Current and Future Marine Optical BuoY (MOBY)

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Abstract

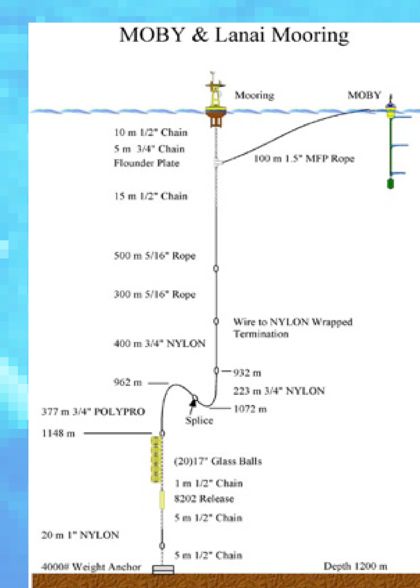
The MOBY system has provided vicarious calibration data for virtually all ocean color satellites since the launch of NASA's SeaWiFS instrument. MOBY has been operating continuously since 1997 in an operational manner, and the current system is described in this poster. Recently we have been funded to "refresh" the internal systems in MOBY with a new optical system and updated control electronics (MOBY-Refresh). This updated system will lead to improved data quality and reliability.

History

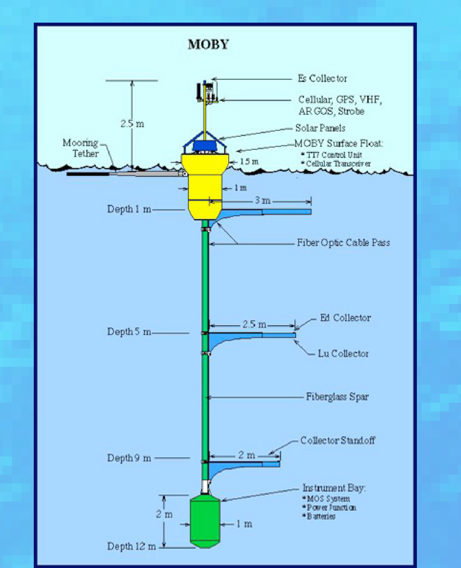
The Marine Optical BuoY (MOBY) (Clark et al. 1997, 2002) is the primary ocean measurement site for vicarious calibration of satellite ocean color sensors (Barnes et al. 2001, Eplee et al. 2001). Since late 1996, the time series of normalized water-leaving radiances nLw(λ), determined from the array of radiometric sensors attached to MOBY, has been the primary basis for the on-orbit vicarious calibrations of the USA Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Japanese Ocean Color and Temperature Sensor (OCTS), the French Polarization Detection Environmental Radiometer (POLDER), the German Modular Optoelectronic Scanner on the Indian Research Satellite (IRS1-MOS), and the USA Moderate Resolution Imaging Spectrometers (MODIS, Terra and Aqua). MOBY support has been provided to Japanese and European Space Agency calibration teams for the Global Imager (GLI) and the Medium Resolution Imaging Spectrometer (MERIS), respectively. The MOBY vicarious calibration nLw(λ) reference is an essential element in the international effort to develop a global, multi-year time series of consistently calibrated ocean color products using data from a wide variety of independent satellite sensors (Franz et al., 2007a).

Description of Present System

MOBY is a 16 m spar buoy (including the lower instrument bay) uniquely designed as an optical bench for measurements of Ed(z,λ) and Lu(z, λ) at depths of 1 m, 5 m, 9 m, and 12 m. Meteorological sensors for wind speed, wind direction, air temperature, relative humidity, and barometric pressure are mounted on the MOBY Mooring Buoy (MMOB). The Marine Optical System (MOS), the heart of MOBY, consists of two single-grating CCD spectrographs connected via an optical multiplexer and fiber optic cables to the Ed(z, λ) and Lu(z, λ) optical heads mounted at the ends of the buoy's three standoff arms. To provide low-loss transmission at ultraviolet wavelengths, 1 mm diameter silica fiber optic cables are used to connect the optical heads to MOS. Lu(12, λ), at z = 12 m, is measured through a window in the bottom of the MOS housing itself. A seventh fiber optic cable connects a surface irradiance, Es(λ), cosine collector, mounted at the top of the MOBY above-water mast, to the spectrographs. Each pair of in-water optical heads is mounted on a standoff arm to minimize radiometric artifacts due to shadows or reflections from the buoy.

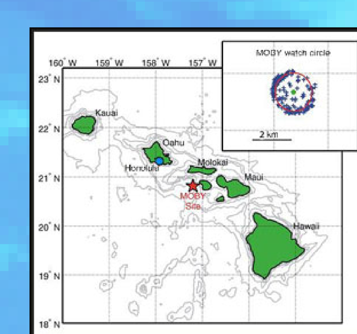


Mooring configuration for MOBY



Instrument Schematic

MOBY is continuously moored approximately 20 km west of the island of Lanai in a water depth of 1200 m. During prevailing trade wind conditions, this location is sheltered in the lee of the island, yet it is far enough offshore to minimize atmospheric perturbations associated with the island's wake. The MOBY Operations Site, located at the University of Hawaii (UH) Marine Facility in Honolulu, is staffed full time by personnel from the Moss Landing Marine Laboratories (MLML) for buoy maintenance, for instrument maintenance and calibration, and for staging buoy relief. The University of Hawaii's research vessels are used for cruises to support buoy deployments, and interim maintenance and quality control operations. A subset of the MOBY data is transmitted daily, via web linked cellular telephone, to the University of Miami (UM) in Florida. The MOBY data are transferred from UM to MLML for processing to produce and extract weighted band-averaged nLw(λ)s. These data are made available to NOAA via an MLML web host and ftp server, and are openly available through the NOAA Coastwatch site.



Location of MOBY

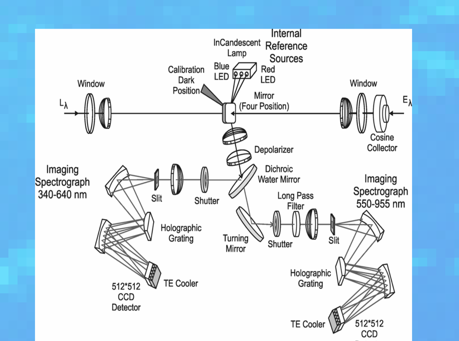
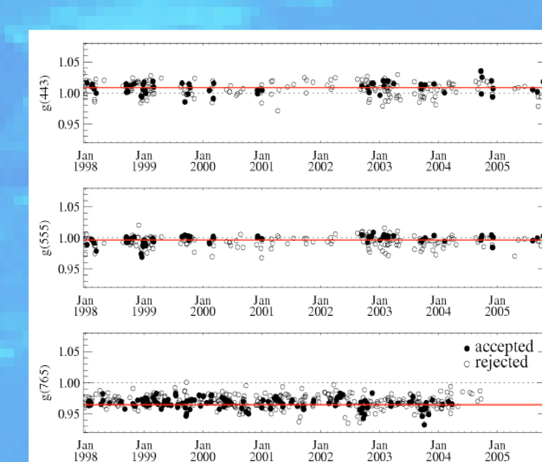


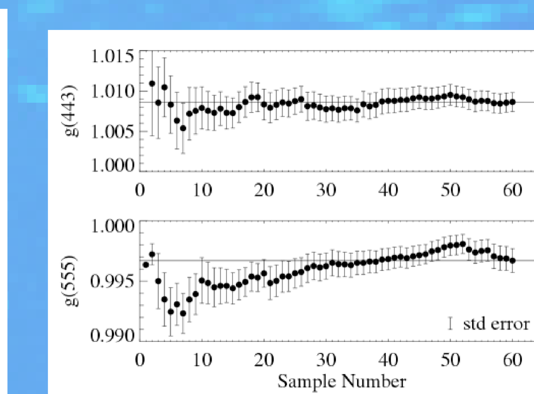
Diagram of current optical system

The current MOBY optical system has two spectrometers, one which covers the region from 350-620 nm (Blue spectrograph or BSG, and another which covers the region from 620 nm to 750 nm (red spectrograph or RSG). The light from each sensor head comes to the MOBY Optical System (MOS) over a fiber which is sequentially introduced to the spectrographs. A dichroic mirror separates the light into the two spectral regions. Along with the measurement fibers, there are internal calibration sources that can measure the instrument stability.

An example of the use of the MOBY system in determining the absolute calibration of a relatively stable satellite sensor (SeaWiFS) is shown in the figures on the right (Franz et al., 2007a). The SeaWiFS project used lunar views to determine the relative temporal drift of the sensor, while the absolute gain factor was determined through a vicarious calibration using the MOBY time series. One aspect of both the noise in the satellite retrieval and the inherent environmental noise in the MOBY system, is that multiple measurements are required for the satellite data to converge to the "true" gain factor. Presumably, if the noise in either of these systems was reduced, the number of data points required to attain convergence would also be reduced in a corresponding manner.



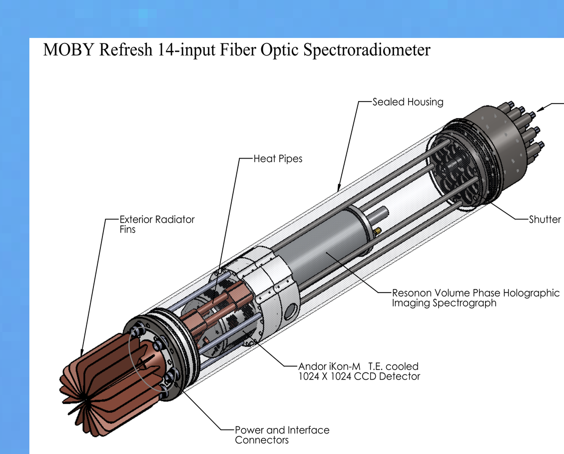
Example of MOBY time Series used in calibration of the SeaWiFS sensor (from Franz et al. 2007a)



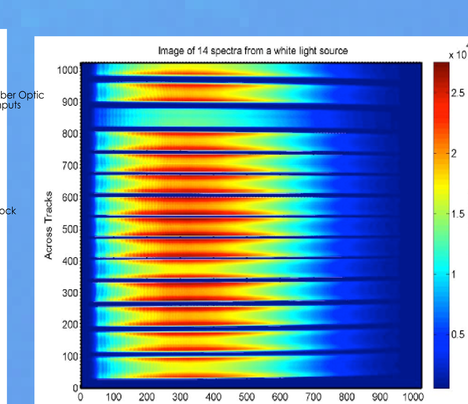
Example of how Satellite calibration converges (with current MOBY data) (from Franz et al. 2007a)

MOBY-Refresh Optical System

In the new optical system, as currently designed, we will be measuring the optical signal from all of the sensors simultaneously using an imaging optical system. The new spectrometers are based on a volume phase grating, and have the imaging capabilities to do this simultaneous imaging. A picture of the spectrograph is shown on the right along with an image taken from a prototype system displaying the imaging capabilities, with 14 individual channels displayed on the spectrograph.

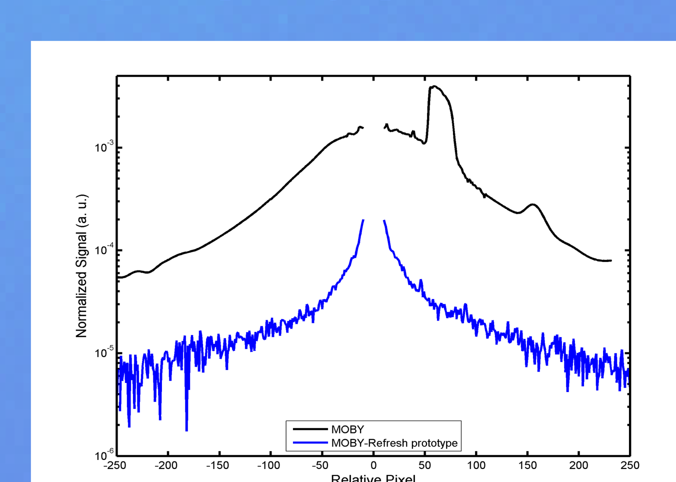


MOBY -Refresh optical system, based on a volume phase spectrograph



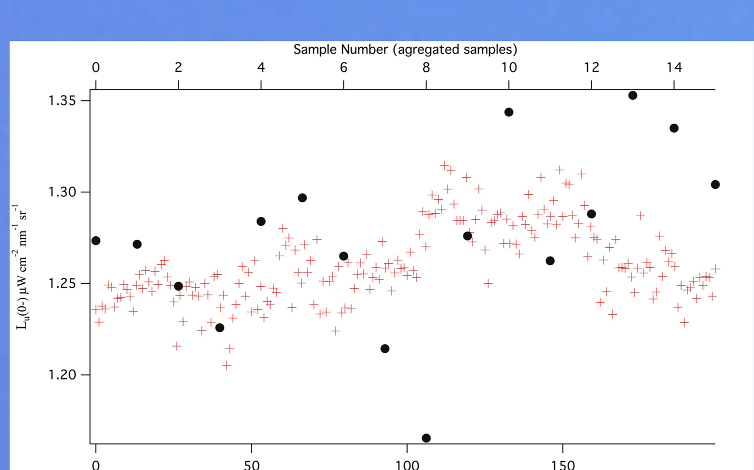
Example of the imaging capabilities of the new optical system

An example comparison of the straylight in the current MOBY instrument vs the MOBY-Refresh prototype, is shown on the right. This figure is normalized by the peak in the central band. The stray light in the figure is due to scattering and imperfect imaging in the optical system. As can be seen, the new system will exhibit straylight approximately two orders of magnitude less than the current system. This improved characteristic will increase the accuracy of the data by decreasing the importance and reliance on the stray light correction in the data.



Comparison of the stray light exhibited by the current optical system (MOBY) and the new optical system (MOBY-Refresh prototype).

The other advantage of the new optical system is shown in the figure below, which shows some results derived from an experiment with the prototype optical system, deployed off of Hawaii (Yarbrough et al., 2007)). Here the water leaving radiance is derived in two ways. First the data were binned and used in a manner similar to the current system, where each measurement depth can only be determined in a sequential manner. The water leaving radiance determined in this way is shown with the large black dots. The scatter in these dots is similar to that seen in the MOBY data set. The data were then used to determine the water leaving radiance using each simultaneously acquired data set to determine an individual data point for the water leaving radiance. In this way the environmental noise is greatly reduced, resulting in less noise for the reported water leaving radiance. Additionally, with the simultaneous data, it is possible to make many more individual measurements, which through averaging will provide a more accurate representation of the natural light field viewed by the satellite. With this data set, the number of calibration points will be greatly reduced, allowing more rapid initialization of a new satellite sensor and the possibility of correcting a sensor which has more frequent instabilities (such as MODIS Terra (Franz, 2007b).



Conclusion

The MOBY system has provided invaluable data to the Ocean Color community for the vicarious calibration of ocean color satellite systems. While it has performed well in the past, many of the components are significantly past their design life time and the need for replacement/updating is critical. We are currently at the beginning of this process as we build up the new optical system and other subsystems in the MOBY platform. This will provide the capability to extend the MOBY time series and continued vicarious calibration capabilities into the future.

References:

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