Practical Paper

Adaptation of a Hand-Held Radiometer for Measuring Upwelling Radiance in the Aquatic Environment

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INTRODUCTION

MULTIBAND RADIOMETERS are instruments used to detect and measure, in particular wavelength intervals, radiant energy emitted or reflected from a target. Commercial radiometers are available with a wide range of features for diverse applications in various types of atmospheric, oceanographic, and land-based studies. The more common types of instruments especially useful for field research have been discussed by Robinson and DeWitt (1983). They range from relatively inexpensive, hand-held instruments, to elaborate, expensive units such as those now on board environmental satellites, to submersible instruments used to measure spectral radiance at different levels of the sea. Several articles have been published on detecting and quantifying upwelling radiance from beneath the water's surface in remote bathymetric studies (Egan, 1980; Jerlov, 1976; Polcyn, 1976). As Jackson *et al.* (1980) have pointed out, hand-held radiometers have typically been used to obtain spectral and thermal data over small *terrestrial* plots.

In our remote bathymetric studies of shallow coastal waters, it was necessary to measure both incoming irradiance and to place a radiometer a few inches beneath the sea surface to measure upwelling irradiance from the water column while, at the same time, eliminating the measurement of specular reflectance from that surface. An Exotech Model 100BX Radiometer* was used to determine if the instrument could be adapted to measure in-band spectral reflectance of the sea floor through the water column in addition to incoming solar irradiance. These measurements are being used to calibrate a remote bathymetric model based on Landsat Thematic Mapper data. A two-part enclosure was designed to adapt this terrestrial, hand-held radiometer to provide *in situ* upwelling radiance measurements. This note describes the design, fabrication, and use of this inexpensive and easily constructed unit which may be used in both fresh-water and marine environments.

The factory-calibrated radiometer (Exotech, Inc., 1987) was fitted with appropriate band pass and correction filters to emulate TM spectral Band 1 (450 to 520 nm), Band 2 (520 to 600 nm), Band 3 (630 to 690 nm), and Band 4 (760 to 900 nm). The radiometer was housed in an open-faced, rectangular enclosure, the bottom of which was constructed to allow an unobstructed view of the surface to be measured (Figure 1-A). A single 1/4-inch stove bolt was threaded into the radiometer's tripod tapped port to secure the radiometer to the enclosure. The enclosure was inserted into an open-ended, waterproof-sealed rectangular box with a 1/4-inch clear Rohm and Haas acrylic plastic Plexiglas "G" bottom (Figure 1-B). The radiometer's lenses were supported 1 1/4 inches from the inside surface of the plexiglass plate by two wooden struts mounted onto the inside walls of the box. Two 1/2-inch plywood skids were attached to the plexiglass along the bottom of the box to prevent scratching of the plexiglass when the box was placed in an upright position.

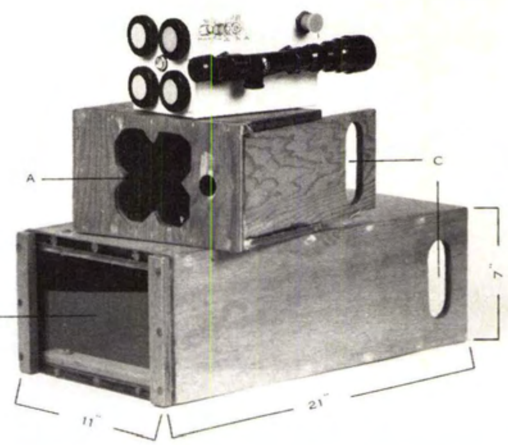

FIG. 1. Enclosure for an Exotech Model 100 BX hand-held multiband radiometer used to measure incoming solar irradiance and upwelling radiance in aquatic environments. (A–opening for radiometer lenses. B–waterproof bottom with plexiglass face. C–Hand hold cut-outs.)

Both the enclosure and the box were constructed of 1/2-inch exterior type AC plywood using Resorcinal Water Proof Glue and #6 finishing nails. The plexiglass plate was attached to the underside of the box with twelve 8- by 1 1/2-inch flat-headed wood screws through pre-drilled holes. Six of these screws secured the skids to the plexiglass and the box. Elmer's Clear Silicone Rubber Sealer was used as sealant between the plexiglass and wood. All screws were countersunk and screwheads were covered with the silicone sealer to prevent corrosion. Nail holes and pits in the wood were filled with Durham's Water Putty (i.e., plastic wood). After sanding, all external wooden surfaces were sealed with three coats of exterior polyurethane. Interior surfaces were spray painted flat black to minimize indirect radiance scatter within the box. Construction with power tools by a novice carpenter required approximately six hours,

*The use of commercial names does not constitute an endorsement of the products.

PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING,
Vol. 55, No. 2, February 1989, pp. 193–194.

0099-1112/89/5502–193$02.25/0

excluding time for the glue to cure and the polyurethane to dry. Materials used to construct the two-part structure cost approximately $25.00.†

This two-part arrangement provided sufficient protection to the radiometer from seawater and enabled collection of both multispectral solar irradiance and upwelling radiance. To measure solar irradiance, the radiometer, fitted with hemispherical field-of-view objectives, was secured in the inner enclosure and pointed directly overhead. To measure radiance reflected from the bottom material, the enclosure was placed downward into the water-tight outer box. The lenses of the radiometer were fitted with 15° field-of-view objectives which allowed collection of radiance reflected from an area of the bottom appropriate for our sampling scheme.** The box was lowered into the water by hand from a boat with a freeboard of approximately 25 inches and held level with the plexiglass plate one to three inches beneath the surface of the water to prevent accumulation or passage of air bubbles under the plate. The enclosure and the box possessed slots cut into the sides (Figure 1-C) allowing a firm hold on both structures.

With the present setup, the spectral characteristics of the plexiglass must be considered. Plexiglass is relatively transparent in the visible spectrum - the region of principal interest in this study. The piece of plexiglass mounted on the box was calibrated for attenuation in the four TM spectral bands being emulated. At ambient light conditions, transmissivity was 95 to 97 percent for Bands 1, 2, and 3 but only 35 percent for band 4. For average bottom-reflected radiance values collected over a sandy substrate at four metres, the attenuation ranged from a low in Band 1 of 0.34 to a high in Band 4 of 2.00. An attenuation correction factor can be applied to adjust to the raw values. Attenuation within each spectral band must be determined empirically at given time intervals or prior to sampling to correct the effects of use (i.e., scratching) and aging (i.e., yellowing) of the plexiglass. Alternatively, glass or another transparent material with suitable spectral transmission properties could be substituted for plexiglass. If glass is used, a frame to mount the glass to the wooden box would have to be designed and constructed.

We thank Gary McCurdy and Paul Belanger of the University of Connecticut's Agricultural Engineering Workshop for aid in design and construction. The research in which this radiometer enclosure is being used is supported by NOAA Grant NA-85AA-D-SG101 as Project R/OE-1 of the Connecticut Sea Grant Program. Scientific Contribution No. 1237 of the Storrs Agricultural Experiment Station, The University of Connecticut.

†Construction plans are available from the authors on request.

**In the future, total direct and diffuse solar irradiance will be referenced using a reflectance standard positioned above the sea surface with the radiometer equipped with 1° field-of-view objectives.

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(Received 28 March 1988; accepted 26 July 1988; revised 16 August 1988)

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