BGC Float ECO

Designed For Profiling Float Sensor Systems

Integrator's Guide

The user's guide is an evolving document. If you find sections that are unclear, or missing information, please let us know. Check our website periodically for updates.

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Sensor Warranty

This sensor is guaranteed against defects in materials and workmanship for one year from the original date of purchase. Warranty is void if the factory determines the sensor was subjected to abuse or neglect beyond the normal wear and tear of field deployment, or in the event the pressure housing has been opened by the customer.

To return the sensor, contact WET Labs for a Return Merchandise Authorization (RMA) and ship in the original container. WET Labs is not responsible for damage to sensors during the return shipment to the factory. WET Labs will supply all replacement parts and labor and pay for return via 3rd day air shipping in honoring this warranty.

Return Policy for Sensors with Anti-fouling Treatment

WET Labs will not service sensors treated with anti-fouling compound(s). This includes but is not limited to tri-butyl tin (TBT), marine anti-fouling paint, ablative coatings, etc.

Please ensure any anti-fouling treatment has been removed prior to returning sensors to WET Labs for service or repair.

Shipping Requirements

1. Please retain the original ruggedized plastic shipping case. It meets stringent shipping and insurance requirements, and protects the sensor.

2. Service and repair work cannot be guaranteed unless the sensor is shipped in its original case.

3. Clearly mark the RMA number on the outside of your case and on all packing lists.

4. Return sensors using 3rd day air shipping or better: do not ship via ground.

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1. Optical Specifications

The custom sensors built for BGC Float ECOs have the optical specifications shown below.

BOSS

	bb2CD	FLbb
Wavelength		
Scattering (bb412)	412 nm	700 nm
Scattering (bb700)	440 nm	
Chlorophyll (chl)	--	470
CDOM (CD)	370 nm	--
Range		
Scattering (bb412)	0.0024–5 m^{-1}	0–3 $m^{-1}sr^{-1}$
Scattering (bb700)	0–3 m^{-1}	--
Chlorophyll (chl)	--	0–30 µg/l
CDOM (CD)	0.18–375 ppb	--
Sensitivity		
Scattering (bb412)	1.2 x 10^{-5} $m^{-1}sr^{-1}$	--
Scattering (bb700)	0.0015 m^{-1}	0.0015 m^{-1}
Chlorophyll (chl)	--	0.15 µg/l
CDOM (CD)	0.18 ppb	--

BOSS-Lite

	FLbbCD
Wavelength	
Scattering (bb)	700 nm
Chlorophyll (chl)	470 nm
CDOM (CD)	370 nm
Range	
Scattering (bb)	0–3 m^{-1}
Chlorophyll (chl)	0–30 µg/l
CDOM (CD)	0–375 ppb
Sensitivity	
Scattering (bb)	0.0015 m^{-1}
Chlorophyll (chl)	0.15 µg/l
CDOM (CD)	0.18 ppb

BOSS-Mini

	FLbbCD
Wavelength	
Scattering (bb)	700 nm
Chlorophyll (chl)	470 nm
CDOM (CD)	370 nm
Range	
Scattering (bb)	0–3 m^{-1}
Chlorophyll (chl)	0–30 µg/l
CDOM (CD)	0–375 ppb
Sensitivity	
Scattering (bb)	0.0015 m^{-1}
Chlorophyll (chl)	0.15 µg/l
CDOM (CD)	0.18 ppb

REMOcean-A

	FLbbCD
Wavelength	
Scattering (bb)	700 nm
Chlorophyll (chl)	470 nm
CDOM (CD)	370 nm
Range	
Scattering (bb)	0–3 m^{-1}
Chlorophyll (chl)	0–30 µg/l
CDOM (CD)	0–375 ppb
Sensitivity	
Scattering (bb)	0.0015 m^{-1}
Chlorophyll (chl)	0.15 µg/l
CDOM (CD)	0.18 ppb

REMOcean-B

	FLbbCD
Wavelength	
Scattering (bb)	700 nm
Chlorophyll (chl)	470 nm
CDOM (CD)	370 nm
Range	
Scattering (bb)	0–3 m^{-1}
Chlorophyll (chl)	0–30 µg/l
CDOM (CD)	0–375 ppb
Sensitivity	
Scattering (bb)	0.0015 m^{-1}
Chlorophyll (chl)	0.15 µg/l
CDOM (CD)	0.18 ppb

ORCA

	FLbb-bb
Wavelength	
Chlorophyll (chl)	470 nm
Scattering (bb)	440 nm
Scattering (bb)	700 nm
Range	
Chlorophyll (chl)	0–30 µg/l
Scattering (bb)	0–3 m^{-1}
Scattering (bb)	0–3 m^{-1}
Sensitivity	
Chlorophyll (chl)	0.15 µg/l
Scattering (bb)	0.0015 m^{-1}
Scattering (bb)	0.0015 m^{-1}

2. Setup and Operation

UV LED Safety Note: Sensors with CDOM measurement

- UV LEDs emit intense UV light during operation.
- Do not look directly into a UV LED while it is in operation, as it can be harmful to the eyes, even for brief periods.
- If it is necessary to view a UV LED, use suitable UV-filtered glasses or goggles to avoid damage to the eyes.
- Keep UV LEDs and products containing them out of the reach of children.
- Take appropriate precautions, including those above, with pets or other living organisms that might suffer injury or damage from exposure to UV emissions.

This label is affixed to all products containing UV LEDs.

WET Labs strongly recommends checking the functionality of the sensor prior to any deployment.

1. Connect the sensor to a regulated power supply at 12V and a host PC.

2. Start a terminal program and configure the following settings:
   - Appropriate COM port
   - 19200 baud
   - 8 data bits, 1 stop bit, no parity, no flow control

3. Supply power to the sensor.

WARNING!
Always use a regulated power supply to provide power to the sensor if not using a 9V battery with the test cable as power spikes may damage the meter.

4. Test the sensor's signal by holding a finger 1–4 cm above the optical paths in an orientation that maximizes exposure. (Parallel with the beams, not intersecting them). The signal will increase toward saturation (maximum value on characterization sheet). The sensor will operate until you remove power or stop in the terminal program.

2.1 Output Formats

FLBB on BOSS

Model_S/N	Chl EM	Chl Data	bb EM	bb Data
FLBB-121	695	5.700	700	2.000
FLBB-121	695	5.700	700	2.000
FLBB-121	695	5.700	700	2.000

Column 1:	Model_S/N	Sensor model and serial number
Column 2:	Chl EM	Chlorophyll emission wavelength
Column 3:	FL Data	Chlorophyll-*a* in µg/l
Column 4:	bb EM	Scattering emission wavelength
Column 5:	bb Data	Scattering output in inverse meters

BB2CD on BOSS

Model_S/N	bb1 EM	bb1 Data	bb2 EM	bb2 Data	CD EM	CD Data
BB2CD-121	412	3.000	440	3.500	460	75.125
BB2CD-121	412	3.000	440	3.500	460	75.125
BB2CD-121	412	3.000	440	3.500	460	75.125

Column 1:	Model_S/N	Sensor model and serial number
Column 2:	bb1 EM	Scattering emission wavelength
Column 3:	bb1 Data	Scattering output in inverse meters
Column 4:	bb2 EM	Scattering emission wavelength
Column 5:	bb2 Data	Scattering output in inverse meters
Column 6:	CD EM	CDOM emission wavelength
Column 7:	CD Data	CDOM output in ppb

FLBBCD on BOSS-Lite and BOSS-Mini

Model_S/N	FL EM	FL Data	bb EM	bb Data	CD EM	CD Data
FLBBCD-121	695	5.700	700	3.500	460	75.125
FLBBCD-121	695	5.700	700	3.500	460	75.125
FLBBCD-121	695	5.700	700	3.500	460	75.125

Column 1:	Model_S/N	Sensor model and serial number
Column 2:	FL EM	Fluorometer emission wavelength
Column 3:	FL Data	Chlorophyll-*a* in µg/l
Column 4:	bb EM	Scattering emission wavelength
Column 5:	bb Data	Scattering output in inverse meters
Column 6:	CD EM	CDOM emission wavelength
Column 7:	CD Data	CDOM output in ppb

FLBBCD on REMOcean A and B—Short Output

Chl RawData	bb RawData	CD RawData	S/N
2223	2010	1766	128
2223	2010	1766	128
2223	2010	1766	128

Column 1: ChlRawData	Chlorophyll output in counts
Column 2: bbRawData	Scattering output in counts
Column 3: CDRawData	CDOM output in counts
Column 4: SN	Sensor serial number

FLBBCD on REMOcean A and B—Long Output

Chl RawData	bb RawData	CD RawData	S/N	Chl SF	Chl Dark	bb SF	bb Dark	CD SF	CD Dark
2223	2010	1766	128	7.00E-03	48	1.89E-06	51	8.80E-02	52
2223	2010	1766	128	7.00E-03	48	1.89E-06	50	8.80E-02	52
2223	2010	1766	128	7.00E-03	48	1.89E-06	51	8.80E-02	52

Column 1: ChlRawData	Chlorophyll output in counts
Column 2: bbRawData	Scattering output in counts
Column 3: CDRawData	CDOM output in counts
Column 4: S/N	Sensor serial number
Column 5: Chl SF	Chlorophyll Scale Factor
Column 6: Chl Dark	Chl Dark Counts
Column 7: bb SF	Scattering Scale Factor
Column 8: bb Dark	Scattering Dark Counts
Column 9: CD SF	CDOM Scale Factor
Column 10: CD Dark	CDOM Dark Counts

FLBB-BB on ORCA

Model_S/N	FL EM	FL Data	bb EM	bb Data	bb EM	bb Data
FLBBBB-121	695	5.700	440	3.500	700	75.125
FLBBBB-121	695	5.700	440	3.500	700	75.125
FLBBBB-121	695	5.700	440	3.500	700	75.125

Column 1: Model_S/N	Sensor model and serial number
Column 2: FL EM	Fluorometer emission wavelength
Column 3: FL Data	Chlorophyll-*a* in µg/l
Column 4: bb EM	Scattering emission wavelength
Column 5: bb Data	Scattering output in inverse meters
Column 6: bb EM	Scattering emission wavelength
Column 7: bb Data	Scattering output in inverse meters

2.2 Terminal Commands

Command	Parameters passed	Description
!!!!!!!	none	Interrupt sensor operation. Do not append a carriage return at the end of the string of exclamation points or it will not work correctly.
$ave	1 to 65535	Number of measurements for each reported value
$asv	1,2 or 4	Analog scaling value for single channel sensors. A value of 1 will cause the analog output to cover only the bottom ¼ of the digital output on a 14 bit sensor. A value of 2 will cause the analog output to cover the bottom ½ of the digital output on a 14 bit sensor. A value of 4 will cause the analog output to cover the full digital range of a 14 bit sensor.
$m1d	0 to 65535	Measurement 1 dark count value for calculating engineering unit output
$m1s	float	Measurement 1 slope value used for calculating engineering unit output
$m2d	0 to 65535	Measurement 2 dark count value for calculating engineering unit output
$m2s	float	Measurement 2 slope value used for calculating engineering unit output
$m3d	0 to 65535	Measurement 3 dark count value for calculating engineering unit output
$m3s	float	Measurement 3 slope value used for calculating engineering unit output
$mnu	none	Prints the menu, including time and date
$pkt	0 to 65535	Number of individual measurements in each packet
$rat	2400 to 230400	Baud rate for sensor communications. It must be a valid baud rate, and will default to 19200 if not. In this case the baud rate will be displayed as 19201 to indicate it defaulted to this value, but the operational baud rate is 19200. Fastest rates will only work over a short distance.
$rfd	none	Reloads original factory settings
$rls	none	Reloads settings from flash.
$run	none	executes the current settings
$seq	0 to 3	Selects which of the pre-defined output sequences to use when outputting data.
$sto	none	stores current settings to internal flash

2.3 Sensor Output Selection

The order in which data is output can be determined using the following commands:

Value	Associated Output
0	serial number
1	date
2	time
3	dummy date, 99/99/99
4	dummy time, 99:99:99
5	ref value 1 counts
6	meas 1 raw counts
7	meas 1 engineering output 1.3E
8	ref value 2 counts
9	meas 2 raw counts
10	meas 2 engineering output 1.3E
11	ref value 3 counts
12	meas 3 raw counts
13	meas 3 engineering output 1.3E
14	internal thermistor counts
15	external thermistor counts
16	pressure sensor counts
17	supply voltage 2.2f
18	numeric part of serial number

Value	Associated Output
19	cSlope1 1.3E, slope for beam C or eng calculation
20	cSlope2 1.3E, slope for beam C or eng calculation
21	cSlope3 1.3E, slope for beam C or eng calculation
22	cleanValue1, clean value for beam C, or dark counts for eng calculation
23	cleanValue2, clean value for beam C, or dark counts for eng calculation
24	cleanValue3, clean value for beam C, or dark counts for eng calculation
240	printf tab
241	putchar 0x09 (tab)
255	printf /n

2.4 Pre-Defined Sensor Output

WET Labs Default	
$ose	0
$00	240
$01	3
$02	4
$03	5
$04	6
$05	8
$06	9
$07	11
$08	12
$09	14
$10	255
$99	
$osd	

FLbbCD-REM (short)	
$ose	1
$00	240
$01	6
$02	9
$03	12
$04	18
$05	255
$99	
$osd	

FLbbCD-REM (long)	
$ose	2
$00	240
$01	6
$02	9
$03	12
$04	18
$05	19
$06	22
$07	20
$08	23
$09	21
$10	24
$11	255
$99	
$osd	

FLbbCD-BOSS	
$ose	1
$00	240
$01	0
$02	5
$03	7
$04	8
$05	10
$06	11
$07	13
$08	255
$99	
$osd	

3. Deployment

Once power is supplied, the sensor is ready for submersion and subsequent measurements. Some consideration should be given to the package orientation. Do not face the sensor directly into the sun or other bright lights. For best output signal integrity, locate the sensor away from significant EMI sources.

Caution
The sensor should be mounted so that the LED source will not "see" any part of a cage or deployment hardware. This will affect the sensor's output.

After each cast or exposure of the sensor to natural water, flush with clean fresh water, paying careful attention to the optical face. Use soapy water to cut any grease or oil accumulation. Gently wipe clean with a soft cloth. The optical face is composed of ABS plastic and optical epoxy and can easily be scratched or damaged.

At the end of an experiment, the sensor should be rinsed thoroughly, air-dried and stored in a cool, dry place.

WARNING!
Do not use acetone or other solvents to clean the sensor.

4. Data Analysis

Raw data from the sensor is output in counts from the sensor, ranging from 0 to 4120 +/- 5.

- Calibration yields scattering data in the form of volume scattering coefficients, $\beta(\theta,\lambda)$ with units of m^{-1} sr^{-1}, where θ is angle and λ is wavelength.
- Characterization yields fluorescence data in the form of µg/l (chlorophyll) or ppb (other fluorescence measurements).

4.1 Scattering Data Corrections

Attenuation coupling—For the population of photons scattered within the remote sample volume in front of the sensor face, there is attenuation along the path from the light source to the sample volume to the detector. This results in the scattering measurements being underestimates of the true volume scattering in the hydrosol. Corrected volume scattering coefficients can be obtained by accounting for the effect of attenuation along an average pathlength. This average pathlength was numerically solved in the weighting function determinations developed by Dr. Ron Zaneveld that are used in the calibration procedures.

Since the calibration of the sensor uses microspherical scatterers, the component of attenuation that can be attributed to scattering is incorporated into the scaling factor, i.e., the calibration itself. Thus, only absorption of the incident beam needs to be included in the correction.

The dependence on absorption, a, is determined as follows, where the measured scattering function at a given value of a, beta_meas(angle, a), is corrected to the value for a = 0 m^{-1}, beta_corr(117°, a=0):

beta_corr(117°, a=0) = beta_meas(117°, a) exp(0.0391a)

Absorption can be measured with an ac-9 sensor. For each scattering wavelength, the matching absorption coefficient must be used from the ac-9. Because the sensor's C3 scattering component incorporates short pathlengths and relatively small scattering volumes in its measurements, this attenuation error is typically small, about 4 percent at $a = 1\ m^{-1}$.

4.2 Derived Parameters

4.2.1 Volume Scattering of Particles

The corrected volume scattering of particles, $\beta(117°,\lambda)$ values represent total volume scattering, i.e., scattering from particles and molecular scattering from water. To obtain the volume scattering of particles only, subtract the volume scattering of water, $\beta_w(117°,\lambda)$:

$$\beta_p(117°,\lambda) = \beta(117°,\lambda) - \beta_w(117°,\lambda)$$

where $\beta_w(117°,\lambda)$ is obtained from the relationship (from Morel 1974):

$$\beta_w(\theta,\lambda)=1.38(\lambda/500nm)^{-4.32}(1+0.3S/37)10^{-4}\ (1+\cos^2\theta(1-\delta)/(1+\delta))m^{-1}sr^{-1},\ \delta=0.09$$

where S is salinity.

For total scattering of pure water,

$b_w(\lambda) = 0.0022533\ (\lambda/500nm)^{-4.23}$.

For total scattering of seawater (35–39 ppt),

$b_{sw}(\lambda) = 0.0029308\ (\lambda/500nm)^{-4.24}$.

For backscattering by water, divide b_w or b_{sw} by 2. The units for the b coefficients are $(10^{-4}\ m^{-1})$.

4.2.2 Backscattering Coefficients

Particulate backscattering coefficients, $b_{bp}(\lambda)$ with units of m^{-1}, can be determined through estimation from the single measurement of $\beta_p(117°,\lambda)$ using an X factor:

$$b_{bp} = 2\pi\ X\ \beta_p(117°)$$

From measurements of the volume scattering function with high angular resolution in a diversity of water types, Boss and Pegau (2001) have determined X to be **1.1** (Boss, E., and S. Pegau, 2001. The relationship of scattering in an angle in the back direction to the backscattering coefficient, *Applied Optics*). This factor estimates b_{bp} with an estimated uncertainty of 4 percent. The conversion can be used for $\beta(117°)$ measurements made at any visible wavelength.

To compute total backscattering coefficients, $b_b(\lambda)$ with units of m^{-1}, the backscattering from pure water, $b_{bw}(\lambda)$ (see above), needs to be added to $b_{bp}(\lambda)$:

$$b_b(\lambda) = b_{bp}(\lambda) + b_{bw}(\lambda).$$

4.2.3 Fluorescence Response

The scale factor is factory-calculated by obtaining a consistent output of a solution with a known concentration, then subtracting the meter's dark counts. The scale factor, dark counts, and other characterization values are on the sensor's characterization sheet.

For chlorophyll, WET Labs uses the chlorophyll equivalent concentration (CEC) as the signal output using a fluorescent proxy approximately equal to 25 µg/l of a *Thalassiosira weissflogii* phytoplankton culture.

Scale Factor = 25 µg/l ÷ (CEC – dark counts)

Example: 25 ÷ (3198 – 71) = 0.0080.

For CDOM, uranine (fluorescein), and phycoerythrin, WET Labs uses a solution where *x* is the sensor output in counts of the concentration of the solution used during instrument characterization.

Scale Factor = 308 ppb ÷ (*x* – dark counts)

Example: 308 ÷ (4148 - 56) = 0.0753.

The scale factor is then applied to the output signal to provide the direct conversion of the output counts to chlorophyll concentration. WET Labs supplies a scale factor that can be found on the sensor-specific calibration sheet that ships with each sensor. While this constant can be used to obtain approximate values, field calibration is highly recommended.

Because of the varied environments in which each user will work, it is important to perform characterizations using similar seawater as you expect to encounter *in situ.* This will provide an accurate dark count value, equivalent phytoplankton types and similar physiological conditions for calculating the scale factor, thereby providing an accurate and meaningful calibration. Once a zero point has been determined and a scale factor established, obtaining a "calibrated" output simply involves subtracting the digital dark counts value from output when measuring a sample of interest and multiplying the difference by the instrument scaling factor:

$$[XX]_{sample} = (C_{output} - C_{dc}) * \text{Scale Factor}$$

where

$[XX]_{sample}$ = concentration of a sample of interest (µg/l or ppb)

C_{output} = raw counts output when measuring a sample of interest

C_{dc} = dark counts, the measured signal output of sensor in clean water with black tape over the detector

Scale factor = multiplier in µg/l/counts or ppb/counts

5. Calibration/Characterization and Testing

Prior to shipment, each sensor is calibrated/characterized and tested to ensure it meets the instrument's stated specifications. Scattering channel(s)s are typically configured for a measurement range of 0–5 m^{-1}. Fluorescence channel(s) are characterized using a specific concentration of a fluorescing material that yields a scaled µg/l or ppb output range:
Chlorophyll: 0–50 µg/l
CDOM: 0–375 ppb

5.1 Scattering Calibration

Definition of Terms

β: phase function	**b**: total scattering coefficient
θ: angle	**θc**: centroid angle
W: weighting function	λ: wavelength
Cp: particulate attenuation coefficient	**SF**: Scaling Factor
m^{-1}: per meter	**sr^{-1}:** per steradian

Each sensor ships with a calibration sheet that provides sensor-specific calibration information, derived from the steps below.

1. For a given scattering centroid angle (θc), compute the weighting function W(θ,θc), by numerical integration of sample volume elements according to the sensor geometry.

2. Determine scattering phase functions, β(θ, λ)/b(λ), for the polystyrene bead microsphere calibration particles by weighting volume scattering functions computed from Mie theory according to the known size distribution of the polystyrene bead microsphere polydispersion and normalizing to total scattering.

3. By convolving W(θ,θ c) with β(θ, λ)/b(λ), compute the normalized volume scattering coefficient for each measurement angle, β(θ, λ)/b(λ), with units of sr^{-1} β(θc)/b for 2.00-micron diameter polystyrene bead microspheres.

4. Experimentally obtain raw scattering counts simultaneously with attenuation coefficients (C_p, using an ac-9) for a concentration series of the polystyrene bead microsphere polydispersion. Absorption by the calibration particles is assumed negligible.

5. Obtain b/counts from the slope of a linear regression between Cp (equivalent to b for the beads) and counts.

6. Multiplying the experimental b/counts by the theoretical β(θc)/b yields the calibration scaling factor, SF.

7. To obtain β(θc), subtract the dark counts from measured raw counts, then multiply by SF.

8. This test also provides a measure of the inherent opto-electronic noise level of the sensor. A standard deviation from the average number of counts on a 1 minute data file is taken. This is translated into the resolution of β(θc) (minimum detectable signal change) in units of m^{-1} sr^{-1}.

5.2 Fluorometer Characterization

Gain selection is performed at WET Labs by setting several gain settings in the sensor and running a chlorophyll (or proxy) dilution series to determine the zero voltage offset and to ensure that the dynamic range covers the measurement range of interest. The dilution series also establishes the linearity of the instrument's response. As is the case with other fluorometers, you must characterize your sensor to determine the actual zero point and scale factor for your application.

5.3 Testing

Dark Counts: The sensor's baseline reading in the absence of source light is the dark count value. This is determined by measuring the signal output of the sensor in clean, de-ionized water with black tape over the detector.

Pressure: To ensure the integrity of the housing and seals, sensors are subjected to a wet hyperbaric test before final testing. The testing chamber applies a water pressure of at least 50 PSI.

Mechanical Stability: Before final testing, sensors are subjected to a mechanical stability test. This involves subjecting the sensor to mild vibration and shock. Proper sensor functionality is verified afterwards.

Electronic Stability: This value is computed by collecting a sample once every 5 seconds for twelve hours or more. After the data is collected, the standard deviation of this set is calculated and divided by the number of hours the test ran. The stability value must be less than 2.0 counts/hour.

Noise: Noise is computed from a standard deviation over 60 samples. These samples are collected at one-second intervals for one minute. A standard deviation is then performed on the 60 samples, and the result is the published noise on the calibration form. The calculated noise must be below 2 counts (3 counts for CDOM).

Voltage and Current Range Verification: To verify the sensor operates over the entire specified voltage range (7–15 V), a voltage test is performed at 7 and 15V, and the current draw and operation is observed. The current must remain constant at both 7 and 15V.

Revision History

Revision	Date	Revision Description	Originator
A	6/9/11	New document (DCN 763)	J. Koegler, W. Strubhar, H. Van Zee
B	8/24/11	Correct output descriptions (DCR 771)	J. Koegler