Calibration report of the profiling reflectance radiometers

Instrument Details

Name: C-OPS

Model: C-OPS#41
Serial Number: 000411 000412 000413
Purchase date: 26-June-2015

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Document Version 1.2, October 7, 2019

I) Instrument Overview

The C-OPS consists of two radiometers: one measuring in-water upwelling radiance and the other downward irradiance. Both are mounted on a free fall frame, which can be optimized with a combination of air filled and rigid foam floats for slow descent rates. Included in the system is an above water reference irradiance sensor, a “BioShade” shadowband assembly for making diffuse measurements, and the “BioGPS” for providing position and time.

Each radiometer is actually a cluster of several micro radiometers, which consist of a filtered photodiode with a microprocessor, a preamplifier with controllable gain, a 24-bit analog-to-digital converter, and a serial port – all on one circuit board assembly the size of a pen. There are a total of 19 micro radiometers for each cluster. The downwelling irradiance (Ed) cluster includes the following channels: 320, 340, 380, 395, 412, 443, 465, 490, 510, 532, 555, 560, 625, 665, 670, 683, 710, 780, and EdPAR. The upwelling radiance (Lu) cluster includes: 320, 340, 380, 395, 412, 443, 465, 490, 510, 532, 555, 560, 625, 665, 670, 683, 710, 780, LuChl. All optical wavelengths are measured in nanometers (nm).

Figure 1 illustrates the instrument with its upwelling radiance sensor (Lu) and downwelling irradiance sensor (Ed) at each side of the instrument body.

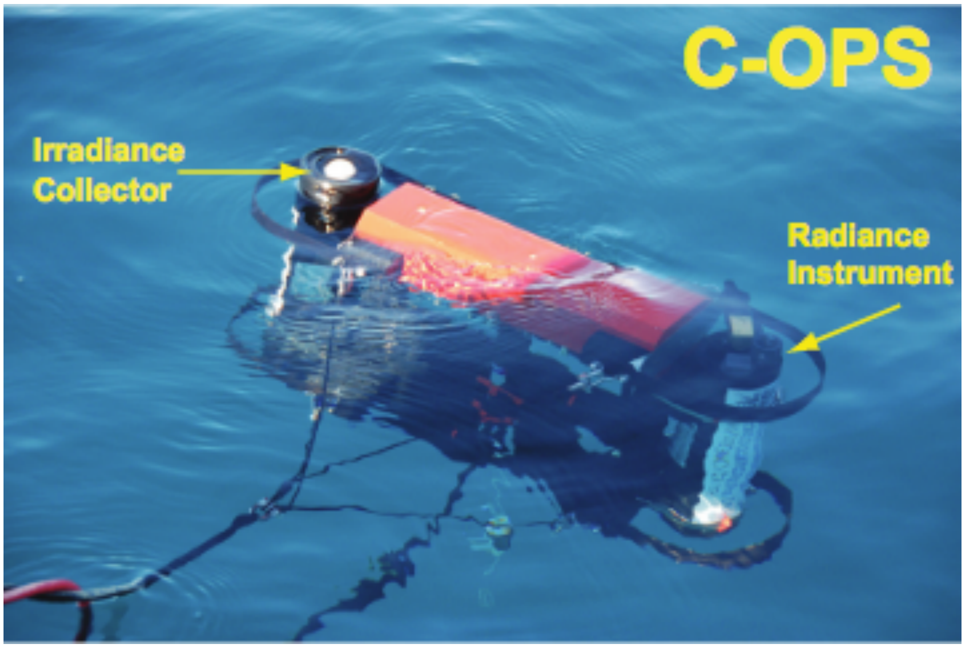

Figure 2: The components of the micro-radiometer and a USB drive for scale.

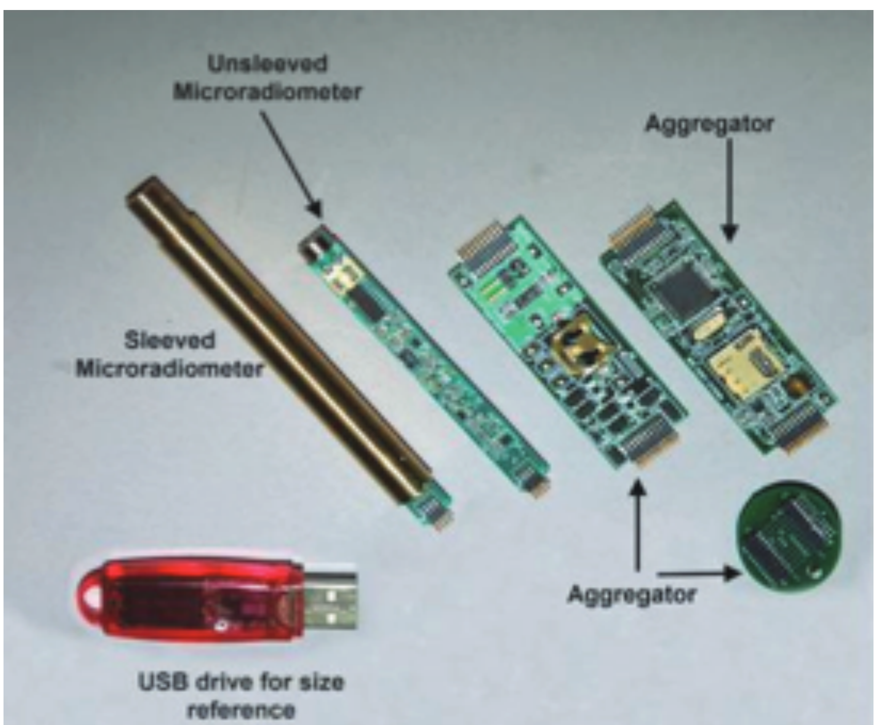

Figure 3: A cluster of 19 micro-radiometers in a pressure housing forms a stand-alone multichannel radiance ocean color sensor that is small enough to hold in one hand.

II) Calibration and Maintenance

A. **Our Facility**

The Satlantic Profiler II sensor heads are calibrated once each year on an optical table in our own climate-controlled lab. Our calibration lamps are attached to a rail mounted to the table and can easily slide back and forth in order to provide calibration distances from 50 cm to over 2 m. The Optical Table and all hardware are black in nature or painted flat black. The Table is surrounded by Black-out curtains including a overhead curtain. NIST standard FEL Lamp holders and shunt are used to secure all lamps. An alignment laser is mounted and used to align all seniors mounted on the table.

B. Calibration Lamp History
Three lamps were used for calibrations of the C-OPS Profilers since 2013: F-514N, F-1101, and F-1102 - all of which are traceable to the National Institute of Standards and Technology (NIST). Lamp F-514 was purchased in 2002 and was used for all routine calibrations at UCSB from 2002– present. Lamp 514N is an NIST Calibrated lamp that all other lamps are inter-compared too. Lamp F-1101 and 1102 are seasoned, uncalibrated FEL lamps, purchased in 2011, and calibrated by Optronics and put into use for routine calibrations at UCSB.

NIST-traceable Optical Calibrations
Traceability of lamps, the calibration set up (e.g.shunts, voltmeters, power supplies) and calibration procedures follow recommendations published by the National Bureau of Standards (US), specifically “NBS Special Publication 250-20 Spectral Irradiance Calibrations (1987)” and “NBS
Publication 594–13 Optical Radiation Measurements: The 1973 Scale of Spectral Irradiance (1977).”

Irradiance Calibration
Irradiance calibrations are performed on our Optical table. The instrument to be calibrated is placed on an optical rail with the plane of measurement (normally the surface of the irradiance diffuser) located 50 cm from the plane of the lamp as defined using a NIST-specified alignment fixture. This fixture is also used with a laser to determine the optical axis of the system; the device being calibrated is aligned to be normal to this axis. A 1,000 W FEL tungsten-halogen lamp is the irradiance source and it is powered by a High precision regulated power supply that can regulate the nominal 8 A of current to better than 100 μA accuracy and stability.

Radiance Calibration
Radiance calibrations are performed on our Optical table. The instrument to be calibrated points to a Spectralon plaque that is in turn illuminated by a 1000 W FEL standard lamp, mounted 200cm away from the plaque. The plaque's reflectivity is regularly being calibrated by Labsphere. The Optical table features a Black aperture, this is mounted between the lamp and plaque to minimize stray light. An instrument holder with fine adjustable mounts point to the center of the plaque at a 45° angle. The lamp is mounted on an optical rail to permit accurate determination of the calibration distances. Depending on the application, other distances can be configured.

C. Procedure
Using our optical table Measurements are recorded over all wavelengths in uW/m2. The Optical table is surrounded by black out curtains and all outside light is isolated from the calibration room. Measurements and are recorded through an open aperture as a Light value (L), obstructed by a Black lollipop giving a Shadow (S) value and then with a closed aperture giving a Dark value (K). Using the transfer value Between the Calibration Lamp and our NIST Standard Lamp e.g. (X) at the differing standard distances of 50cm and 200cm we then calculate a Calibration coefficients using: X/(L-S).

These Instrument Wavelength Calibration coefficients are tracked and inter-compared for each FEL lamp used over time. This allows us to monitor both degrading lamps and the changes in instrument wavelength responses. A certificate is created after each calibration event and includes information about the following references:

- Dark readings
- In-house calibration factors
- Manufacturer’s original calibration coefficients
- Percent change for each sensor

III. Deployment / Sample collection

The C-OPS is used as a free-falling profiling device with a buoyancy system that allows for slow descents. It is easily adjustable using a combination of air filled and rigid foam floats. As the system descends, the increasing water pressure compresses air-filled bladders, which reduces buoyancy and increases the descent rate from <3 cm s-1 at the surface to over 30 cm s-1 below 10m.

The instrument is carefully lowered to the water by slowly releasing the cable hand over hand with the goal of maintaining a constant velocity with tilts as close to zero or vertical as possible (typically less than 5 degrees is acceptable; less than 2 degrees desirable). Maximum depth is typically 200m. Dark corrections are then recorded on deck after each cast.

The battery-powered master aggregator deck box provides power and telemetry to a Windows-based laptop computer. µProfile – a Biospherical Instruments custom software package – is used to acquire and display the data. The software was written using Microsoft Visual Studio 2008 and requires the installation of Microsoft's .NET ("DotNet") Frame- work 3.5, which is an integral Windows component that supports various applications.

IV. Data Processing

The C-OPS data are initially processed by µProfile, which converts the raw measurements to bio-optical data, but further post-processing must be completed to flag pitch and roll limits and to extrapolate the data to near- surface values.

V. Additional Information A. Factory Specifications:

A. Factory Specifications:

- Detectors: Si (13 mm2), InGaAs (7 mm2), or GaAsP (7 mm2)
- Photocurrent-to-Voltage Conversion: Electrometer amplifier with three gain stages—1, 200, and 40,000. ADC: 24-bit bipolar: 4–125 Hz data rates
- Dynamic Range (usable): 9 decades
- Linearity: Measured on all microradiometers over a signal current range of 1 x 10-12 to 1 x 10-5 A using a programmable light source. Typically, errors are <1% compared to a reference system electrometer. Gain ratios are individually measured using a computer controlled optical source and programmed into each microradiometer.
- Speed: ADC sample rate is programmable from 4–125 Hz, and is normally set to 125 Hz, with averaging over the sampling period performed internally by the microradiometer.
- Response Time: Exponential change with a time constant of <0.01 s. Time required for gain change is < 0.1 s
- Electronic Sensitivity: ADC resolution is 0.5V with a current resolution of <10-15 A. The saturation current is 160 μA. The 3-gain signal-range is 1.6 x 1011, defined as the saturation signal divided by minimum resolvable signal
- Noise: Si detector typically has 15–20 fA of noise when ADC is sampling at 125 Hz with the internal microradiometer averaging of 25 samples, resulting in a data rate of 5 Hz
- Optical Sensitivity: Sensitivity depends on the spectral region and the entrance optics (irradiance or radiance). It is expressed as Noise Equivalent Signals at 5 Hz for radiance W cm-2 nm-1 sr-1) and irradiance Wcm-2 nm-1)
- Dark Offsets: Dark offsets are measured and set at the time of calibration for each gain level. Offsets can also be automatically measured and applied in the field to accommodate different temperature regimes.
- Microradiometer Power: +/- 5 VDC at 4 mA total.
- Optical Filters: 10nm full width at half maximum multicavity ion deposited interference filters selected for greatest out-of-band blocking and minimum fluoresence and maximum long term stability
- Spectral Range: 250–1650 nm. InGaAs detectors.)
- Cluster Sizes: Microradiometers are assembled into collections of 13 and 19 wavebands in a single housing.
- Diameter: 2.75 inches
- Depth: 125m maximum depth rating standard.
- Wavelength Selection: Wavelengths are selectable from 250–1650 nm
- Speed: A single, 19-waveband optical instrument can be operated at rates greater than 30Hz. Complete systems composed of three 19 waveband radiometers can operate at rates greater than 15 Hz.
- Data Rate: Optical instruments communicate at 115,200 baud, using RS232 or RS485 (full or half duplex). Deck box communicates at 115,200 baud using RS232
- Power Requirements: Optical instrument with 19 channels: 7.5V at 90mA. Three instrument system, 19 wavebands, 0.30A typical at the deckbox
- Field-of-view Radiance Instrument: 7° half-angle in water (SeaWiFS specification)

- Cosine Error Irradiance Instrument: ± 3% for zenith angles smaller than 60°; ± 5% for zenith angles 60–70°, and ±10% for zenith angles from 70–80°
- Free-fall Speed: < 1 cm depth resolution; adjustable terminal velocity 6cm to 35cm s-1; manually adjustable pitch and roll
- Ancillary Sensors: Water temperature, water pressure transducers, and pitch and roll
- The depth sensor is 0.054 m below the Ed heads and 0.238 m above the Lu heads

B. Online Access to C-OPS Calibration Files

Calibration files for both System #41 can be found online using the following links:

- http://oceanexports.org/documents/calibration_docs/C-OPS/Ed0_411_Calibration_Certificate_20180612.pdf

- http://oceanexports.org/documents/calibration_docs/C-OPS/EdZ_412_Calibration_Certificate_20180612.pdf

- http://oceanexports.org/documents/calibration_docs/C-OPS/LuZ_413_Calibration_Certificate_20180612.pdf