflectance	Beam Spectral Attenuation Profiles
Phytoplankton Pigments (HPLC)	Phytoplankton Pigments (Fluorimetric)
Cyanobacteria Pigments (Exp. Fluorimetric)	Fluorescence Profiles
Chl a Profiles	Trackline Salinity
Trackline Temperature	Trackline Beam Attenuation (530 nm)
Trackline Chlorophyll a	Total Suspended Material
Inorganic Suspended Material	Organic Suspended Material
Detritus Spectral Absorption Coefficient	Particle Spectral Absorption Coefficient
Particle Size Frequency Distribution	Particulate Organic Carbon
Particulate Organic Nitrogen	Primary Productivity (Occasional)
Phytoplankton Speciation Videos	Secchi Disk Depth
Atmospheric Pressure	Relative Humidity
Wind Velocity	Sea & Sky State Photographs

4.2 Ocean Mapping to GCOS Tiers

The MOCEAN plan maps to the Tier structure proposed by GCOS:

Tier 1: Process studies, initialization cruises, and intensive ocean color and SST validation cruises. Examples of process studies are the JGOFS Arabian Sea Study and JGOFS Southern Ocean Study. Initialization cruises and MODIS Marine Optical Characterization Experiment (MOCE) Cruises will occur annually. Tier 1 efforts are intensive in regions of particular interest for scientific and validation reasons, e.g., a MOCE effort to characterize the impact of absorbing aerosols on atmospheric correction off NW Africa, and M-AERI deployments to understand relationships between surface brightness temperature and bulk temperature. These studies may include moorings, but for limited duration.

Tier 2: These are high level time-series stations which include measurements of key and ancillary parameters, and possess high accuracy. Examples of these are the MOBY mooring and the JGOFS biogeochemical times series stations at Hawaii (HOT) and Bermuda (BATS). It should be noted that there are presently no coastal sites in the US, although plans are developing. These stations include permanent moorings to provide near continuous, high quality observations directly related to satellite derived data products throughout the 15 year observation period.

Tier 3: The permanent, automated, operational moorings and platforms which usually measure a more limited suite of primarily physical properties. Prime examples of these are the operational weather buoys and tide gauge networks. These sites provide key information for several ocean physical missions such as scatterometry, altimetry, and SST.

Tier 4: This level includes multiple efforts which provide broad global validation data, and includes individual cruise efforts for regional validation as well as expendable optical and SST drifters which report data via satellite links.

Tier 5: Includes combined multi-platform (ship, buoy, aircraft, satellite) multi-year climatologies and model outputs which are used to test consistency of satellite observations.

4.3 Surface Networks

There are two surface networks that are highly relevant to validation of MODIS over the ocean: the island AERONET sites and the MOBY site(s). AERONET is a network of CIMEL sun photometers/sky radiometers operated by B. Holben at NASA/GSFC. Island stations of the network yield aerosol properties over the oceans. Data from these sites are being used in support of algorithm development efforts (atmospheric correction). Included are some non-CIMEL stations, such as those operated in Japan. The MOBY site is being used to provide data in support of atmospheric correction and bio-optical algorithm development.

4.4 Previous Cruises

A number of cruises have been carried out in support of the algorithm development and validation effort. These include two MOCE cruises (D. Clark) in support of the development of MOBY as well as several cruises dedicated to the deployment and retrieval of MOBY. Numerous cruises were carried out in the Gulf of Mexico (K. Carder) in support of the development of the Chlorophyll *a* algorithm, and in the Gulf of Maine in support of the detached coccolith/calcite algorithm (W. Balch). Two long cruises in the Arabian Sea were carried out by W. Balch as part of a JGOFS effort. These data are being

used in support of the development of several bio-optical algorithms. MOCEAN participated in cruises in the Gulf of Mexico and the Tropical Western Pacific (Brown/Minnett) in which the principal SST-validation instrument (M-AERI) was field tested. At-sea participation in the TARFOX experiment was carried out (Gordon/Voss) to provide information for atmospheric correction regarding anthropogenic absorbing aerosols. Twenty-four bio-optical drifters were deployed in the California Current System between 1993 and 1995 and a set of two bio-optical drifters deployed in the Southern Ocean in 1994-1995 (Abbott). These data are being used to develop a set of specific laboratory experiments which were begun in summer 1995 in collaboration with Dr. Paul Falkowski (Brookhaven National Laboratory), which are designed to determine the relationship between sun-stimulated fluorescence and the photosynthetic rate of phytoplankton.

5.0 Future Activities

The next major MOCEAN campaign is a cruise off the coast of NW Africa, during the season of major desert dust outbreaks over the Equatorial Atlantic. The main purpose is quantifying the accuracy that can be expected in the presence of significant quantities of dust, and providing additional data with which to fine-tune the atmospheric correction algorithm. In contrast to the Hawaii site, the waters in the area are very productive and will provide an excellent test area for validation of the bio-optical products as well. It also provides a good opportunity to study the effects of upper troposphere dust and aerosols on SST. After this W Africa cruise, the M-AERI will be deployed in Baffin Bay to study SST retrievals through polar atmospheres.

Approximately 1 year after launch, Carder will conduct a cruise in the Middle Atlantic Bight (MAB) for the purpose of studying the transition between Case 1 and Case 2 waters. This is accomplished by traversing lines from the Gulf Stream into the shelf water and finally the turbid near-shore waters.

Three large full MOCEAN campaigns are under consideration for the 2000-2001 time frame. The first is in the Southern Ocean, staged from Tasmania for the purpose of validating the algorithms and MODIS products at high latitudes, the second will be for validating the algorithms (atmospheric correction in particular) in a region in which anthropogenic aerosol resulting from urban pollution transported by the winds over the ocean (MAB), and the third will be off Hawaii for initialization of MODIS PM-1. Two shorter cruises will be carried out to validate the CDOM (Carder) and coccolith/calcite (Balch) algorithms.

Finally, the MOBY (Hawaii), MAB, and NASDI (N.W. African Saharan Dust Input) and other (as yet to be determined) SST, campaigns could benefit P-3 and ER-2 aircraft support. Shipboard resources are still undetermined for the Africa and MAB campaigns.

5.0 Implementation of Validation Results

Our primary effort is focused on comparison of the MODIS-retrieved products with *in situ* observations. This is effected through the match-up database (MDB) being developed at the University of Miami by R. Evans. These will be collaborative with the SeaWiFS/SIMBIOS matchup activity to compare MODIS retrievals with similar retrievals from other sensors: MISR, SeaWiFS, OCI, GLI, etc.

5.1 Approach

A key component of the validation exercise, in addition to the collection of data and comparison with MODIS retrievals, is the concomitant increase in understanding the operation of the MODIS system (sensor *plus* algorithms) required to fine-tune the geophysical algorithms in a rational manner. This fine tuning process is particularly important for the atmospheric correction process in the visible, which requires candidate aerosol models and a more accurate sensor calibration than can be provided by traditional approaches. (This calibration is established during the "initialization" process). The results of the initial validation campaigns will be used during the first year to effect this fine-tuning of the algorithms and the calibration coefficients. Following this, a period of intense evaluation of the MODIS products in which the consistency and stability of the data and the applicability of the retrievals to validation data acquired at Ocean Test Sites, will take place. We expect the algorithms to be stable within the first year after launch; however, some changes will be required during the second year as more specific areas are examined, e.g., the effects of anthropogenic absorbing aerosols transported over the oceans (MAB campaign). During the first-year, only research reprocessing of MODIS data will take place at Team Member Computing Facilities, with full-scale reprocessing of the first-year data at the MODAPS Facility to begin at time TBD.

52 Archival of Validation Data

All data collected as part of team member validation activities will be permanently archived within the larger EOSDIS framework. Initially, these data will reside within local data bases at individual Team Member Computing Facilities. Mark Abbott's group at Oregon State will expand their data base for in-situ data in support of all MODIS Ocean Group investigations, to provide ready exchange capability among team members. When the data are stable, they will be transferred to the NASA sites, the MDB at U. Miami and SeaBASS at GSFC. It is essential during the test and evaluation phase, that the quality assessment of the *in situ* data be the direct responsibility of the individual Science Team Members. When algorithms mature, the responsibility for maintaining these data bases, and incorporating new data, should shift to the appropriate DAAC.

6.0 Summary

The validation and initialization of MODIS on Terra builds on the success demonstrated for SeaWiFS. The optical time series from MOBY, coupled with augmented measurements on the MOBY servicing cruises, will provide the team with highly accurate ocean optical observations for clear waters and clear atmospheres. The MOCE initialization cruise will focus on higher chlorophyll waters off Southern California and Baja, with more complex aerosol conditions. This combination will provide a larger dynamic range of spectral radiance values than was available for SeaWiFS. In addition to the visible optical measurements by Clark, Gordon, Voss, and Carder, measurements of fluorescence productivity, and surface IR brightness tempereratures.

7.0 References

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Appendix A PRELIMINARY CRUISE PROSPECTUS

MODERATE RESOLUTION IMAGING SPECTROMETER
INITIALIZATION EXPERIMENT
FOR OCEANS

RV Meville
October 1-21 1999

Dennis K Clark, Chief Scientist
NOAA/NESDIS
April 23, 1999

MODERATE RESOLUTION IMAGING SPECTROMETER INITIALIZATION EXPERIMENT FOR OCEANS

PURPOSE:

This Moderate Resolution Imaging Spectrometer (MODIS) Initialization Experiment is to be conducted by NASA and NOAA in support of the US Earth Observing System. Over the next decade, several Earth Observing Satellites will be launched into space with instruments measuring the color of the ocean's surface waters from which the abundance of microscopic marine plants can be determined. The abundance of these plants (phytoplankton) are critically important to the marine food chain and influence the balance of carbon dioxide within the Earth's atmosphere. The first of the NASA Earth Observing System satellites is scheduled to be launched on July 28, 1999. The application of the observations acquired by MODIS requires that coincident at-sea marine and atmospheric optical measurements are obtained early in the sensor's life in order to initialize the sensor calibrations and to parameterize the atmospheric correction models.

The primary cruise objective is to provide radiometric characterizations (visible & infrared spectral regions) of the water-leaving radiances and atmospheric transmittances and their spatial variability concurrent with MODIS observations. The secondary objective is to acquire pertinent bio-optical measurements which will validate the MODIS derived products. Additionally, these observations will serve to provide validation data for other ocean color instruments i.e. Sea-viewing Wide Field-of-View Sensor (SeaWiFS) and the Republic of China's Ocean Color Imager (OCI).

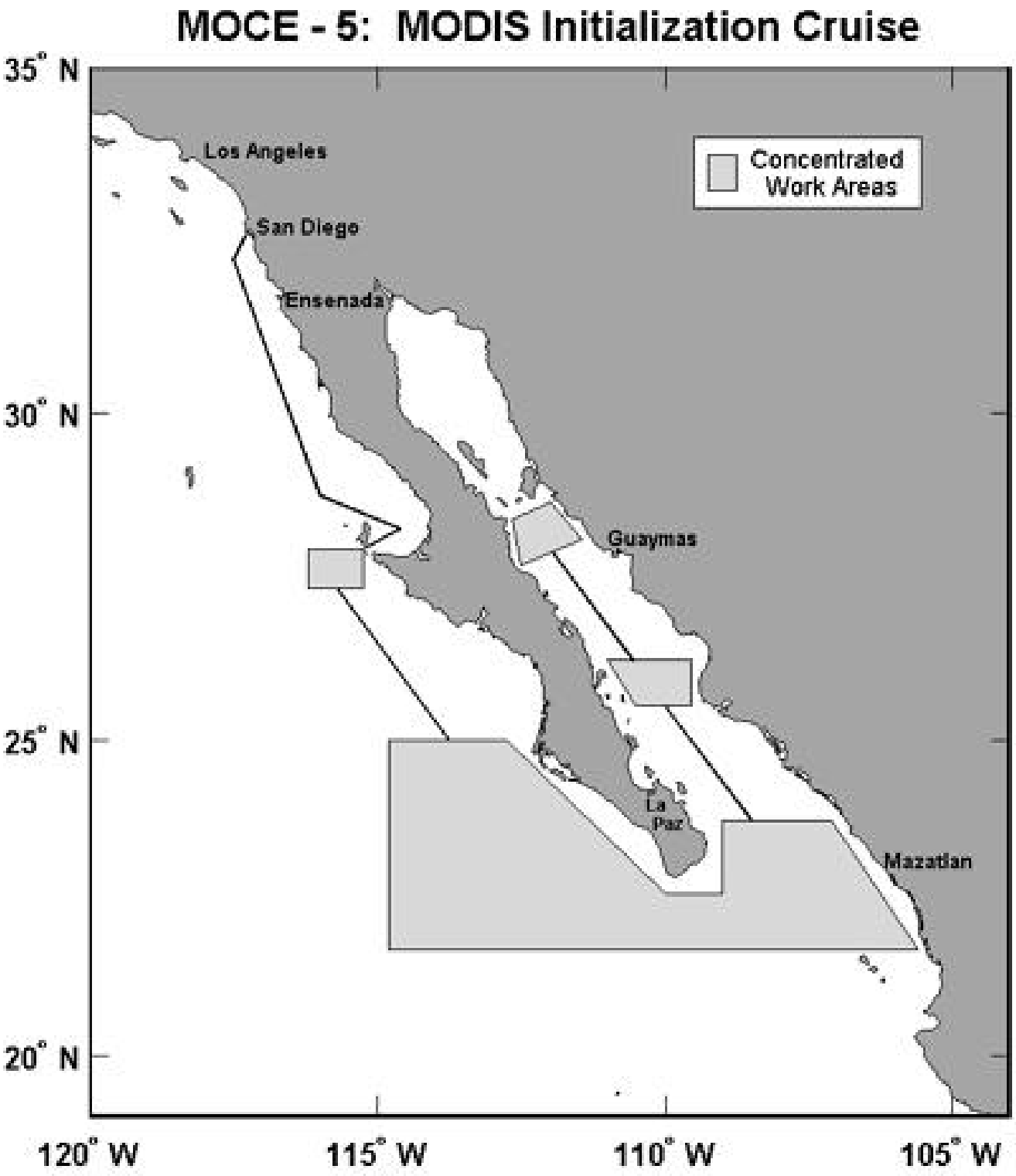
SCHEDULE:

Ship Honolulu to San Diego: August 23,1999
Off Load and Setup: September 21-26, 1999
Load Melville: September 27-30,1999
Sail: 08:00 October 1, 1999
Return: 08:00 October 22, 1999
Off Load: October 22-23, 1999
Load Containers: 24-26, 1999
Ship San Diego to Honolulu: October 27, 1999

OPERATIONS:

During this experiment, extensive measurements will be conducted at locations along the coast of Baja and within the Sea of Cortez. Potential operating areas and associated ship tracks are depicted on Figure 1. A complete suite of measurements, designed to characterize the bio-optical state, up to a depth of 150 meters, will be performed at stations within these sites during the satellite overpasses. During the ship transits, an abbreviated set of observations documenting the surface waters and atmospheric state will be conducted in order to address spatial variability uncertainties. The observations acquired at the proposed sites will provide a variety of marine optical, atmospheric, and biological signals for calibration and validation purposes.

FIGURE 1


MOCE - 5: MODIS Initialization Cruise
35° N
30° N
25° N
20° N
120° W
115° W
110° W
105° W
Los Angeles
San Diego
Ensenada
Guaymas
La Paz
Mazatlan
Concentrated Work Areas

A list of the observations focused on the primary initialization objective are listed in the following table:

Optical Observations - Ocean	**Responsible**
Incident Spectral Irradiance	NOAA
Downwelled Spectral Irradiance	NOAA
Upwelled Spectral Radiance	NOAA
Upwelled Spectral Radiance Distributions	Miami
Whitecap Spectral Reflectance	Miami
Spectral Beam Attenuation	NOAA
Sea Surface Thermal Infrared	Miami
Attenuation Coefficients Upwelled Radiance	NOAA
Optical Observations - Atmosphere	
Sky Radiance Distributions Miami	
Sky Polarization	Miami
Solar Transmittance	NOAA
Solar Aureole	Miami
MPL Lidar	Miami
Meteorological Observations	
Surface Atmospheric Pressure	NOAA
Surface Humidity	NOAA & Miami
Surface Temperature	NOAA & Miami
Radiosondes	Miami
Wind Speed & Direction	NOAA
Sky Video	NOAA
Physical Observations - Ocean	
Sea Surface Temperature	Miami
Salinity Profiles & Trackline	NOAA
Temperature Profiles & Trackline	NOAA

Measurements associated with the secondary product validation objective are:

Beam

Optical - TSRB Natural Fuorescence, FRR Fluorescence, Spectral Scattering, Spectral Transmission, Surface Spectral Reflectance, Secchi Disk Depth and Munsell Color.

Biological - Particle Size Distribution, Particle Absorption, Colored Dissolved Organic

Matter Absorption, Dissolved Oxygen, HPLC Phytoplankton Pigment Concentrations, Fluorometric Chlorophyll a Concentration, Total Suspended Matter, and ^{14}C PvsI

A nominal daily operational schedule for MODIS overpasses is detailed in Figure 2. Schedule requirements for Oregon State University and are to be determined.

RV MELVILLE EQUIPMENT/FACILITIES REQUIRED:

There are no known special requirements at this time. The RV Melville is a well founded research vessel and offers capabilities which this effort will not require. A complete description of the RV Melville is found at:

http://sio.ucsd..edu/supp_groups/Melville/shipinfo.html

General operational requirements for the following activities are:

Bio-optical Characterizations:

- 0 Stern A-Frame for surface optical buoy deployments and retrieval Hydrographic winch for CTD deployment.
- 0 Laboratory Space (wet and general).
- 0 Deck space for five 8 X 12 feet laboratories and 14 C lab.
- 0 Uncontaminated seawater.

Paravane Towed System:

- 0 Starboard A-Frame for Paravane deployment, retrieval, and near- surface towing off the starboard side.

PERSONNEL:

Presently there are twenty nine scientists, technicians, and students scheduled for this deployment. The science party personnel and affilations are listed in the following table.

PERSONNEL	TITLE
NOAA/NESDIS	**Marine Optics Team**
Dennis Clark	Senior Scientist
Marilyn Yuen	Research Associate
Edward King	Research Technician
Eric Stengel	Research Technician
Ed Fisher	Research Technician
Larisa Koval	Research Associate
Mike Ondrusek	Research Associate
Yong Sung Kim	Research Associate
San Jose State University	**Moss Landing Marine Laboratories**
William Broenkow	Professor
Mark Yarbrough	Senior Research Associate
Mike Feinholz	Research Associate

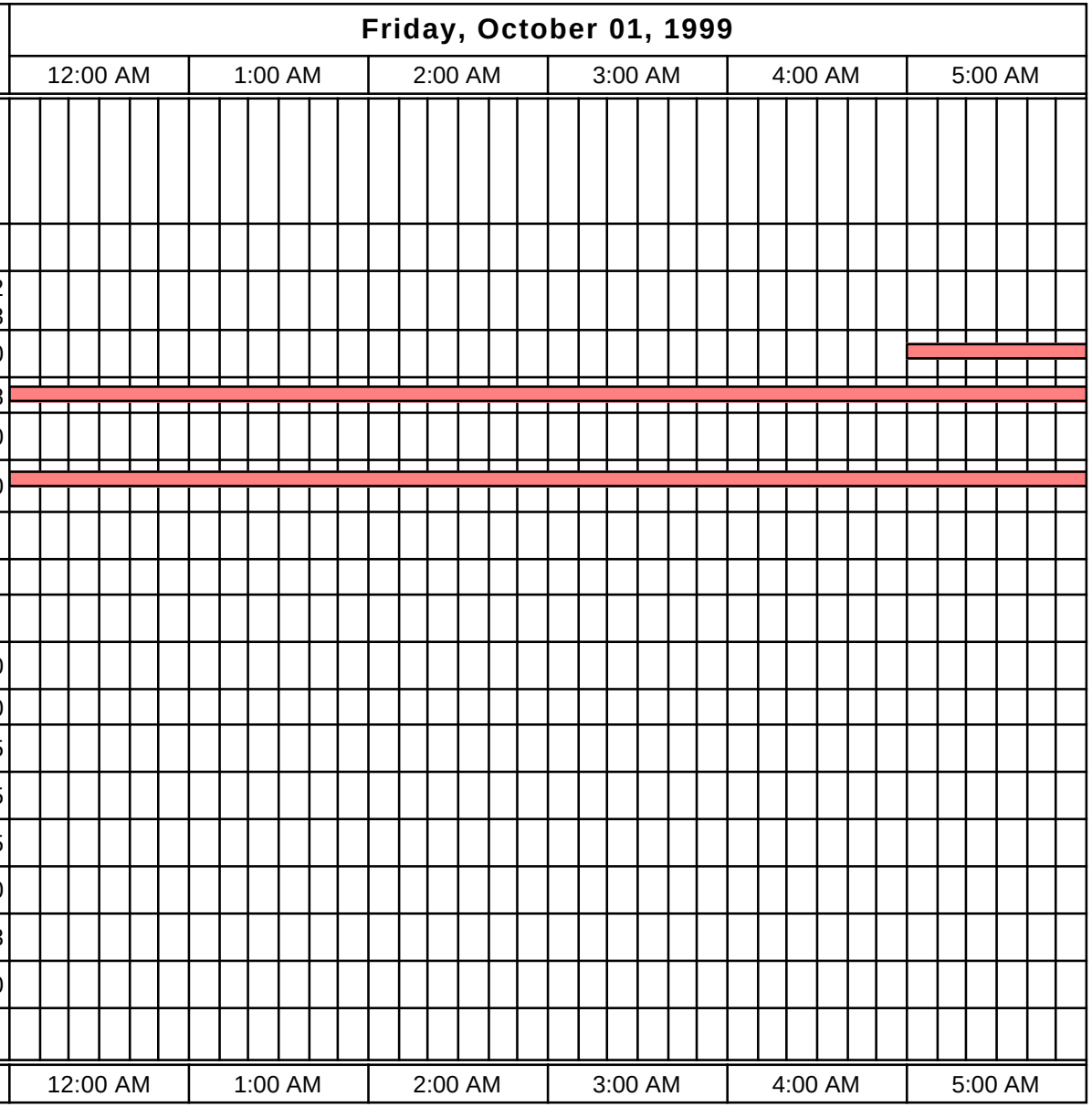
Stephanie Flora	Research Technician-Student
Rachel Kay	Research Technician-Student
Darryl Peters	Research Technician-Student
San Diego State University	**Center for Hydro-Optics & Remote Sensing**
Chuck Trees	Research Professor
Chris Kinkade	Post-Doc
University of Miami	**Physics Department**
Ken Voss	Professor
Peter Minnet or alternate	Research Professor
Robert Evans	Research Professor
Albert Chapin	Research Technician
Oregon State University	**College of Oceanic and Atmos. Sciences**
Ricardo Letelier	Research Associate
Ronald Zaneveld or alternate	Professor
TBD	Research Associate
TBD	Research Technician-Student
University of South Florida	**Marine Sciences**
Zhang Ping Lee	Research Associate
CICESE - Mexico	**Ecology Department**
Roberto Millan	Professor
TBD	Professor
Two TBD's	Students

REFFERENCE: MODIS OCEAN TEAM VALIDATION APPROACH

Clark, D.K, Gordon, H.R., Voss, K.J., Ge, Y., Broenkow, W., and Trees, C. (July 1997) Validation of Atmospheric Correction over the Oceans., Special issue J.Geophys. Res. .

Figure 2: MODIS Initialization - Nominal Daily Schedule

STATION DEPLOYMENT SEQUENCE	Start Time	Finish Time	Duration
SATELLITE PASS **MODIS** **SeaWiFS** **MODIS**	10:30 AM 12:45 PM 10:30 PM		
MOBY OBS.	12:37 PM 10:24 AM	12:56 PM 10:44 AM	0.32 0.33
PARAVANE TOW	5:00 AM	9:00 AM	4.00
SEA CHEST	12:00 AM	11:59 PM	23.98
STATION GRID	4:30 PM	8:30 AM	16.00
MAERI	12:00 AM	12:00 mid	24.00
BIO-OPTICS			
CTD-O2/FRR Cast	9:15 AM	9:45 AM	0.50
SIS	6:30 AM	6:00 PM	11.50
SATLAN Cast	9:45 AM	10:00 AM	0.25
MOS Cast	10:00 AM	1:15 PM	3.25
RADS-UW	10:15 AM	1:00 PM	2.75
VLST Cast	11:00 AM	1:00 PM	2.00
SATLAN Cast	1:25 PM	1:45 PM	0.33
WHITECAP RAD	10:00 AM	1:00 PM	3.00
SECCHI DISK	11:30 AM		



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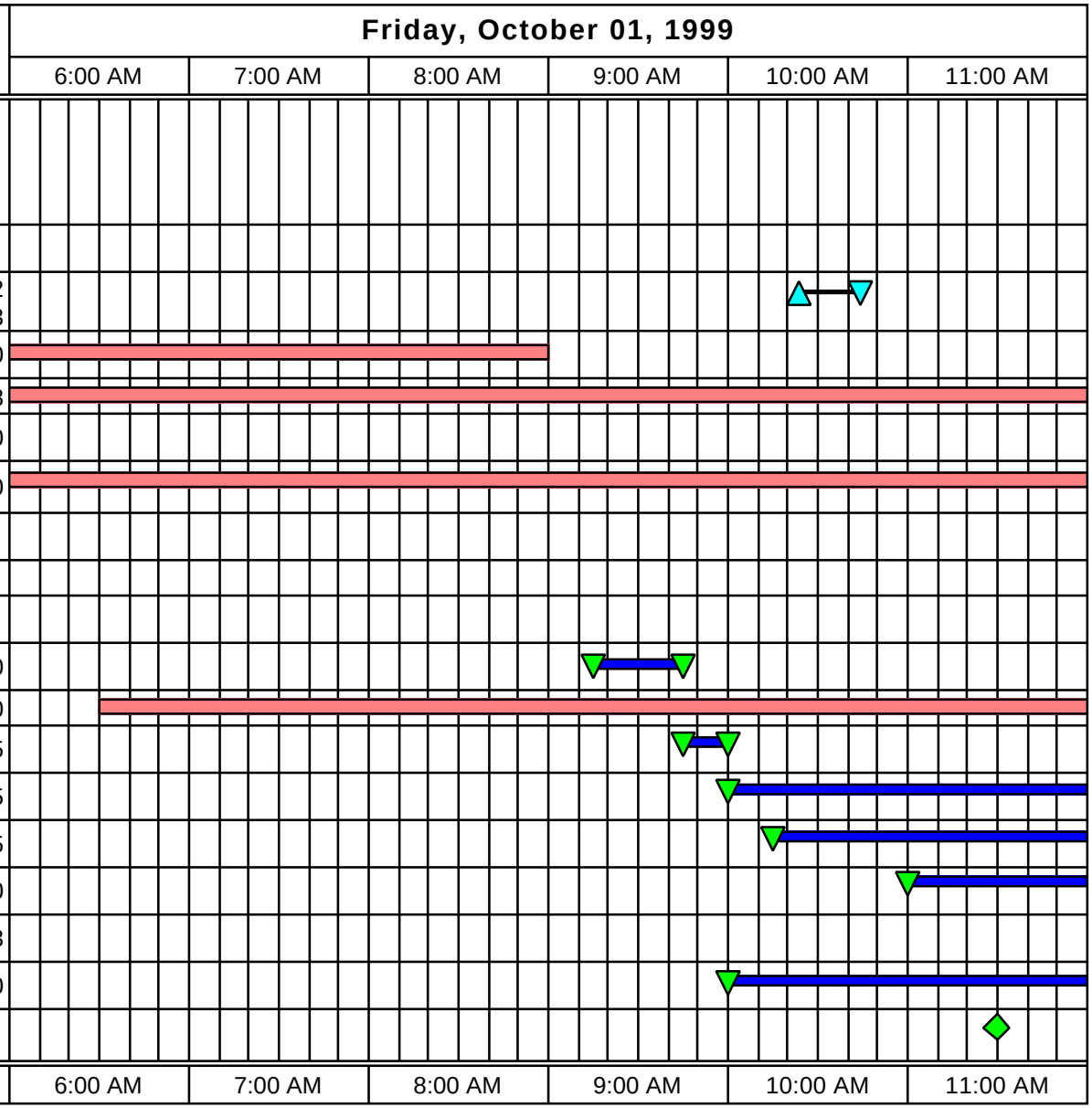

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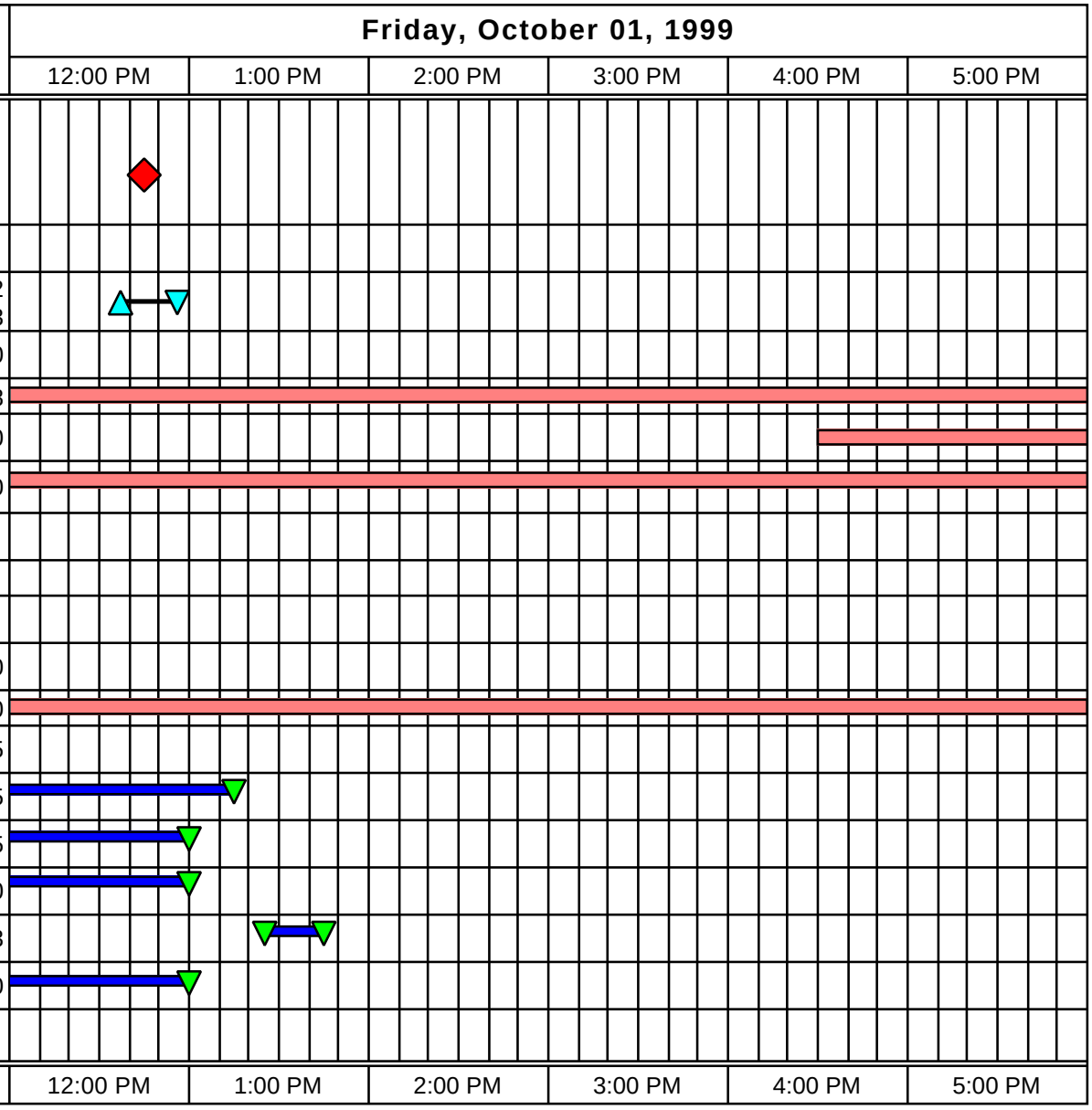

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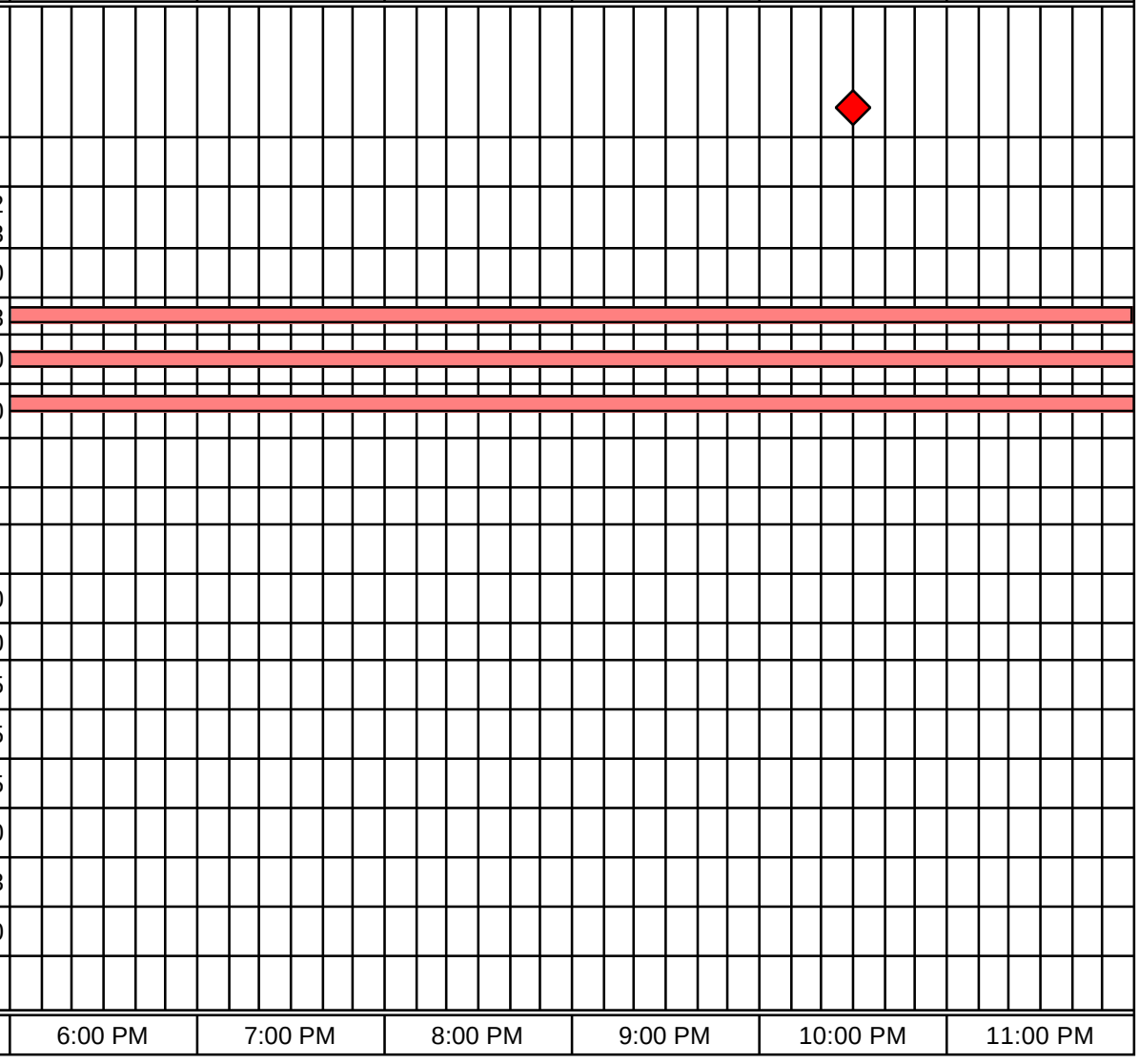
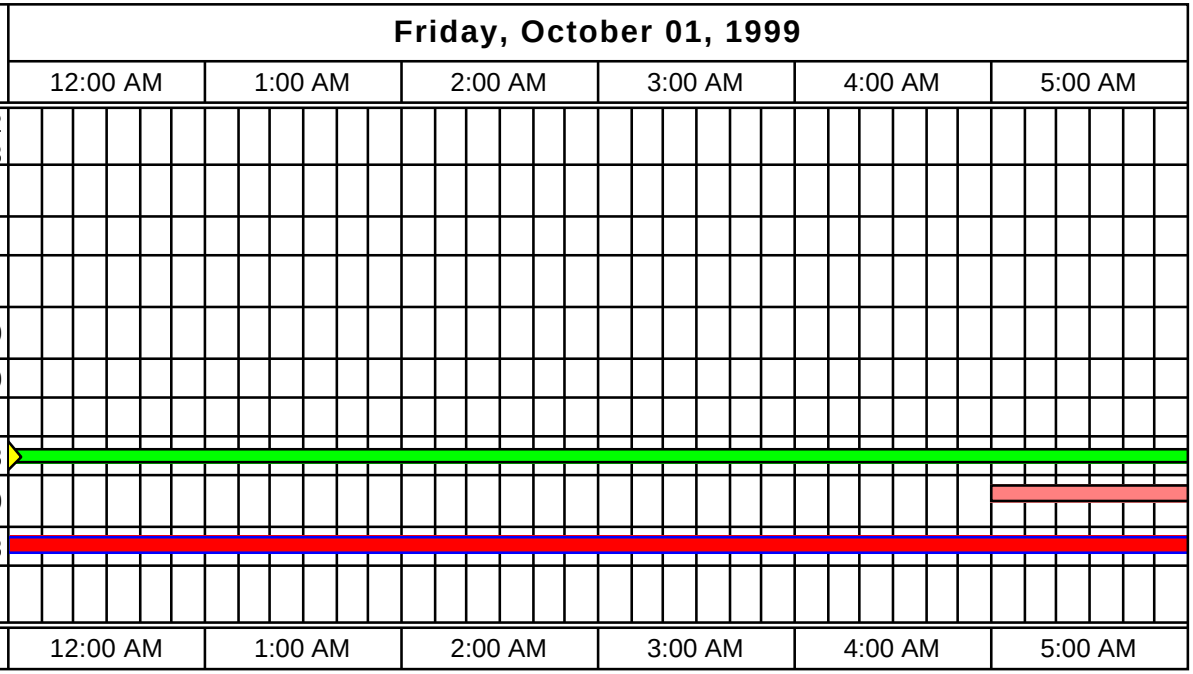


Figure 2: MODIS Initialization - Nominal Daily Schedule

STATION DEPLOYMENT SEQUENCE	Start Time	Finish Time	Duration
SURF. REFLECT.	10:26 AM 12:51 PM	10:33 AM 12:59 PM	0.12 0.13
ATMOSPHERICS			
HHCRM/Microtop	7:00 AM	5:00 PM	10.00
RADS-SKY	9:30 AM	3:00 PM	5.50
AUREOLE			
MPL LIDAR	12:00 AM	11:59 PM	23.98
SKY VIDEO	5:00 AM	7:00 PM	14.00
METEROLOGICAL	12:00 AM	11:59 PM	23.98
RADIOSONDES	10:30 AM 10:30 PM		



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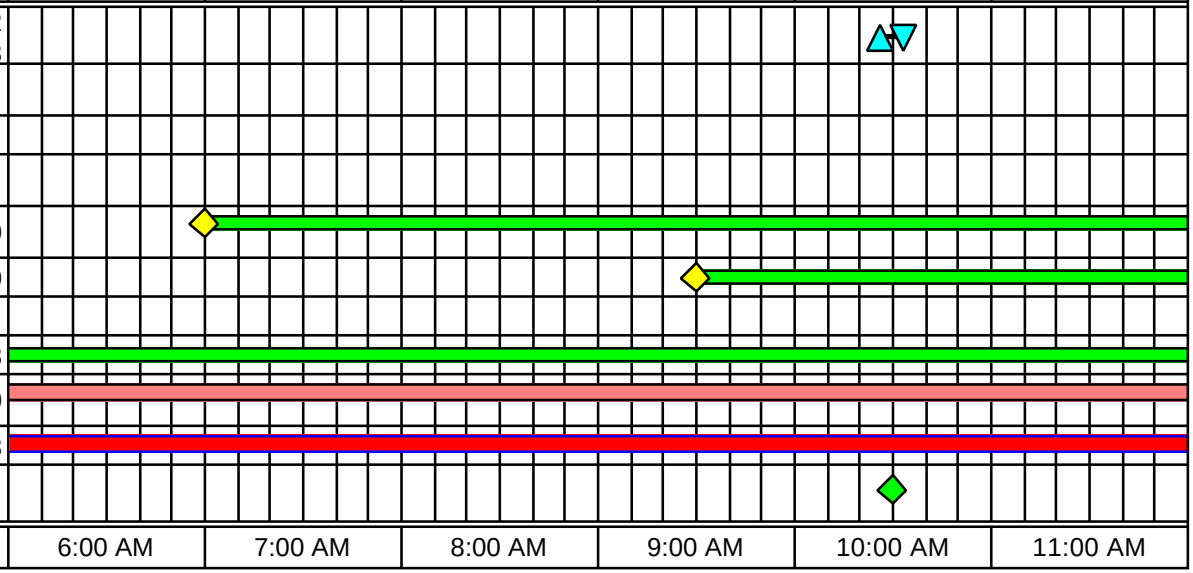

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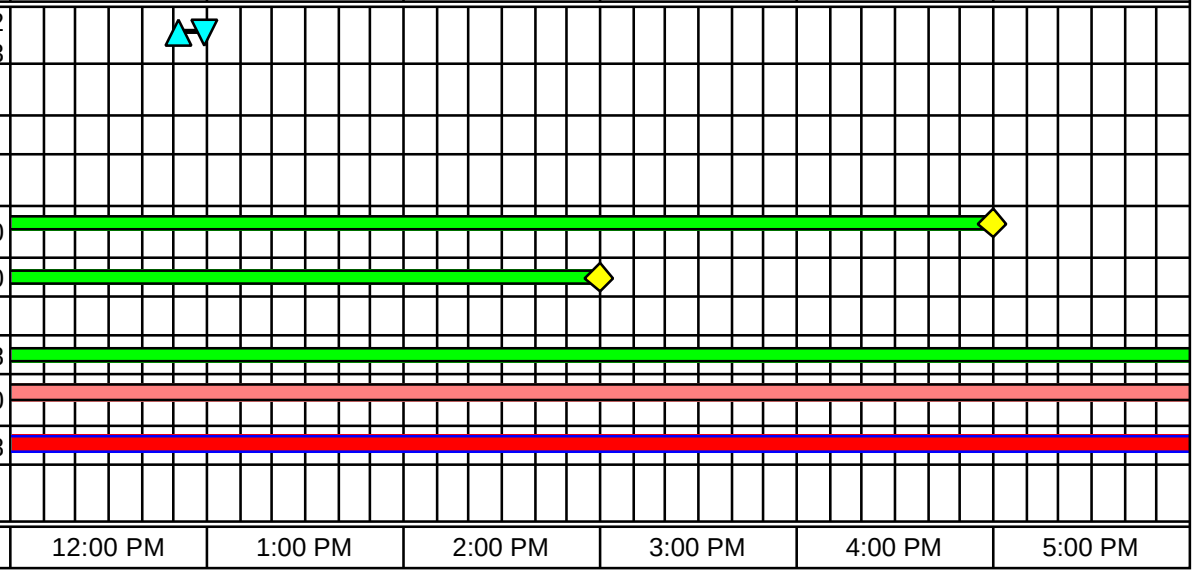

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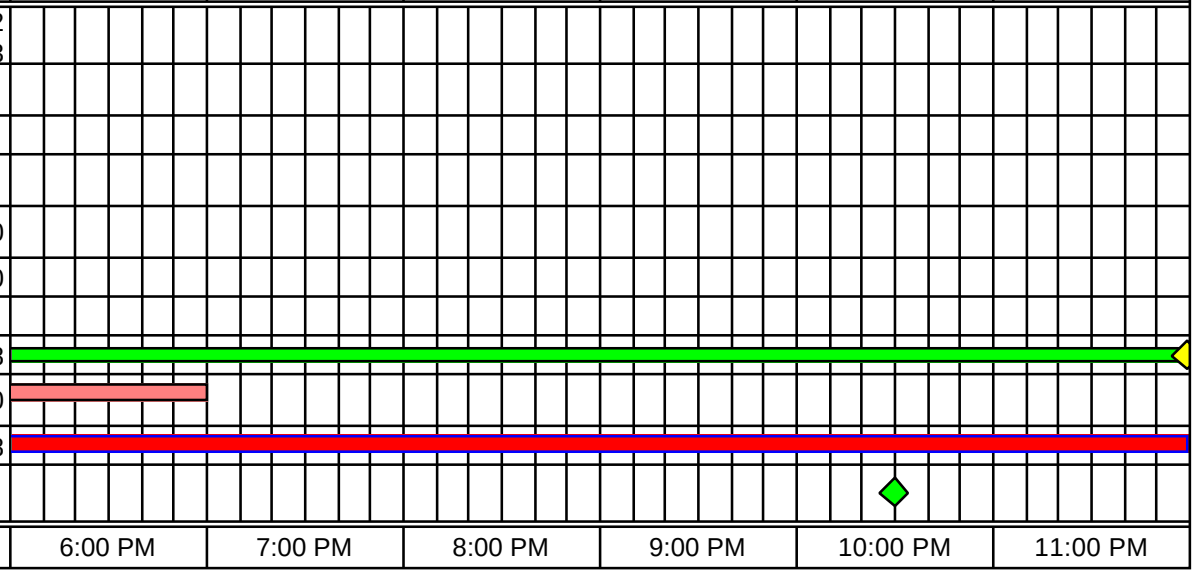

Appendix B Schedule of Acitivities for Case 2 Cruises K. Carder.

These will provide cal/val data for both the Rrs values from MODIS and the algorithm-derived values for chlorophyll, gelbstoff, and absorption coefficient data.

Activity Name	Start Date	Measurement Suites	1999				2000				2001			
			1	2	3	4	1	2	3	4	1	2	3	4
L. Okeechobee	2/15/99	*	X											
GOM	3/1/99	*	X											
TOTO (Stray Light)	4/15/99	* + ✓∇		X										
Sargasso, Bahamas	5/25/99	* + ✓∇		X										
GOM (min. packaging)	7/1/99	*			X									
Gulf of California	10/15/99	* + ✓∇				X								
GOM	12/7/99	* + ✓				X								
GOM	3/1/00	* + ✓					X							
TOTO (Stray Light)	4/15/00	** + ✓						X						
Sargasso, Bahamas	5/25/00	* + ✓						X						
GOM, Miss. Plume	6/15/00	* + ✓						X						
GOM	7/15/00	* + ✓							X					
GOM	10/1/00	* + ✓								X				
GOM	1/10/01	* + ✓									X			
Tasmania (S. hi lat.)	2/15/01	* + ✓∇									X			
TOTO (Stray Light)	4/15/01	* + ✓∇										X		
GOM	5/1/01	* + ✓										X		

Activity Abrreviation and Location

Okeechobee – Lake Okeechobe FL
GOM – Eastern Gulf of Mexico
TOTO – Tongue of the Ocean (Bahamas)
Miss. Plume – Mississippi Plume off Louisiana

Key for Measurement Suites:

* 1. Rrs (λ, 0^+), above water
* 2. $a_g(\lambda)$, hydro casts
* 3. $a_\varphi(\lambda)$, hydro casts
* 4. Chla (fluor.), hydro casts
* 5. Phaeophytin *a* (fluor.) hydro casts
* 6. Salinity (z)
* 7. Temperature (z)
* 8. Wind velocity

\+ 1. $L_u(\lambda, z)$, *in situ*
\+ 2. $k_d(\lambda, z)$, *in situ*
\+ 3. $E_d(\lambda, z)$, *in situ*
\+ 4. $k_u(\lambda, z)$, *in situ*
\+ 5. $a_g(\lambda, z)$, $a_p(\lambda, z)$, *in situ*
\+ 6. $a_g(\lambda, z)$, *in situ*

x 1. Bottom albedo

∇ 1. τ_a, τ_{oz}, τ_{wv}, τ_R

✓ 1. Fluor_Chl (z)
✓ 2. Fluor_gelb (z)

APPENDIX C : M-AERI sea-going deployments 1995-98

Project	Ship	Start date	Start port	End date	End Port	Instrument	Comments
	R/V Pelican	15 January 1995	LUMCON	17 January 1995	LUMCON	Proof of Concept	See Smith et al, 1996
Combined Sensor Cruise	NOAA Ship Discoverer	14 March 1996	Pago-pago, American Samoa	13 April 1996	Honolulu, HI	Prototype	About 10 days spent off Manus, PNG in middle of cruise. See Post et al, 1998
Hawaii - New Zealand Transect	R/V Roger Revelle	28 September 1997	Honolulu, HI	14 October 1997	Lyttleton, NZ	MAERI-1 & MAERI-2	
OACES 24 N Section	NOAA S Ronald H. Brown	8 January 1998	Miami, FL	24 February 1998	Miami, FL	MAERI-1	In port in Las Palmas, Canary Islands. January 21-23.
NOW 98	CCGS Pierre Radisson	26 March 1998	Quebec City, Canada	28 July 1998	Nanisivic, Canada	MAERI-2	Data from 980328 to 980722
OACES Gasex-98	NOAA S Ronald H. Brown	2 May 1998	Miami, FL	7 July 1998	Miami, FL	MAERI-1	In port in Lisbon, May 20-25; Ponta Delgada, June 26-28
Panama Transit	NOAA S Ronald H. Brown	12 July 1998	Miami, FL	27July 1998	Newport, OR	MAERI-1	Through Panama Canal.
PACS-Mooring recovery	R/V Melville	8 September 1998	San Diego, CA	29 September 1998	San Diego, CA	MAERI-1	To TAO mooring line at 125W

Last updated : 15 December 1998

Comments to: Peter Minnett, RSMAS-MPO.

Planned M-AERI deployments 1999

Project name	Ship	Departure Date	Departure Port	Arrival Date	Arrival Port	Comment
Western pacific Transect and St. Lawrence Island Polynya	USCGC Polar Sea	1 Mar 99	Adelaide, Australia	12 May 99	Seattle	
Nauru 99	R/V Mirai	8 June 99	Yokohama, Japan	20 July 99	Sikenehama, Japan	Need to ship from RSMAS on May 15 (TBC) Begin loading 5 June. 6/17 - Mirai arrives at Nauru. 7/5 - Mirai departs Nauru. Arrive 16 July, Tsuruga, Japan
NOW 99	CCGS Pierre Radisson	24 August 99	Quebec City	~10 October 99	Quebec City	Canadian Coast Guard charter flight from Quebec to Resolute on August 24. Ship leaves Quebec June 25.
MODIS Initialization	R/V Melville	1 October 1999	San Diego	20 October 1999	San Diego	Off Baja California, Dennis Clark et al.
Straits of Sicily	R/V Urania	15 October 1999	??	15 November 1999	??	Details under discussion. Collaboration with Institute of Atmospeheric Physics, Rome.
MITEC Microstructure Technology Experiment	Pontoon on Soppensee, Switzerland	November 1999	Soppensee	November 1999	Soppensee	Details under discussion. Likely to be 2nd and 3rd week of Nov, just before the lake freezes over. Collaboration with Joint Research Centre, Ispra. To study air-sea fluxes
Eastern Atlantic Transect	R/V Polarstern	15 December 1999	Bermerhaven, Germany	6 January 2000	Cape Town	

Last updated : 8 April 1999 1:50

Comments to: Peter Minnett, RSMAS-MPO.

MAERI Cruises