Climate Quality Ocean Color Time Series: Vicarious Calibration Requirements - MOBY

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Water-leaving Radiance Retrieval Uncertainty

SeaWiFS - NIST Calibration 4%  MODIS ¡  5%
Assume Atmospheric Correction is Perfect
Vicarious Calibration Required for Ocean Color Science

Atmospheric Correction is an Inherent Part of the Calibration Process.

Laboratory and On-board Sensor Calibrations Cannot Meet the Accuracy Requirements for this Science Application.

A Minimum of an Order of Magnitude Improvement in Radiometric Calibration Accuracy is Required.
Vicarious Calibration Site Criteria

**Oligotrophic Waters** - Stable Target
- Low Horizontal Gradients
- Optically Deep
- High Signal In Blue

**Maritime Atmosphere**
- Small Aerosol Component
- Avoid Absorbing Aerosol

**Characterize**
- Physical, Biological, & Optical
- BDRF Measurements & Models

**Serviceability**
- Convenient Logistic Support
- Safety - Diver & small boat operations
Vicarious Calibration Optical System Criteria

Optical

- High Spectral Resolution (1-2 nm)
- Large spectral range (350 - 900 nm)
- High stray light rejection
- Temperature Stabilization
- Reference lamps for stability monitoring

Calibration

- NIST traceability & overview
- Wavelength calibrations - low pressure lamps and lasers

Characterization

- Stray light
- Thermal
- Linearity
Vicarious Calibration Buoy System Criteria

**Buoy**
- Stable - small tilt angles
- Minimized shadowing effects
- Data & system status telemetry

**Characterization**
- Shadowing Correction Models

**Reliability**
- Minimize structural degradation for deployment periods of four months.
- Minimize bio-fouling and provide for systematic cleaning and *in situ* reference calibrations.
Initial Proposal for MODIS Vicarious Calibration

Based on DOE Ozone Monitoring Program:

A few primary sites instrumented with high-end optical systems (Fastie -eight meter double spectrometers).

High density geographic coverage with Dobson meters.

MODIS Proposal:

MOBY’s at five sites - Hawaii, Bermuda, Mediterranean, Brazil, and Australia.

Optical Drifters and at-sea bio-optical campaigns
MOBY Mooring Site

Hawaiian Islands

MOBY & Lanai Mooring

- 10 m 1/2" Chain
- 5 m 3/4" Chain Flounder Plate
- 100 m 1.5" MFP Rope
- 15 m 1/2" Chain
- 500 m 5/16" Rope
- 300 m 5/16" Rope
- Wire to NYLON Wrapped Termination
- 400 m 3/4" NYLON
- 962 m
- 932 m
- 225 m 3/4" NYLON
- 1072 m
- 377 m 3/4" POLYPRO
- 1148 m
- (20) 17" Glass Balls
- 1 m 1/2" Chain
- 8202 Release
- 20 m 1" NYLON
- 5 m 1/2" Chain
- 4000# Weight Anchor
- Depth 1200 m
MOBY Operations Site - Univ. Hawaii

Pier Side - 30,000 sq. ft

16 Portable vans/tent
offices, shops, storage, labs (calibration, optics assembly, filtration)

6 Shipboard Vans
3 labs - (wet, optics, data acquisition) power, storage, & office

Pier side Support - cranes, machine shop.
Marine Optical Buoy

- Es Collector
- GPS, RDF, ARGOS, Cellular, Strobe
- Solar Panels 4 x 40 W
- MOBY Surface Float:
  * TT7 Control Unit
  * Cellular Transceiver

- Mooring Tether
- Depth 1 m
- Fiber Optic Cable Pass
- Fiberglass Mast
- Depth 5 m
- Ed Collector
- Lu Collector
- Depth 9 m
- Collector Standoff
- Instrument Bay:
  * MOS System
  * Power Junction
  * Batteries
- Depth 12 m

Subsurface Instrument Bay

- New Optic Cells/Pass
- New Optic Tether/Pass
- Air Inlet/Exhaust
- Instrument Bay
- Collector Standoff

Irradiance Collector Diagram

- Floating Micro
- Shading Disk
- Band
- Ballast
- Buoy
- Buoy Tether
- Railing Ring
- Instrument Bay
MOBY Optical System

Marine Optical System - Dual Spectrographs
MOBY Calibration Process

NIST Collaborations

Training
NIST Primary Lamb Standards
Annual On Site Calibration Systems Check
Pre/Post Cal. System monitoring with NIST Cal. Radiometers
SIRCUS - Stray Light Characterizations on MOBY and Shipboard Spectrometers
MOCE Calibration Systems (OL420 & OL425) now Calibrated at NIST
Initiating the development of new LED Radiometric Calibration Sources for Oceans
Internal Reference Lamps - Stability QC

MODIS-1 Total-Band  MOBY Internal Calibration Lamp/LED Variability

- Blue: < 0.5%
- Red: < 0.5%
- Both: ± 0.5%
Spectral Calibration QC-Solar

Blue Spectrograph
2.5 years
Approx. +/- 0.6nm

Red Spectrograph
2.5 years
Approx. +/- 1nm
MOBY Crossover Comparisons

- **M210 1999**
- **M211 1999**

- **M212 2000**
- **M213 2000**
Horizontal Chlorophyll-a Variability Survey

Grid Size: 12x12 Km

Min: 0.089
Max: 0.126
Mean: 0.110
Delta: 0.038
• MODIS views MOBY from 14 specific geometries.
• Sun-MODIS geometry varies in a regular manner throughout the year.
• Use NuRADS data to empirically model this variation.

Example for measurement at 22:04 UT., Satellite view is 53 degrees.
Spectral Band Considerations
Spectral Band Pass Matching

High Resolution Spectra Convolved to Sensor’s Spectral Band Pass

nLw's Converted into MODIS Bands
Spectral Band Uncertainties-MODIS Terra

Total to In-band Ratios for: Incident Solar Irradiance, Blue, Green, Brown Water-leaving Radiance, and a Calibration Lamp Spectra.

Band | Wavelength nm
--- | ---
8 | 411.8
9 | 442.1
10 | 486.9
11 | 529.7
12 | 546.8
13 | 665.6
14 | 676.7
15 | 746.4
16 | 866.2
Spectral Band Systematic Uncertainties
Wavelength Shifts - Es - 0.05nm steps
Spectral Band Systematic Uncertainties
Wavelength Shifts - $L_{wn}$ - 0.05nm steps

MODIS-Terra In-Band Wavelength Uncertainty
MOBY Solar Normalized Water Leaving Radiance

MODIS-Terra InBand wavelength uncertainty
MOBY Solar Normalized Water Leaving Radiance
Spectral Band Passes - OC Missions
Spectral Band Pass Matching
High Resolution Spectra Convolved to Sensor’s Spectral Band Pass

![Graph showing spectral data with different lines for Lw1, Lw2, Lw3, and Es.](Image)
Spectral Band Systematic Uncertainties
SeaWiFS In-Band Response Ratios to Other OC Sensors
Reduction of Systematic Uncertainties - MOBY
SeaWiFS Stray Light Time Series Corrections
Major MOBY Reprocessing Elements

**Thermal Corrections** - A correction for temperature of approximately 0.5% per degree is being applied to system responses and \textit{insitu} data.

**Stray-light Model Version 2** - Implemented an improved characterization of the MOS spectrographs to develop a more detailed model of the instrument slit scatter function. This resulted in a more accurate measure of scattered light in the system and impacted the measured Lu’s - primarily at the ends of each spectrograph.

**System Responses** - The pre and post radiometric and wavelength calibrations are being recomputed with new stray-light and thermal corrections. The average of the pre and post calibrations will applied as the final response functions.

**Quality Control** - Changed to Mueller pure water KI’s and added a flag for questionable data.
Initial Test Results: MOBY Reprocessing

![Graph showing MODIS-Terra Total Band ratio over time. The x-axis represents Julian Day from 2003, and the y-axis represents the ratio of new processing to old. Different colored lines represent different bands (8, 9, 10, 11, 12, 13, 14).]
Thermal Corrections

MOBY221-23 TT7 Temperature used in the thermal corrections

- In-water TT7 temp
- LuTop Rsp TT7 Temp
- LuMid Rsp TT7 Temp
- LuBot Rsp TT7 Temp
- TT7 Set Temp

Sequential Day
Nov, Dec, Jan, Feb, Mar, Apr, May, Jun, Jul

MOBY TT7 board temperature (°C) - LuTop
MOBY Water temperature (°C)
Initial Results: MOBY Reprocessed Lwn
Work In Progress - Reprocessing 3 Potential

Apply Mueller Shadowing Model Corrections

Improve NIR Lw Computations

Improve UV System Responses with Blue LED Calibration Sources

Reduce Calibration System Uncertainty with NIST SLM’s & VXR MOBY Time Series
MOBY - A Primary Reference Standard for Climate Quality Ocean Color Time-Series

- Six Year + Time-Series 7/20/97 to Present
- NIST Radiometric Scale & Collaboration
- Verification of System Performance
- Stray Light and Thermal Characterizations
- Sensor Spectral Band Matching
- Ocean Color Sensors Supported with MOBY Scale:
  - Japan - OCTS
  - French - POLDER
  - US - SeaWiFS
  - US - MODIS (Terra and Aqua)
  - US - MISR (Terra)
  - Europe - MERIS
  - Japan - GLI
Ancillary slides
Stray Light & MOBY

Traveling SIRCUS

Uniform sphere

Tunable laser

Standard detector

MOBY

Response found at many wavelengths

Corrected Lu’s
- increase in UV
- better agreement in overlap region

Graph showing relative response at various wavelengths.
Site Location & Watch Circle

CIMEL Sites

MOBY Site

Kauai
Oahu
Molokai
Maui
Hawaii

1 Km

mm