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Processing BGC-Argo particle backscattering at the DAC level

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Argo data management
Processing BGC-Argo particle backscattering at the DAC level

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History of the document

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1.1	March 2016	Catherine SCHMECHTIG, Antoine POTEAU, Hervé CLAUSTRE, Fabrizio D'ORTENZIO, Giorgio DALL'OLMO, Emmanuel BOSS	DOI
1.2	July 2016	Catherine SCHMECHTIG, Antoine POTEAU, Hervé CLAUSTRE, Fabrizio D'ORTENZIO, Giorgio DALL'OLMO, Emmanuel BOSS	khi values updated
1.3	January 2017	Catherine SCHMECHTIG, Antoine POTEAU, Hervé CLAUSTRE, Fabrizio D'ORTENZIO, Giorgio DALL'OLMO, Emmanuel BOSS	SENSOR, SENSOR_MODEL updated, Bio-Argo -> BGC-Argo
1.4	March 2018	Catherine SCHMECHTIG, Antoine POTEAU, Hervé CLAUSTRE, Fabrizio D'ORTENZIO, Giorgio DALL'OLMO, Emmanuel BOSS	Correction of the Factory calibration coefficients according to presentation at ADMT18 in Hamburg made by Andrew Barnard (Wetlabs) and change angles for MCOMS from 149° to 150°

Preamble:

This document does NOT address the issue of particle backscattering quality control (either real-time or delayed mode). As a preliminary step towards that goal, this document seeks to ensure that all countries deploying floats equipped with backscattering sensors document the data and metadata related to these floats properly. We produced this document in response to action item 9 from the first BGC-Argo Data Management meeting in Hyderabad (November 12-13, 2012).

If the recommendations contained herein are followed, we will end up with a more uniform set of particle backscattering data within the BGC-Argo data system, allowing users to use the same procedures to analyze backscattering data irrespective of the float they were on, in the spirit of Argo data.

1 Introduction

The scattering coefficient (b) of a medium is the scattered fraction of incident light flux, divided by the infinitesimal thin layer of the medium. It is usual, for bio-optical purposes, to decompose the scattering coefficient in two components depending on the direction of the scattered flux. The forward scattering coefficient (b_f), indicating the flux scattered from the beam in the forward direction, and the backscattering coefficient (b_b), related to light scattered from the beam in the backward direction. b_b is directly related to the concentration and size of particles, but also to their composition (i.e. organic vs inorganic). Recent derived empirical relationships were found, correlating b_b to POC concentration and total suspended matter (Stramski et al., 2008, Cetinic et al., 2012) and b_b to phytoplankton carbon (Martinez-Vicente et al, 2013, Graff et al., 2015).

To estimate it: if $\beta(\theta, \lambda)$ is the volume scattering function (VSF) ([m-1 sr-1], the angular distribution of scattering relative to the direction of light propagation, θ, at the optical wavelength λ), b_b [m-1] is defined as:

$$b_b(\lambda) = 2\pi \int_{\pi/2}^{\pi} \beta(\theta, \lambda)\, sin\theta d\theta \qquad (1)$$

From a single angle measurement of the VFS in the backward direction, to obtain particulate VSF contribution, the contribution of pure seawater, β_{sw}, has to be removed (Equation (2)). The values of β_{sw} with dependencies on temperature and salinity and a depolarization ratio of 0.039 are derived from the study of Zhang et al. (2009).

$$\beta_p(\theta, \lambda) = \beta(\theta, \lambda) - \beta_{sw}(\theta, \lambda) \qquad (2)$$

Using χ as a conversion factor, which relate b_{bp} to β_p and allows to extrapolate the measurement at a single angle to the total coefficient (Boss and Pegau, 2001), it follows that :

$$b_{bp}(\lambda) = 2\pi\chi\big(\beta(\theta, \lambda) - \beta_{sw}(\theta, \lambda)\big) \qquad (3)$$

The backscattering meters from WETLabs allow the estimation of the optical backscattering at one wavelength (several wavelengths are available for different instruments). Different configurations of the instrument exist with different centroid angles and χ values. (Sullivan et al., 2013). These properties are reported in the Table 1.

Wetlabs Sensor	Measurements angle	Full Width at Half Maximum (FWHM)	Bandwidth	χ
MCOMS and SeaOWL UV-A	150°	20°	20nm	1.142*
Single Channel Sensors	124°	20°	20nm	1.076**
Dual Channel Sensors	142°	30°	20nm	1.097*
Three Channel Sensors	124°	20°	20nm	1.076**

Combined Three Channel Sensors	124°	20°	20nm	1.076**

Table 1: Summary of all the WETLabs ECO sensors' characteristics for backscattering meters. (cf 5. Annexes) (* Mike Twardowski, Com. Pers) (** Sullivan et al., 2013)

Following the user manual, raw data from the scattering meter is in counts. Counts are transformed by applying manufacturer-provided scaling factors and dark counts corrections in total volume scattering coefficient. When possible the dark counts should be measured on the float.

At the moment all backscattering sensors implemented on floats are developed by the WETlabs Company. On Floats, backscattering meters often combine the backscattering measurements together with one or two other measurements (ECO_FLBB, ECO_FLNTU, ECO_FLBBCD), one of them is often Chlorophyll-a fluorescence (FL). The present document is focused on the management of the backscattering data flow acquired by those sensors (section 3). Similar sensors begin to be proposed by other companies (e.g. the Cyclops integrator Submersible Fluorometer from Turner). As soon as these sensors are implemented and successfully tested on floats, the present document would be updated.

2 Recommendations for addressing the particle backscattering processing

2.1 General recommandations

The official BGC-Argo unit for particle backscattering is m^{-1}. Presently the backscattering meters implemented on floats provide counts for the VSF, β at specific angles (in $m^{-1}.sr^{-1}$) reported in table 1. Here are the recommendations to address the particle backscattering processing at one wavelength:

- Store any data transmitted by the backscattering meter with meaningful names. It is important to store those raw data, if changes occur in the calibration/conversion equations used to convert the sensor output in particle backscattering. The proposed name for the counts transmitted by the backscattering meter is "BETA_BACKSCATTERINGxxx", where xxx stands for the wavelength of the measurements (for example, at 532nm : BETA_BACKSCATTERING532)

- Store in "BBPxxx" the particle backscattering in m^{-1}, estimated from the "BETA_BACKSCATTERINGxxx" counts.

- Fill properly the metadata to document the calibration, the conversions equations and the fields to identify a sensor.

As for other sensors, the model number and serial number of the backscattering sensor must be provided. This tracking is essential if a specific failure concerns all the sensors from the same batch for instance, or if the manufacturing process changes after a certain serial number. The resolution of the sensor is provided by the manufacturers.

Indications provided in the two following sections and the examples on how to fill metadata are valid as of the date of writing this document. It is very likely that changes in calibration and conversion equations will occur in the future. Metadata will then have to be filled accordingly with the new procedures.

2.2 Recommandations after ADMT18

At ADMT18, Andrew Barnard highlighted the fact that a reprocessing is necessary for backscattering meter. BGC dacs gather all serial numbers of the different backscattering sensors mounted on floats and the manufacturer provided the new scale factor. All these information are stored in the document http://doi.org/10.17882/54520. It is recommended to track that this update was taken into account in the metadata NetCDF file in the PREDEPLOYMENT_CALIB_COMMENT. (cf 3.2.1 Examples)

3 Backscattering sensor

3.1 Measurements and Data processing

Both the ECO or MCOMS sensors might measure backscattering at different wavelengths. We will take as an example 700nm.

Raw data from the backscattering meter (BETA_BACKSCATTERING700) are transmitted as counts.

The basic equation allowing the retrieval of particle backscattering from raw transmitted measurement is:

BBP700 =2*π*χ[(BETA_BACKSCATTERING700 – DARK_BACKSCATTERING700)* SCALE_BACKSCATTERING700 - BETASW700]

where:
χ is the conversion factor defined in equation (3) and provided in Table 1;

BETASW700 ($\beta_{sw}(700)$) is the contribution to the VSF by the pure seawater at 700nm defined in equation (2), which depends on temperature and salinity (TEMP, PSAL) and which is estimated from Zhang et al. (2009). The Matlab code to calculate β_{sw} at the appropriate angle (Table 1) and different wavelengths is available (http://doi.org/10.17882/42916).

BBP700 is particulate backscattering (m^{-1})

BETA_BACKSCATTERING700 are the raw counts output (digital counts);

DARK_BACKSCATTERING700 are the dark counts, the factory measured signal output of the backscattering meter in clean water with black tape over the detector (ditigal count).

SCALE_BACKSCATTERING700 is the scaling factor in $m^{-1}.sr^{-1}.counts^{-1}$.

The scaling factor (SCALE_BACKSCATTERING700), dark counts (DARK_BACKSCATTERING700) are on the instrument's characterization sheet. They will be supplied by WETLabs for every wavelengths and will be stored in the "**PREDEPLOYMENT_CALIB_EQUATION**" and in the "**PREDEPLOYMENT_CALIB_COEFFICIENT**", as well as χ.

In case where dark measurements have been collected on the float, the median of these measuremens should be stored as **DARK_BACKSCATTERING700_O**. Even if not used in RT, **DARK_BACKSCATTERING700_O** could be potentially useful in DMQC.

Examples :

PREDEPLOYMENT_CALIB_EQUATION="BBP700=2*pi*khi *((BETA_BACKSCATTERING700-DARK_BACKSCATTERING700_O)*SCALE_BACKSCATTERING700-BETASW700)"

PREDEPLOYMENT_CALIB_COEFFICIENT="DARK_BACKSCATTERING700=71, DARK_BACKSCATTERING700_O=80, SCALE_BACKSCATTERING700=0.008, khi=1.076, BETASW700 (contribution of pure sea water) is calculated at 124°"

PREDEPLOYMENT_CALIB_COMMENT="Sullivan et al., 2013, Zhang et al., 2009, BETASW700 is the contribution by the pure seawater at 700nm, requiring temperature, salinity and using a depolarization of 0.039, its default value. the script can be found at http://doi.org/10.17882/42916. Reprocessed from the file provided by Andrew Barnard (Seabird) following ADMT18. This file is accessible at http://doi.org/10.17882/54520"

3.2 Sensor METADATA and Configuration parameters

3.2.1 Sensor and parameter metadata

This section contains information about the sensors of the profiler and the parameters measured by the profiler or derived from profiler measurements that need to be filled. All the reference tables can be found in the Argo user's manual.

Sensor metadata	
SENSOR	BACKSCATTERINGMETER_BBP700
SENSOR MAKER	WETLABS
SENSOR_MODEL	ECO_FLBBCD (see table 2)
SENSOR_SERIAL_NO	*To be filled*

Parameter metadata	
PARAMETER	BETA_BACKSCATTERING700
PARAMETER_SENSOR	BACKSCATTERINGMETER_BBP700
PARAMETER_UNITS	Counts
PARAMETER_ACCURACY	
PARAMETER_RESOLUTION	
PARAMETER	BBP700
PARAMETER_SENSOR	BACKSCATTERINGMETER_BBP700
PARAMETER_UNITS	m^{-1}
PARAMETER_ACCURACY	
PARAMETER_RESOLUTION	

SENSOR_MODEL	See Table 1 for Angles
ECO_BB	Single channel sensor
ECO_FLBB	Dual channels sensor
ECO_FLBB_AP2	Dual channels sensor
ECO_FLBB_2K	Dual channels sensor
ECO_BB2	Dual channels sensor
ECO_FLBBCD	Combined three channels sensor
ECO_FLBB2	Combined three channels sensor
ECO_BB3	Three channels sensor
MCOMS_FLBB2	MCOMS
MCOMS_FLBBCD	MCOMS

Table 2: Wetlabs sensor model

3.2.2 Configuration parameters

CONFIG_EcoBetaWavelength<I>_nm

Wavelength of Eco Beta #<I> measurements (in nanometer)

<I> is the number of the wavelength: : in case of two BBP 1, 2

CONFIG_EcoBetaBandwidth<I>_nm

Bandwidth of Eco Beta #<I> measurements (in nanometer)

<I> is the number of the wavelength : in case of two BBP 1, 2

CONFIG_EcoBetaAngle<I>_angularDeg

Angle of Beta measurements #<I> (in degrees)

<I> is the number of the wavelength : in case of two BBP 1, 2

Backscattering sensors do not collect data at the same pressure as the CTD sensors. We define a configuration parameter to illustrate the offset in pressure due to the difference of the vertical alignment between the Eco and the CTD.

CONFIG_EcoVerticalPressureOffset_dbar

Vertical pressure offset due to the fact that the sensor is not exactly at the CTD pressure

As an example on floats with backscattering sensors with one wavelength :

CONFIG_EcoBetaWavelength_nm=700

CONFIG_EcoBetaBandwidth_nm=20

CONFIG_EcoBetaAngle_angularDeg=142

CONFIG_EcoVerticalPressureOffset_dbar=0.1

As an example on floats with backscattering sensors with two wavelengths:

CONFIG_EcoBetaWavelength1_nm=532

CONFIG_EcoBetaWavelength2_nm=700

CONFIG_EcoBetaAngle1_angularDeg=124

CONFIG_EcoBetaAngle2_angularDeg=124

CONFIG_EcoVerticalPressureOffset_dbar=0.1

3.3 Particle backscattering related parameters

During the ADMT13, the decision to separate data files for floats with biogeochemical sensors was taken. Then for biogeochemical floats, there are three files : one (c-file) for P,T,S, one (b-file) containing

P, intermediate parameters (b-file) and ocean state variables and one merged file (m-file) containing P, T, S and ocean state variables.

3.3.1 Particle backscattering related parameters for the b-file

Raw data from the sensor are in counts (BETA_BACKSCATTERING700).

PARAMETER="BETA_BACKSCATTERING700"

PREDEPLOYMENT_CALIB_EQUATION="none"

PREDEPLOYMENT_CALIB_COEFFICIENT="none"

PREDEPLOYMENT_CALIB_COMMENT="Uncalibrated backscattering measurement"

3.3.2 Particle backscattering related parameters for the b-file and the merged file

BETA_BACKSCATTERING700 is converted into particle backscattering BBP700

PARAMETER="BBP700"

PREDEPLOYMENT_CALIB_EQUATION="BBP700=2*pi*khi *((BETA_BACKSCATTERING700-DARK_BACKSCATTERING700)*SCALE_BACKSCATTERING700-BETASW700)"

PREDEPLOYMENT_CALIB_COEFFICIENT="DARK_BACKSCATTERING700=71, SCALE_BACKSCATTERING700=0.008, khi=1.076, BETASW700 (contribution of pure sea water) is calculated at 124°"

PREDEPLOYMENT_CALIB_COMMENT="Sullivan et al., 2013, Zhang et al., 2009, BETASW700 is the contribution by the pure seawater at 700nm, requiring temperature, salinity and using a depolarization of 0.039, its default value. the script can be found at http://doi.org/10.17882/42916. Reprocessed from the file provided by Andrew Bernard (Seabird) following ADMT18. This file is accessible at http://doi.org/10.17882/54520"

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5 Annexes

<u>WET Labs ECO Centroid Angles for Back Scatter Measurements, June 2016</u>

The WET Labs' ECO sensors have multiple back scattering angles depending upon type of sensor. This document will describe these angles based upon the type of ECO sensor selected by the customer.

Single Channel Sensors:

WET Labs' single channel ECO backscattering sensors with the LED source bore paired with the backscattering detector have an in-water centroid angle of 124°. These include the following ECO models: ECO BB and ECO NTU versions along with OEM variants of these sensors (AP2, 2K, SLC, etc.).

Dual Channel Sensors:

ECO backscattering sensors that have backscattering at 700nm and a paired chlorophyll fluorescence channel have an in-water centroid angle of 142°. These include the following ECO models: FLNTU and FLBB versions along with OEM variants of these sensors (AP2, 2K, SLC, etc.).

Three Channel Sensors:

WET Labs' three channel ECO backscattering sensors with the LED source bore paired with the backscattering detector have backscattering sensors with an in-water centroid angle of 124°. These include the following ECO models: ECO BB3, ECO BBFL2, ECO BB2FL (AP2, 2K, SLC, etc. includes W versions).

Combined Three Channel Sensors:

WET Labs' combined three channel ECO backscattering sensors that have backscattering at 700nm and a paired chlorophyll fluorescence channel along with either another back scatter channel or FDOM channel have an in-water centroid angle of 124°. These include the following ECO models: ECO FLBBCD, ECO FLBBBB along with OEM variants of these sensors (AP2, 2K, SLC, etc.).

MCOMS and SeaOWL UV-A:

WET Labs' MCOMS and SeaOWL UV-A have backscattering at 700nm paired with chlorophyll fluorescence channel along with either another back scatter channel or FDOM channel have an in-water centroid angle of 150°.

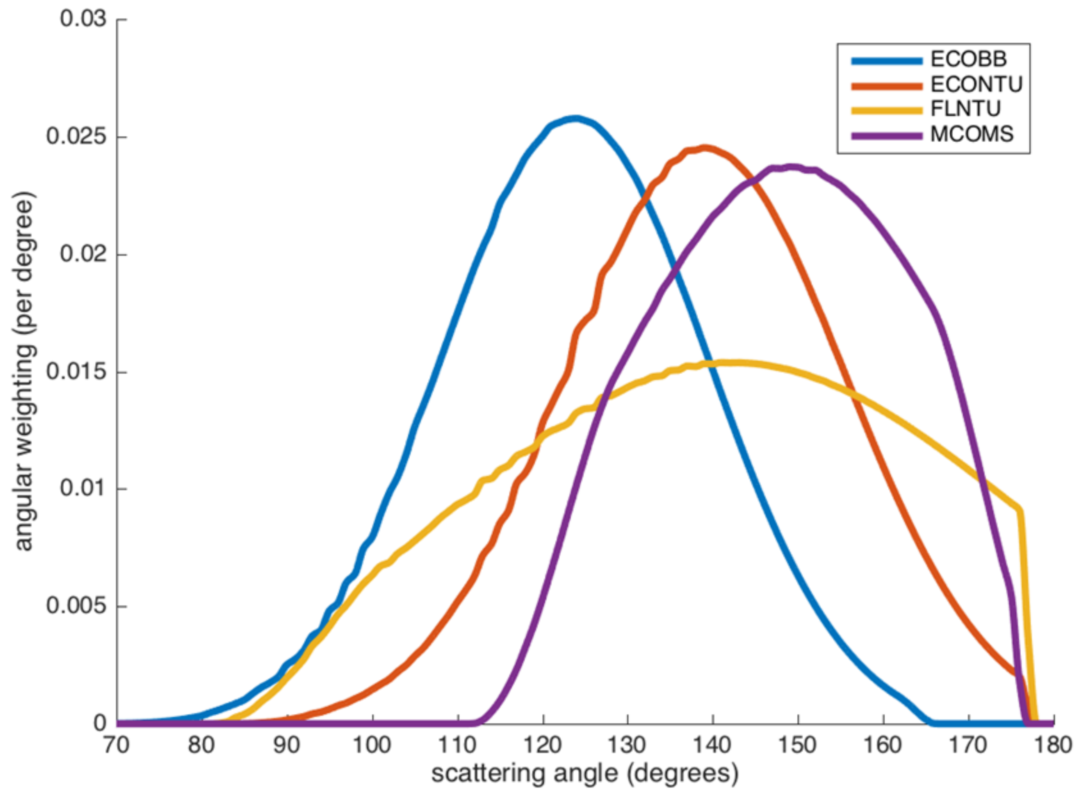

Fig. A1. Angular sensitivity for WETLabs sensors as provided by WETLabs.

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