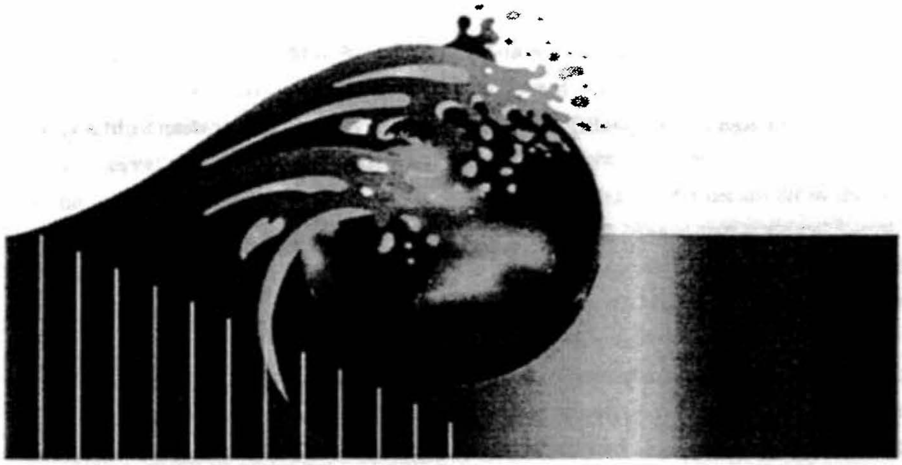

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The SeaWiFS Quality Monitor - a portable field calibration light source

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ABSTRACT

A portable and stable source, the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Quality Monitor, has been developed for use as a field instrument. The source can be used with either radiance- or irradiance-measuring sensors to transfer the laboratory calibration to the field so that the stability of the sensors can be monitored during the experiment. Temperature-controlled silicon photodiodes with colored glass filters are used to monitor the stability of the SeaWiFS Quality Monitor.

Keywords: calibration, field instrument, portable source, radiometric source, SeaWiFS

1. INTRODUCTION

Oceanographic field studies are an essential component of the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) Calibration and Validation Program.[1,2] Ocean-color data collected during cruises will be used to assist in the analysis of the data collected by the SeaWiFS satellite, with the ultimate goal to improve the atmospheric correction and bio-optical algorithms. The quality of these ocean-color data is critical to the success of the SeaWiFS project, and protocols have been established for the measurements.[3] To ensure data quality, each marine radiometer is generally calibrated before and after the field experiment. Ideally, the stability of the calibration should be monitored during the cruise. Because on-board calibration facilities are difficult to realize in practice, current investigative cruises rely on the manufacturer's calibration data or pre- and post-cruise calibration data. Considering the severe environmental changes encountered by marine radiometers, especially during shipment, the stability of the radiometer is in question and that, in turn, raises the concern that the data are not accurate enough for the success of the project.

In response to the requirement to monitor the stability of the marine radiometers, the National Institute of Standards and Technology (NIST) along with National Aeronautics and Space Administration's Goddard Space Flight Center

(NASA/GSFC), jointly developed a portable field light source, the SeaWiFS Quality Monitor (SQM). The goals were to produce a uniform large-area light source that is stable when used on board ships or other field platforms (e.g. aircraft), affordable to the relevant scientific community, and otherwise practical for field use. Because the stability of the marine radiometers over long time intervals is critical to the field experiments, the stability of the SQM was the key parameter. To utilize the SQM, the radiance or irradiance responsivity of the marine radiometer is first measured in the laboratory using calibration sources (e.g., integrating sphere, irradiance standard lamp, or diffuse plaque and standard lamp). At the same time, the signal levels corresponding to these calibration values are transferred to the SQM by making measurements with the marine radiometers and the SQM. Then the SQM and the marine radiometers are sent to the field experiment and the SQM is used to monitor the stability of the sensors.

A prototype SQM has been built and used on the second and third Atlantic Meridional Transect experiments as well as at the fifth SeaWiFS Intercalibration Round-Robin Experiment.[4] This prototype source includes three temperature stabilized, filtered photodiodes so that the stability of the SQM can be monitored at all times. The 20 cm diameter exit aperture is a plastic diffuser that is protected by a glass window. An adaptor plate, customized for each class of marine radiometers, mounts to the exit aperture. The adaptor plate is designed so that the position of the radiometer is reproducible with respect to all six degrees of freedom. Because the exit aperture is a diffuser, the SQM can be used with radiance or irradiance sensors. The relative spectral shape of the SQM source (including the diffuser) corresponds to an apparent blackbody temperature of about 2250 K as measured at seven wavelengths using two radiometers. The radiance variability over a circle of 15 cm in diameter is no larger than 4% (peak-to-valley). The optical design of the SQM resulted in an aspect ratio (diameter/length of lamp chamber) of two, so compared to traditional radiance calibration standards, the SQM is compact. Rugged construction and consideration of the marine environment resulted in a stable and portable device.

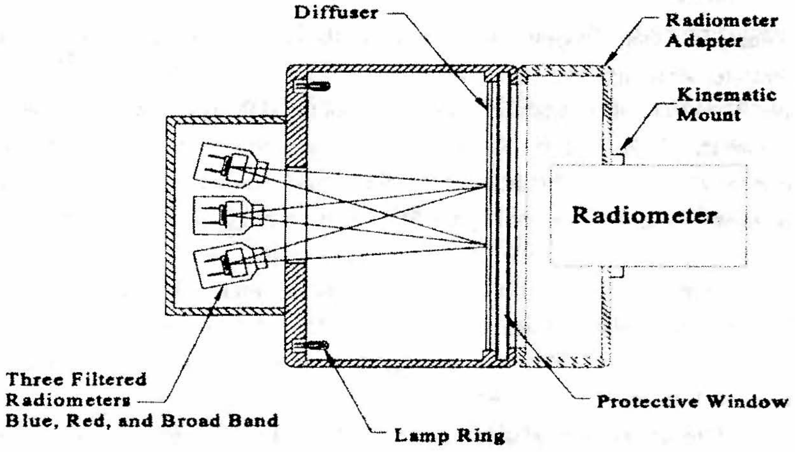

Figure 1. Simplified schematic of the SQM Prototype.

2. SQM PROTOTYPE

The basic design of the SQM is shown in Fig. 1. Additional details and complete description of the modeling of the radiometric output are discussed elsewhere.[5] Briefly, the source consists of a ring of 16 miniature quartz-halogen lamps. Eight are 5.0 V at 3.45 A lamps, and eight are 4.2 V at 1.05 A lamps. Each set of lamps are connected in series and operated by separate precision current sources; normal operation provides three different output levels. The 3.2-mm-thick plastic diffuser, which serves as the exit aperture, is about 12 cm from the plate containing the ring of lamps. The three monitor silicon photodiodes are mounted behind small apertures in the center of the lamp mounting plate and three different glass filter combinations are located between the apertures and each photodiode in order to limit the spectral coverage. The filters and photodiodes are temperature stabilized at 35 °C using a single thermoelectric cooler, a calibrated thermistor, and a commercial temperature controller. The measured photocurrents are converted to voltages using a custom amplifier circuit based on the design used in the NIST standard detectors. The result is stable and precise monitoring of the SQM in the red, blue, and broad-band/visible spectral region. The diffuser and the lamp ring assembly are enclosed in a cylindrical housing made of bead-blasted aluminum so that the diffuse component of the reflectance is significant. This cylindrical structure is sealed using o-rings to protect the light source from the environment. Because the lamps are enclosed in the cylindrical housing, the equilibrium temperature of the SQM at 22 °C is high, about 50 °C. A fan assembly mounted to the rear of the SQM is used to cool the device and under normal laboratory conditions the temperature is about 30 °C. A closed-loop electrical heater, which is independent of the other control systems, can be used to maintain the SQM at a fixed temperature, thus decreasing the time required to reach thermal equilibrium when the lamps are turned on.

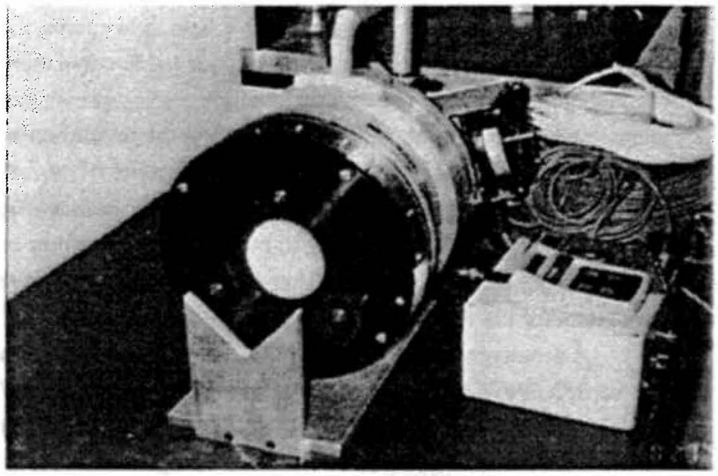

Figure 2. SQM prototype with radiometer adaptor

The radiometer adaptor, which is painted black, satisfies the kinematic mounting requirements for the marine radiometers. It also eliminates stray light from the environment, so that the field tests could occur outdoors under full solar illumination if necessary. The effect of the adaptor on the output of the SQM is not a factor in the calibration chain, since the adaptor is in place for all measurements with the SQM and the marine radiometers. The assembled SQM and adaptor is shown in Fig. 2. Because the reflectance of the front face of the marine radiometers may change during the field experiment, with a concomitant change in the signals measured by the SQM monitor photodiodes and perhaps the marine radiometer as well, a set of fiducial "radiometers" were produced. These fiducials simply consist of cylinders made from white plastic or aluminum. The aluminum was painted with a diffuse black paint and one end of the cylinder was covered with a clear glass plate in order to simulate the glass window on actual radiometers. The fiducials are kept clean and are not exposed to the environment. Normal operation consists of recording the signal on the SQM monitor photodiodes using the fiducials, followed by measurements with the marine radiometers.

The two power supplies for the two lamp sets in the SQM are stabilized precision current sources. The design of each system is similar to the automated current control of standard lamps described by Walker and Thompson.[6] In this method, the current through each set of eight lamps is measured using an accurate 0.5 Ω shunt resistor. If the current is not at the desired value, the power supply is adjusted via voltage programming. Both lamp systems are controlled with a single computer program, and the two power supplies as well as a digital voltmeter with an eight-channel multiplexer are interfaced to the computer using the IEEE GPIB interface protocols. A 16-bit D/A, which resides on a slot in the computer, is used to convert the programming voltage to an analogue signal. The digital voltmeter measures the voltages across the shunt resistors, the output of the three monitor photodiodes, and the resistance of two thermistors, one attached to each of the shunt resistors. All data are recorded in an ASCII file along with the current time, day, and year. Ancillary data from the SQM can also be collected using the SQM "deckbox". This unit attaches to auxiliary connections on the SQM so that the voltage across each of the 16 lamps can be recorded manually. The temperature of the SQM, as measured by three thermistors integrated into the cylindrical housing and the detector assembly, can also be recorded using the SQM deckbox. These data were found to be useful during testing of the SQM prototype. Finally, an automated timer circuit records elapsed lamp operating time.

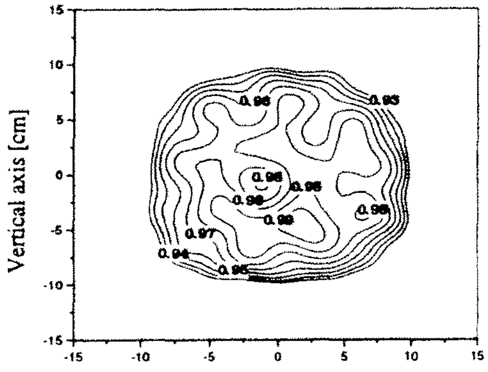

Figure 3. Measured uniformity at 412 nm during the development of the SQM.

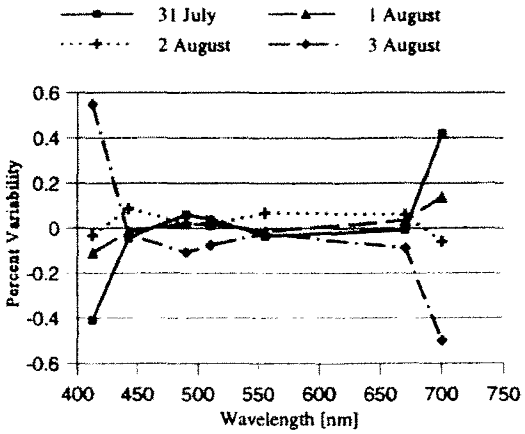

Figure 4. Variability of an irradiance sensor over a four-day interval when monitored using the SQM.

3. PERFORMANCE OF THE SQM PROTOTYPE

Figure 3 shows the radiance uniformity, normalized to the maximum value, of the SQM prototype as measured with the SeaWiFS Transfer Radiometer at 412 nm (see Ref. 4 and references therein). In the central area of the exit port, a 4% uniformity is achieved within an area with a diameter of 15 cm. Because the radiometers are kinematically mounted to the SQM, the effect of this non-uniformity is negligible.

The stability of the SQM prototype was measured during a four-day interval by monitoring the output of radiance and irradiance ocean-color sensors. On each day, the SQM was turned on and allowed to stabilize. The signals from the SQM photodiodes were recorded in one computer file as described above, and the signals from the test radiometers were recorded by a second computer using the normal data acquisition software. These radiometers are designed to record down-welling irradiance or up-welling radiance at seven wavelengths. The stability of the SQM as measured using the SQM monitor photodiodes and the black fiducial attached to the SQM is given in Table 1. The stability of the test radiometers is illustrated in Fig. 4 for the down-welling irradiance radiometer. The daily results for the SQM indicate a stability of about 0.1% or better, while the test radiometer results varied by up to 1%.

Table 1. Variation from the mean for the SQM monitor photodiodes.

	31 July	1 August	2 August	3 August
Blue Monitor	-0.037%	0.025%	-0.027%	0.039%
Red Monitor	0.073%	0.000%	0.017%	-0.090%
Broad Band Monitor	0.029%	0.004%	0.009%	-0.041%

4. CONCLUSION

We have designed, constructed, and tested a portable field source that is a prototype for general field use in support of SeaWiFS calibration and validation. This large-area source is simple in construction, stable, portable, and suitable for monitoring sensor stability during a field experiment. Laboratory tests demonstrated the ability to monitor changes in the calibration coefficients of marine radiometers at about the 0.1% level. This result is very satisfactory given that the combined standard uncertainty in the absolute radiometric calibration of the marine radiometers is typically between 1% and 2%. Monitoring of the ocean color senors using the SQM during field experiments will greatly improve the reliability of these ocean color data.

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