ECO Three-Measurement Sensor

Triplet Puck

User'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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ECO Sensor Warranty

This unit 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 unit 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 instrument, contact WET Labs for a Return Merchandise Authorization (RMA) and ship in the original container. WET Labs is not responsible for damage to instruments 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 Instruments with Anti-fouling Treatment

WET Labs cannot accept instruments for servicing or repair that are 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 instruments to WET Labs for service or repair.

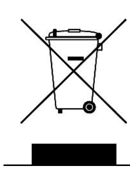
Shipping Requirements

1. Please retain the original shipping material. We design the shipping container to meet stringent shipping and insurance requirements, and to keep your meter functional.

2. To avoid additional repackaging charges, use the original box (or WET Labs-approved container) with its custom-cut packing foam and anti-static bag to return the instrument.
   - If using alternative container, use at least 2 in. of foam (NOT bubble wrap or Styrofoam "peanuts") to fully surround the instrument.
   - Minimum repacking charge for ECO meters: $25.00.

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

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



Electrical equipment marked with this symbol may not be disposed of in European public disposal systems. In conformity with EU Directive 2002/96/EC (as amended by 2003/108/EC), European users of electrical equipment must return old or end-of-life equipment to the manufacturer for disposal at no charge to the user.

1. Overview

WET Labs offers the custom *ECO* Triplet as a three-sensor instrument that can be configured for a variety of measurements:

- Three scattering
- Three fluorescence
- Two scattering, one fluorescence
- Two fluorescence, one scattering

Available measurement options:

Scattering	Fluorescence
Blue	Chlorophyll
Green	CDOM (limited to one CDOM channel)
Red	Uranine (fluorescein)
Custom	Phycoerythrin, phycocyanin
	Rhodamine

ECO Pucks are delivered with the following components:

- the instrument
- this user's guide
- instrument-specific calibration sheet
- protective cover for optics
- fluorescent stick for bench testing

2. Instrument Operation

Please note that certain aspects of instrument operation are configuration-dependent. These are noted where applicable within the manual.

2.1 Initial Checkout

Supplied from the factory, *ECO*s are configured to begin continuously sampling upon power-on. Electrical checkout of *ECO* is straightforward.

Units with CDOM measurement: UV LED Safety Note

- 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.

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

Connect the instrument to a regulated power supply; when turned on, light should emanate from the meter.

Note
ECO scattering meters are sensitive to fluorescent light. Before making measurement, turn AC lighting off.

2.3 Deployment

Once power is supplied, the unit 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 instrument away from significant EMI sources.

Caution
The Triplet 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.

Other than these basic considerations, one only needs to make sure that the unit is securely mounted to whatever lowering frame is used and that the mounting brackets are not damaging the unit casing.

2.4 Upkeep and Maintenance

The *ECO* Triplet is compact device and its maintenance can be easily overlooked. However, it is a precision instrument and does require a minimum of routine upkeep. After each cast or exposure of the instrument to natural water, flush the instrument with clean fresh water, paying careful attention to the sensor face. Use soapy water to cut any grease or oil accumulation. Gently wipe clean with a soft cloth. The sensor face is composed of ABS plastic and optical epoxy and can easily be damaged or scratched.

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

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

3. Data Analysis

Data from the *ECO* meter is output in counts.

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).

3.1 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 Triplet's scattering wavelengths 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 device. For each scattering wavelength, the matching absorption coefficient must be used from the ac-9. Because the *ECO* 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}.

3.2 Derived Parameters

3.2.1 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}).

3.2.2 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 Table above), needs to be added to $b_{bp}(\lambda)$:

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

3.2.3 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 instrument's characterization sheet.

For chlorophyll, WET Labs uses the chlorophyll equivalent concentration (CEC) as the signal output using a fluorescent proxy.

Scale Factor = x µg/l ÷ (Chl Equivalent Concentration – dark counts)

Example: 25 ÷ (3198 – 71) = 0.0080.

For CDOM, uranine (fluorescein), and phycoerythrin, WET Labs uses a solution where *x* is the meter 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 instrument-specific calibration sheet that ships with each meter. 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} = output when measuring a sample of interest

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

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

4. Testing and Calibration/Characterization

Prior to shipment, each *ECO* is tested and calibrated/characterized to ensure that 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 output range:

Chlorophyll:	0.02–50 µg/l
CDOM:	0.3–375 ppb
Phycoerythrin and rhodamine:	0.1–175 ppb
Phycocyanin:	0.15–300 ppt
Uranine (fluorescein):	0.002–5 ppm

4.1 Testing

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

Pressure: To ensure the integrity of the housing and seals, *ECO*s are subjected to a wet hyperbaric test before final testing. The testing chamber applies a water pressure of at least 40 PSI.

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

Electronic Stability: This value is computed by collecting a sample once every second 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 counts.

Noise: The noise value 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 characterization sheet. The calculated noise must be below 2 counts.

Voltage and Current Range Verification: To verify that the *ECO* operates over the entire specified voltage range (7–15 V), a voltage test is performed at 7 and 15 V. The meter is operated at these settings and the current and operation is observed. The current must remain constant at both 7 and 15 volts.

4.2 Scattering Calibration

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

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

2. Determine scattering phase functions, $\beta(\theta, \lambda)/b(\lambda)$, 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 $W(\theta,\theta\ c)$ with $\beta(\theta, \lambda)/b(\lambda)$, compute the normalized volume scattering coefficient for each measurement angle, $\beta(\theta, \lambda)/b(\lambda)$, with units of sr^{-1} $\beta(\theta c)/b$ 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 $\beta(\theta c)/b$ yields the calibration scaling factor, SF.

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

8. This test also provides a measure of the inherent opto-electronic noise level of the instrument. 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}.

Definitions of Terms

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

4.3 Fluorometer Characterization

Gain selection is performed at WET Labs by setting several gain settings in the instrument 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 perform a detailed characterization to determine the actual zero point and scale factor for your particular use.

5. Terminal Communications

ECO sensors can be controlled from a terminal emulator or customer-supplied interface software. This section outlines hardware requirements and low-level interface commands for this type of operation.

5.1 Interface Specifications

- baud rate: 19200
- data bits: 8
- parity: none
- stop bits: 1
- flow control: none

5.2 Command List

Command	Parameters passed	Description
!!!!!	none	Stops data collection; allows user to input setup parameters.
$ave	single number, 1 to 65535	Number of measurements for each reported value
$mnu	none	Prints the menu
$pkt	single number, 0 to 65535	Number of individual measurements in each packet
$rls	none	Reloads settings from flash
$run	none	Executes the current settings
$sto	none	Stores current settings to internal flash

WET Labs WEEE Policy

In accordance with Directive 2002/96/EC and the Council of 27 January 2003, WET Labs policy regarding the collection and management of Waste Electrical and Electronic Equipment (WEEE) is published here and is available at www.wetlabs.com.

A core component of our corporate vision is to accept responsibility for preserving our environment and we embrace the opportunity to work with our customers and the EU to reduce the environmental impact resulting from the continuous improvement of our products.

WEEE Return Process

To meet the requirements of the WEEE Directive, WET Labs has instituted a product end-of-life take back program. To arrange return for an end-of-life WEEE product:

1. Contact WET Labs Customer Service
   - By phone: 1-541-929-5650
   - By email: support@ wetlabs.com

   WET Labs will provide:
   WEEE RMA number
   Shipping account number, method, and address

2. Package and ship the WEEE back to WET Labs

WEEE will be processed in accordance with WET Labs' equipment end-of-life recycling plan.

Revision History

Revision	Date	Revision Description	Originator
A	12/7/05	New document (DCR 475)	M. Johnson, H. Van Zee
B	1/13/06	Clarify warranty statement (DCR 481)	A. Gellatly, S. Proctor
C	2/7/06	Move specifications to individual appendices (DCR 485)	H. Van Zee
D	7/10/08	Change dark counts derivation to reflect current production methodology (DCR 600)	A. Barnard, M. Johnson, H. Van Zee
E	9/9/08	Add phycocyanin spec, delete "ref" columns (DCR 614)	I. Walsh
F	5/7/09	Delete references to ECOView, device files (DCR 666)	M. Johnson, H. Van Zee
G	9/2/10	Add safety note for CDOM UV LED (DCR 713)	A. Barnard, H. Van Zee
H	9/14/11	Add WEEE Statement (DCN 775)	H. Van Zee