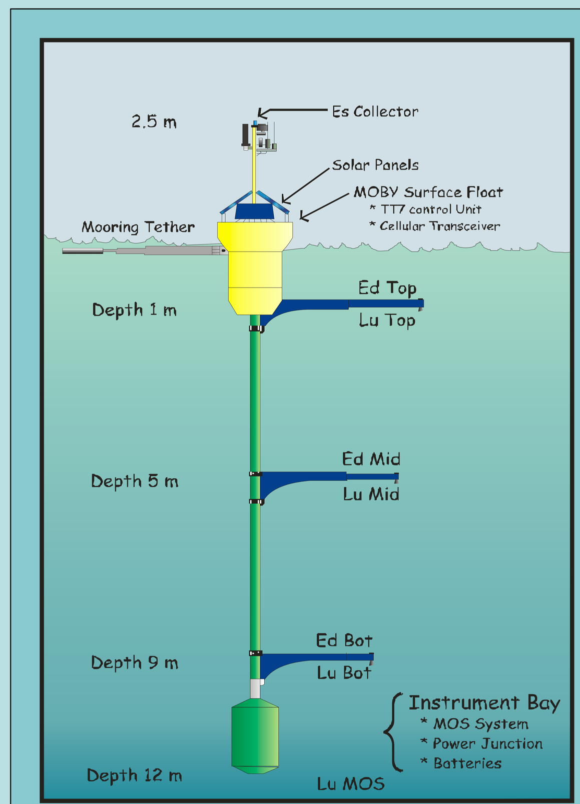
Data Processing and Archival in the Marine Optical Buoy Project (MOBY)

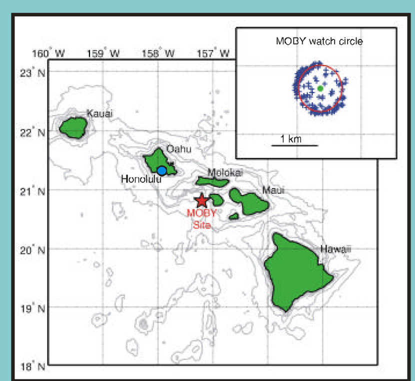
B. Carol Johnson, Dennis K. Clark, Steven W. Brown, Michael E. Feinholz, Mark A. Yarbrough, Stephanie J. Flora, Darryl Peters, Terrence Houlihan and Yong Sung Kim

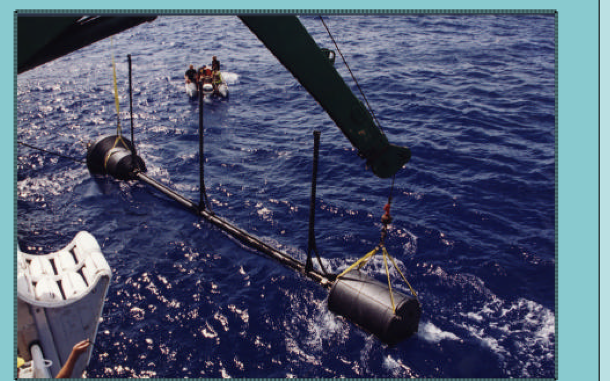


Introduction

The primary reference instrument for ocean color satellites, including the U.S. Moderate Resolution Imaging Spectroradiometer (MODIS) and the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS), is the Marine Optical Buoy (MOBY), a radiometric buoy stationed in the waters off Lanai, Hawaii. MOBY uses a hyperspectral instrument known as the Marine Optical System (MOS) to detect radiation over the spectral range from 350 nm to 955 nm. In MOBY, MOS is fiber-optically connected to radiance and irradiance ports on the three MOBY arms (denoted Top, Mid, and Bot) that are located at depths of approximately 1.5 m, 5 m, and 9 m, as well as a surface irradiance port.

Data acquisition is autonomous and designed to overlap with the overpass of the sun-synchronous satellites, resulting in daily acquisitions at 20 h, 22 h, and 23 h, corresponding to SeaWiFS, MODIS-Terra and MODIS-Aqua, respectively. In this presentation, we describe the processing of the MOBY data sets, including what is collected, analysis and quality control, and dissemination and archival.





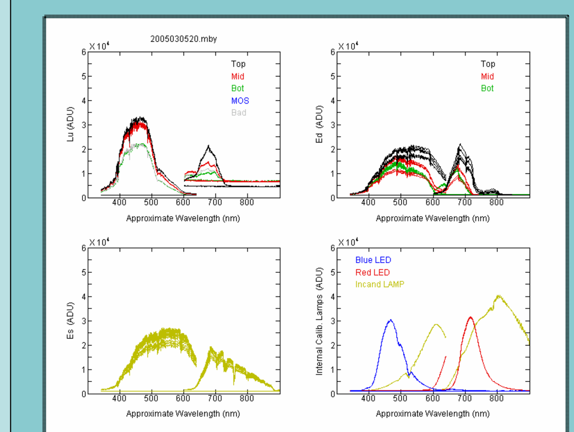
Optical Buoy

- E_s, L_u (at four depths), E_d (at three depths)
- CCD parameters (integration time, bin factor, slit temperature)
- Temperatures (instrument and sea water)
- Attitude (x, y tilt; pressure at top arm; compass heading)
- System housekeeping (battery status, coolant flow, etc.)
- Time (onboard, GPS)

Mooring Buoy

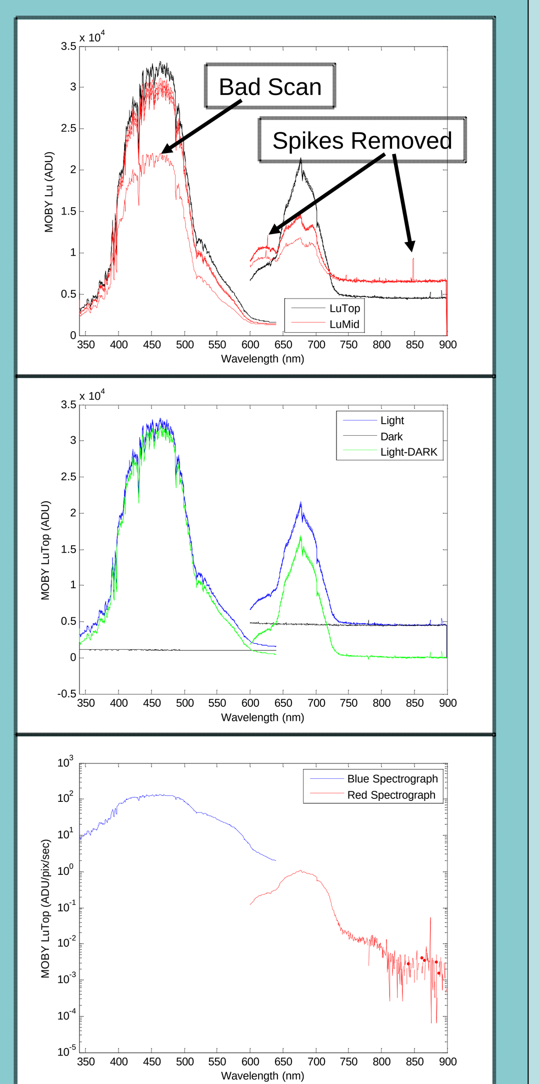
- Wind velocity
- Surface pressure
- Air temperature
- Relative humidity
- Sea surface temperature
- Sea surface conductivity
- Photosynthetically Active Radiation

MOBY Data Processing

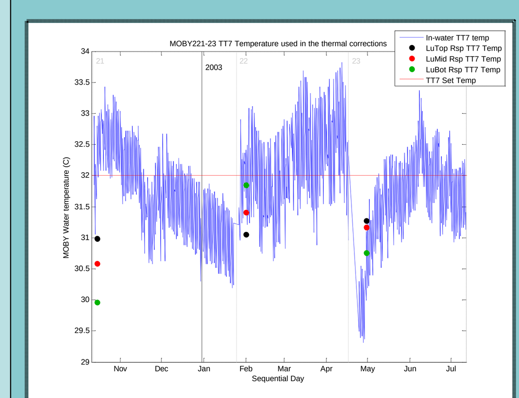


The optical measurements (e.g., E_s and L_u) by MOBY are sequential – the inputs from the different optical fibers are coupled to the spectrographs using an optical multiplexer mirror assembly. A complete data set for L_u at each depth includes multiple scans of L_u, bracketed by a dark scan; this L_u measurement is bracketed in turn by a set of E_s scans (which are also bracketed by dark scans). The optical and ancillary data are stored on hard drive until transmittal to a server at MLML via modem and cellular antenna.

Pre-processing of the entire data set includes the incorporation of time stamps for the ancillary data, if necessary, rejection of anomalous radiometric scans, and removal of "spikes" in the radiometric data. Multiple scans are averaged, the data are normalized for integration time and bin factor (a sub-sampling along the slit direction in the CCD spectrographs), and the net counts are determined using the associated dark scans. Corrections are made for instrument temperature, which affects the radiometric responsivity as 0.5 %/°C. The temperature correction algorithm is based on laboratory measurements at the MOBY facility in Honolulu using a temperature controlled bath and stable radiometric sources.



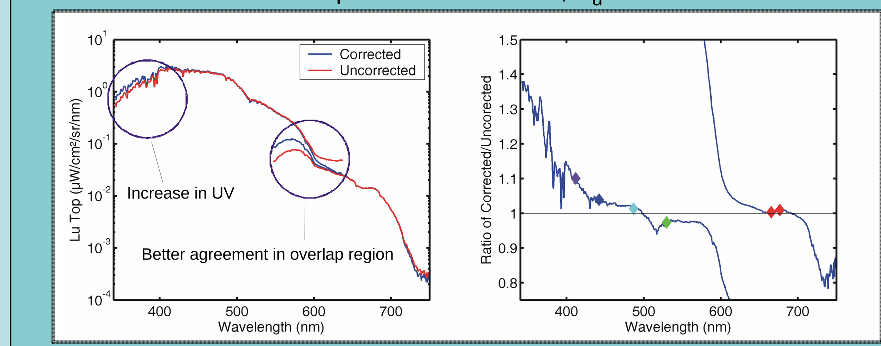
MOBY processing steps



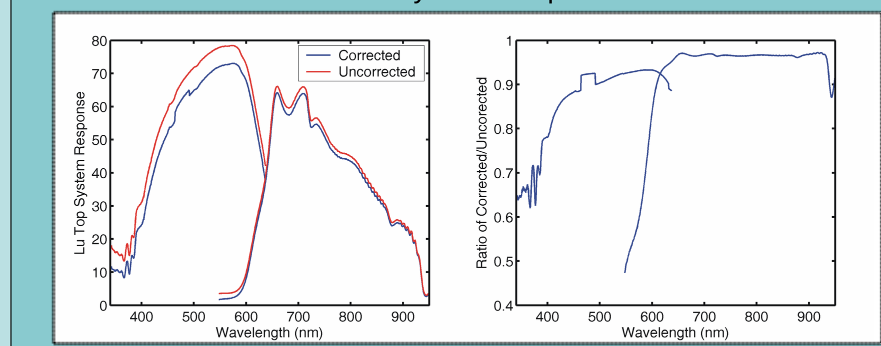
In-water and system response temperatures (ref. is 32°C)

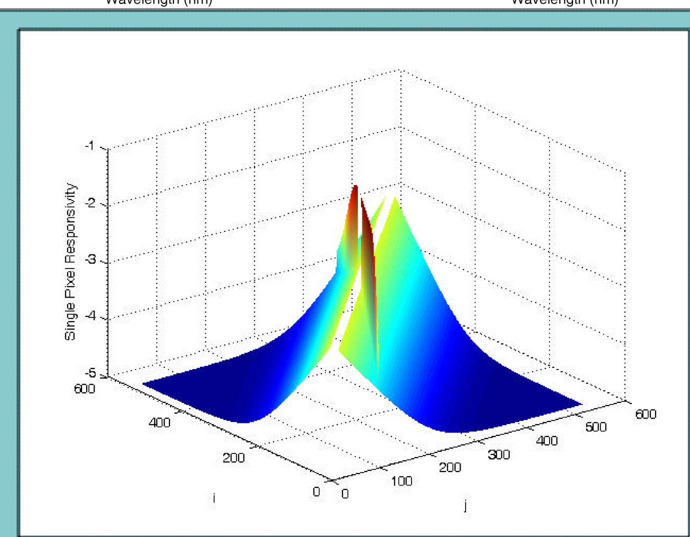
MOS in temperature controlled bath

Upwelled Radiance, L_u



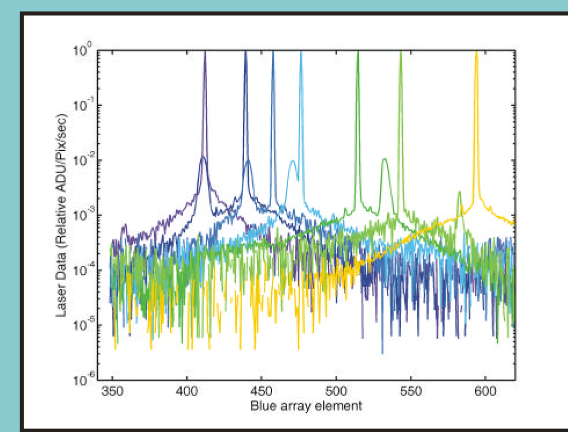
MOBY System Response



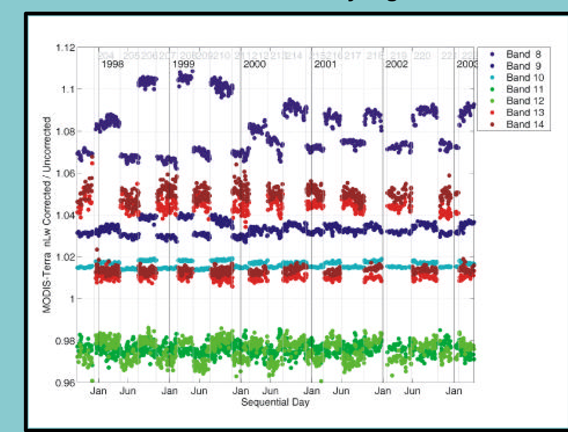


Single Pixel Responsivity correction matrix

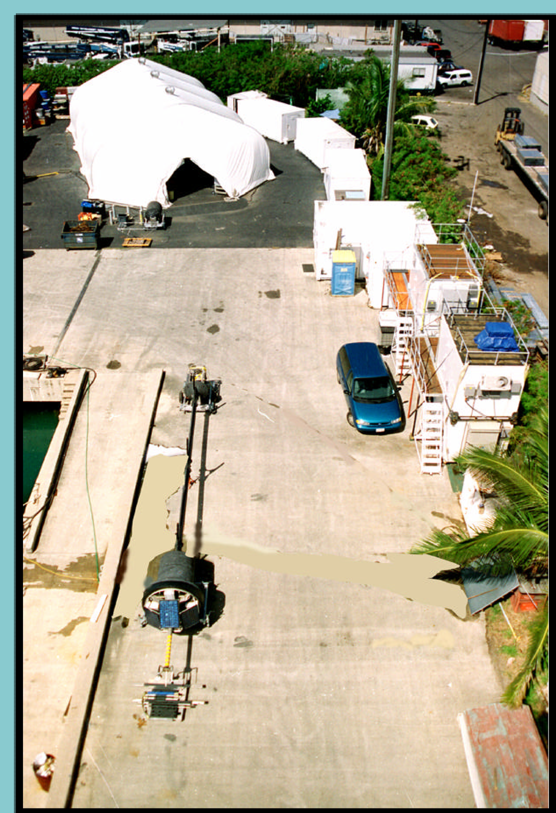
Corrections are made for spectral stray light effects in the spectrographs. The magnitude of this correction depends on wavelength and the relative spectral shape of the source being measured. The stray light correction algorithm iterates to a solution based on laser characterizations at the MOBY facility.

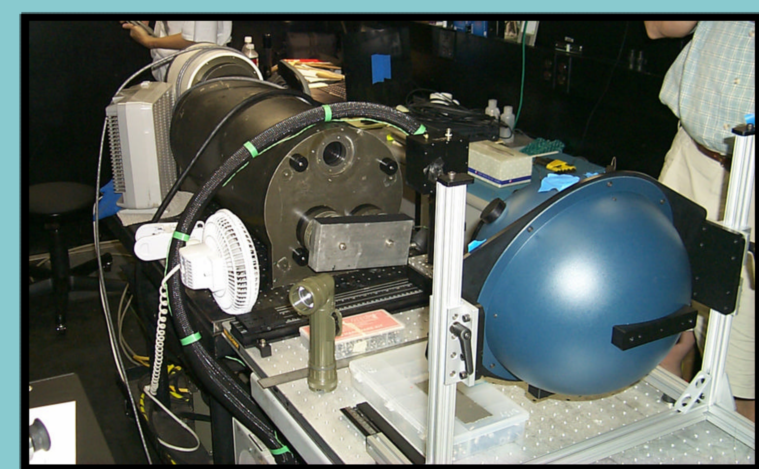


Laser data used for stray light correction

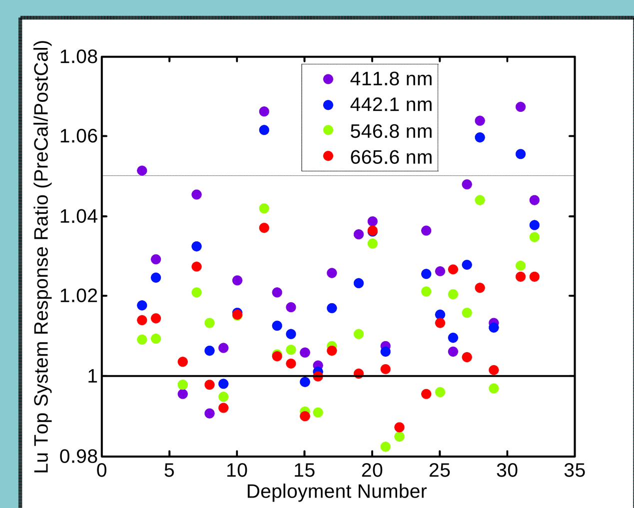


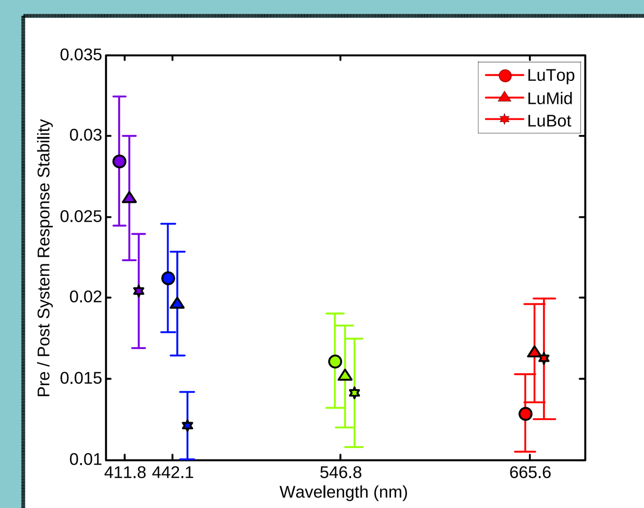
Stray light correction ratios for MODIS Bands



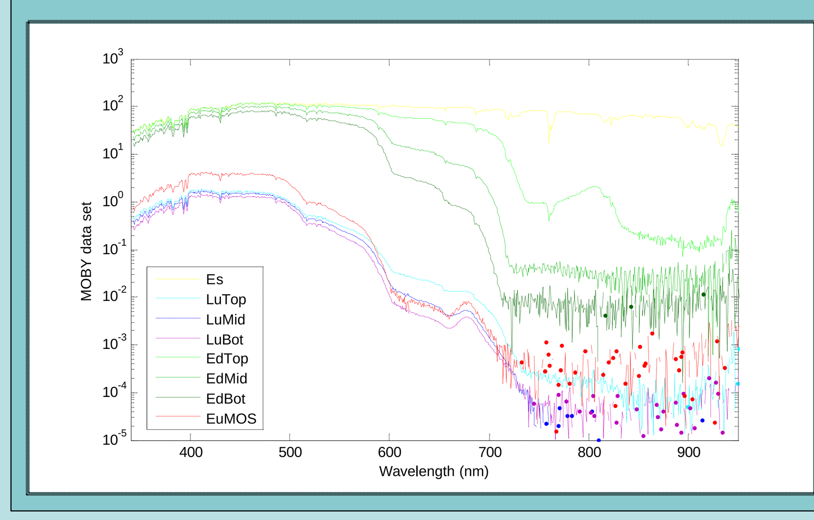


MOBY uses two optical buoys, rotating between them every 3 mo or so. During the deployment of one system, the other is being refurbished and calibrated at the MOBY facility. These wavelength and radiometric calibrations are performed twice on each system – before and after the deployment. This information is used to convert the corrected counts to radiometric data.





Pre and post system responses are evaluated for each MOBY deployment once the post calibrations are done and the entire deployments data set have been downloaded and processed. The mean of the pre and post system responses are used when appropriate.

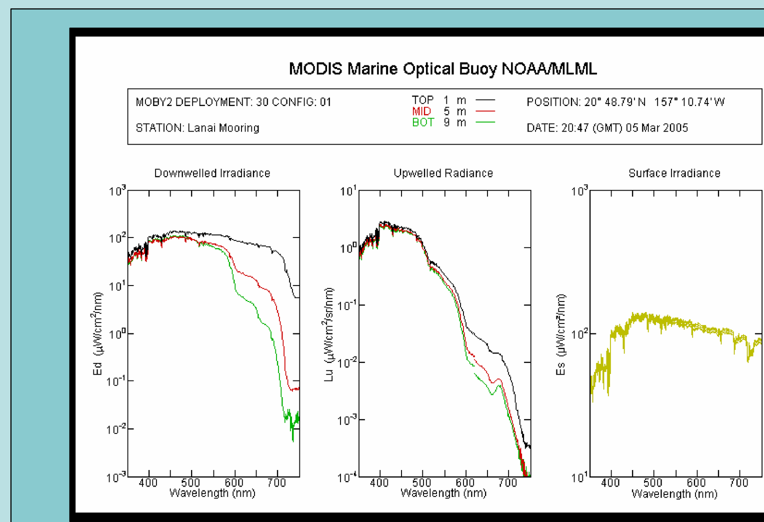


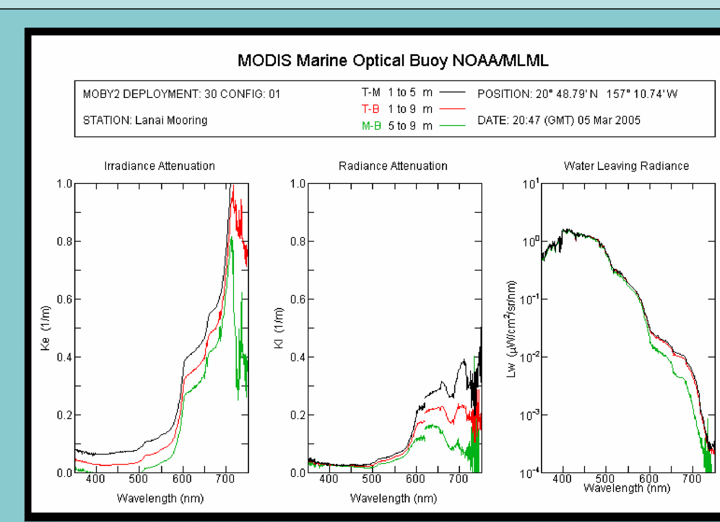
The result of all this processing are E_s, Lu (at four depths), E_d (at three depths), and for some deployments E_u at 11 meters, which have been quality checked, thermally corrected, stray light corrected and converted to scientific units.

Total files processed: 7660

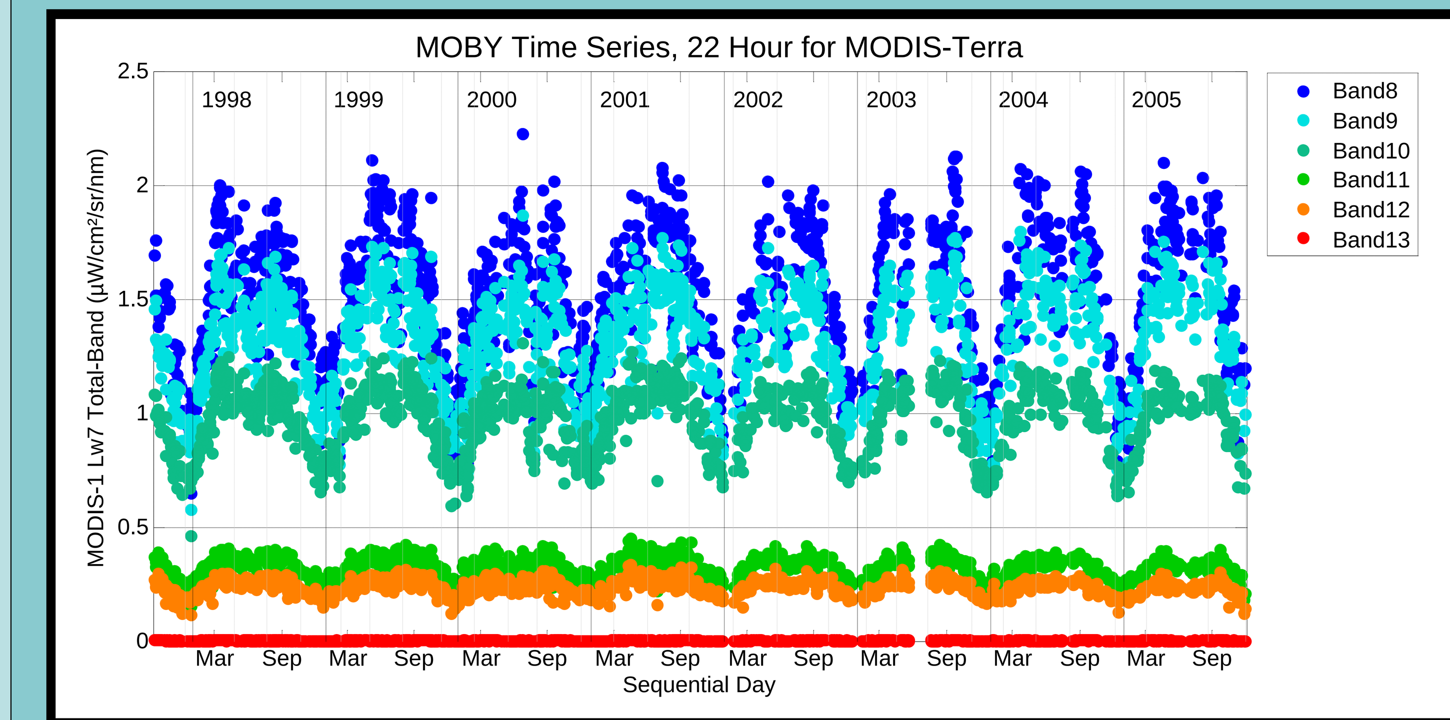
Total number of good days: 3456

Total number of questionable days: 720

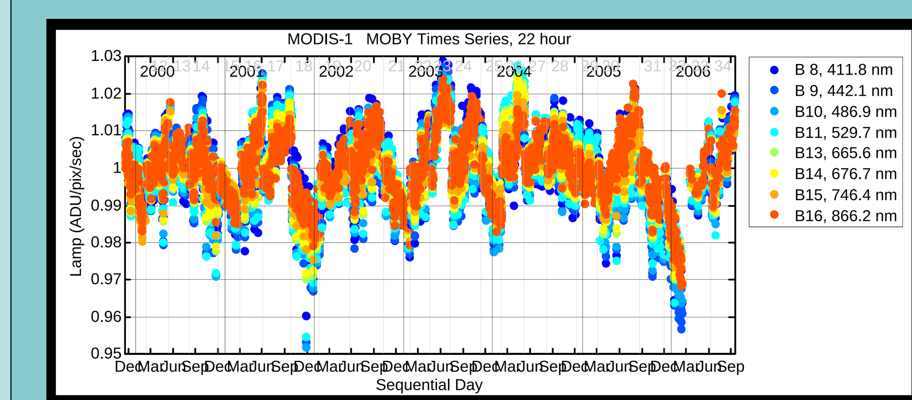




Next, L_u attenuation coefficients, K_L, are computed from the different depths, using the possible combinations: Top/Mid arms, Mid/Bot arms, and Top/Bot arms. The average of the surface irradiance measurements that bracket the corresponding L_u depths are used to normalize these values in order to correct for any variations in downwelling irradiance. Quality control is incorporated, for example the K_L values using different arm pairs must be consistent, GOES visible imagery is used to assess cloud contamination, and provisions are made for special cases, such as a bent upper arm. A clear-water K_L, known from optical properties of sea water, is compared to the measured values; if the results are non-physical, the data are marked "bad." In some cases, the data are flagged as "question-able." Situations where this may occur are when there is no evidence of clouds but the standard deviations in the E_s measurements are larger than what is typically the case.



The water-leaving radiances, L_w, are computed by upward extrapolation using the K_L and L_u data and propagation through the surface for nadir viewing. A solar-normalized water leaving radiance, L_{wn}, is calculated by correcting for variations in the Earth-Sun distance and atmospheric transmittance (this is a simplified approach, aerosols are not included). Then, using relative spectral responsivity data provided by the satellite teams, band-averaged radiances are determined for L_u (all depths), L_w, and the L_{wn} values.



Additional quality control data are available. This includes scans of an internal lamp and two internal LEDs, verification of the stability of the wavelength calibration from observation of Fraunhofer lines, and assessment of the system level responsivity utilizing diver-deployed stable calibration lamps on monthly intervals.

Distribution and Archival of Data

The satellite band averaged values for L_w, E_s, and L_{wn} are downloaded automatically to NASA. They are also displayed on the internet, see http://physoce.mlml.calstate.edu/moby/. These data are also password-protected and are available to NASA authorized users. Requests for access authorization should be made to NASA.

Data Submissions

In October of 2006 spectral MOBY data from deployments 2-32 were provided to NASA. This data included upwelled radiance (L_u), surface irradiance (E_s), downwelled irradiance (E_d) and upwelled irradiance (E_u). All of the satellite weighted products were also provided. The data are in the Moss Landing database format (MLdbase). Documentation describing the format and ancillary data have been included .

Summary

The MOBY data consist of a nine year record of in situ radiometric measurements. The values are derived using a robust system of multiple calibration and measurement procedures. Extensive instrument characterizations are the basis for correction of known systematic effects. The data are made available to users according to NASA guidelines.