DATA PRODUCT SPECIFICATION FOR PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR)

FROM BIOSPHERICAL INSTRUMENTS ON CGSN PROFILERS AND MOBILE ASSETS

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Document Control Sheet

Version	Date	Description	Author
0-01	2012-05-21	Initial Draft	S. Banahan
0-02	2012-06-21	Incorporate comments; correct test data table.	S. Banahan
0-03	2012-06-22	Minor updates to Accuracy appendix.	S. Webster
1-00	2012-07-10	Initial Release	E. Chapman
1-01	2014-03-11	Edits to address the fact that there are two types of Biospherical PAR sensors. QSP-2100s are mounted on the gliders and QSP-2200s are mounted on the WFPs.	C. Risien

Signature Page

This document has been reviewed and approved for release to Configuration Management.

OOI Senior Systems Engineer: 

Date: 2012-07-10

This document has been reviewed and meets the needs of the OOI Cyberinfrastructure for the purpose of coding and implementation.

OOI CI Signing Authority: 

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Table of Contents

1 Abstract

This document describes the computation used to calculate the OOI Level 1 Photosynthetically Active Radiation (PAR) data product (OPTPARW), which is calculated using the Biospherical Instruments linear calibration equation for the QSP-2100 and QSP-2200 series scalar PAR instruments. This DPS pertains only to the data product produced from these instruments, which are deployed on CGSNglider (QSP-2100), and profiler (QSP-2200) and autonomous underwater vehicle (UAV) platforms. This document is intended to be used by OOI programmers to construct appropriate processes to create the Level 1 OPTPARW product.

2 Introduction

2.1 Author Contact Information

Please contact Susan Banahan (sbanahan@oceanleadership.org) or the Data Product Specification lead (DPS@lists.oceanobservatories.org) for more information concerning the computation and other items in this document.

2.2 Metadata Information

2.2.1 Data Product Name

The OOI Core Data Product Name for Photosynthetically Active Radiation (PAR) data product is
OPTPARW

The OOI Core Data Product Descriptive Name for this product is
PAR (Photosynthetically Active Radiation)

2.2.2 Data Product Abstract (for Metadata)

The OOI Level 1 Photosynthetically Active Radiation (PAR) core data product (OPTPARW) is the measurement of irradiance within the spectral range (wavelength) of solar radiation from 400 to 700 nanometers (nm) that photosynthetic organisms are able to use in the process of photosynthesis.

2.2.3 Computation Name

Not required for data products.

2.2.4 Computation Abstract (for Metadata)

This computation takes an ASCII-encoded digital output voltage from the Biospherical Instruments QSP-2100 and QSP-2200 series PAR instrument and computes the OOI Level 1 OPTPARW (PAR) core data product using the linear calibration equation provided by the manufacturer.

2.2.5 Instrument-Specific Metadata

There are no instrument-specific metadata that need to be added for the algorithm.

2.2.6 Data Product Synonyms

Synonyms for this data product are

- PAR
- Photosynthetically Active Radiation
- Photosynthetically Available Radiation

2.2.7 Similar Data Products

N/A

2.3 Instruments

The Biospherical Instruments QSP-2100 and QSP-2200 series measure irradiance across the spectral range of 400 to 700 nm. PAR is normally quantified as micromoles of photons per square meter per second (µmol photons • $m^{-2} s^{-1}$), which is a measure of the photosynthetic photon flux (area) density (PPFD). The QSP-2100 is calibrated to report PAR in units of microeinsteins per square meter per second (µE • $m^{-2} s^{-1}$), which is equivalent to µmol photons • $m^{-2} s^{-1}$. The QSP-2200 is calibrated to report PAR in units of quanta per square centimeter per second (quanta • $cm^{-2} s^{-1}$). The units for the OPTPARW data product will be reported as µmol photons • $m^{-2} s^{-1}$; it is a derived SI (Système International) unit. For information on the instrument from which the Level 1 OPTPARW core data product inputs are obtained, see the PARAD Processing Flow document (DCN 1342-00720). This document describes the flow of data from the PARAD sensor through all of the relevant QC, calibration, and data product computations and procedures.

Please see the Instrument Application on the OOI Software Application Framework (SAF) for specifics of instrument locations and platforms.

2.4 Literature and Reference Documents

Biospherical Instruments QSP-2150 and QCP-2150 Submersible PAR Sensors with ASCII Output User's Manual, Version QSP_QCP2150_Manual.DOC (2007-03-13)

Biospherical Instruments QSP-2200 and QCP-2200 Analog Output Quantum Profiling Sensor User's Manual, Version ManualQSP_QCP2200_Manual.doc (2007-03-13)

Biospherical Instruments Application Note: Sensitivity and Dynamic Range in ASCII Output Sensors, AN-2012-0005-Rev1, BSI DCN: 006413KA (2012)

These references and related materials can be found in the OOI document management system on Alfresco:
(OOI > REFERENCE > Data Product Specification Artifacts > 1341-00721_OPTPARW).

2.5 Terminology

2.5.1 Definitions

Photosynthetically Active Radiation (PAR)**:** Photosynthetically Active Radiation (PAR) designates the spectral range (wavelength) of solar radiation that photosynthetic organisms are able to use in the process of photosynthesis. The Biospherical Instruments QSP-2100 and QSP-2200 series PAR sensors measure irradiance across the spectral range of 400 to 700 nm. PAR is normally quantified as micromoles of quanta per square meter per second (µmol photons • $m^{-2} s^{-1}$), which is a measure of the photosynthetic photon flux (area) density (PPFD). The QSP-2100 and QSP-2200 report PAR in units of microeinsteins per second per square meter (µE • $m^{-2} s^{-1}$), which is equivalent to µmol photons • $m^{-2} s^{-1}$, the OOI-designated output unit for the OPTPARW data product, and quanta per square centimeter per second (quanta • $cm^{-2} s^{-1}$), respectively. PAR is an important parameter used in energy balance models, ecosystem characterization, and productivity analyses for oceanic and climatological studies.

2.5.2 Acronyms, Abbreviations and Notations

General OOI acronyms, abbreviations and notations are contained in the Level 2 Reference Module in the OOI requirements database maintained on a Dynamic Object Oriented Requirements System (DOORS). The following acronyms and abbreviations are defined here for use throughout this document.

PAR	Photosynthetically Active Radiation (400-700 nm)
PPFD	Photosynthetic Photon Flux Density

2.5.3 Variables and Symbols

The following variables and symbols are defined here for use throughout this document.

PAR Photosynthetically Active Radiation (400-700 nm) in µmol photons • $m^{-2} s^{-1}$

QSP-2100

Scale_2100 [wet]	Wet calibration scale factor in volts per µmol photons • $m^{-2} s^{-1}$
dark offset_2100	Dark reading (i.e., signal) in volts
reading _2100	Observation signal in volts.

QSP-2200

scale [wet] _2200	Wet calibration scale factor in volts per quanta • $cm^{-2} s^{-1}$
dark offset _2200	Dark reading (i.e., signal) in millivolts
reading _2200	Observation signal in millivolts.

The sensor output is in volts. The vendor furnished wet calibration scale factor is specific to in-water measurements and includes the immersion coefficient correction.

3 Theory

3.1 Description

Photosynthetically Active Radiation (PAR) designates the spectral range (wave band) of solar radiation from 400 to 700 nm that photosynthetic organisms are able to use in the process of photosynthesis. Each PAR value is an integrated number of the solar radiation at each wavelength between 400 to 700 nm and reported as either µmol photons • $m^{-2} s^{-1}$ or quanta • $cm^{-2} s^{-1}$. PAR is a function of Date, Time, Latitude, Longitude, and Depth. Latitude, Longitude, and Depth are metadata associated with the Level 0 and Level 1 sensor products. The computational technique is a linear conversion from Level 0 volts (millivolts) to Level 1 PAR µmol photons • $m^{-2} s^{-1}$ (quanta • $cm^{-2} s^{-1}$).

3.2 Mathematical Theory

See section 4.3

3.3 Known Theoretical Limitations

Sensor operation is valid for operating temperatures between -2 and 35°C. Typical dynamic measurement range for QSP-2100 and -2200 is 0.14 – 4,700 µmol photons • $m^{-2} s^{-1}$.

3.4 Revision History

No revisions to date.

4 Implementation

4.1 Overview

L1 OPTPARW algorithm is a simple linear scaling and offset defined by instrument calibration.

4.2 Inputs

- Level 0 OPTPARW input (i.e., instrument signal) in volts or millivolts
- The *dark offset* and *scale [wet]* are from instrument-specific calibration metadata furnished by Biospherical Instruments. These values are to be recorded as metadata and shall be updated when calibration is completed by the vendor. The dark offset may also be determined by the operator (see instructions in the instrument user's manual) and may be performed as specified by OOI Operations and Maintenance policies/procedures.

Instrument inputs to the computation are floating point numbers with six (6) decimal places in units of volts or millivolts.

The computation described herein only produces valid results when the observation inputs are within the range of 0.14 – 4,700 µmol photons • m^{-2} s^{-1} over the light spectrum of 400 to 700 nm.

Range checks on the outputs are applied as part of the global range check (GLBLRNG, DCN 1341-10004) specified in the PARAD Processing Flow document (DCN 1342-00720).

Input Data Formats:

The Biospherical Instruments QSP-2150 (QSP-2200) instrument default data consists of three floating point numbers as follows:

2.016793, 23.11, 5,307 (**2 016.793**, 23.11, 5,307)

The three numbers in the series are 1) the sensor reading in volts or millivolts (i.e., *reading*), 2) the circuit board temperature (degrees Celsius) and, 3) the supply voltage (volts). The data produced in 2 and 3 are useful for trouble-shooting purposes but not required for OPTPARW processing.

4.3 Processing Flow

The specific steps necessary to create all calibrated and quality controlled data products for each OOI core instrument are described in the instrument-specific Processing Flow documents (DCN 1342-00720 for the PARAD instrument). These processing flow documents contain flow diagrams detailing all of the specific procedures (data product and QC) necessary to compute all levels of data products from the instrument and the order in which these procedures should be applied.

A linear fitting function is used to convert between input volts and output PAR. The relationship between PAR and volts is described by:

PAR = (*reading – dark offset*) / *scale [wet]*

Where *reading* is the sensor (QSP-2100) input in volts, *dark offset* is the dark reading in volts, and *scale [wet]* is the wet calibration scale factor in volts per µmol photons • m^{-2} s^{-1}. Where *reading* is the sensor (QSP-2200) input in millivolts, *dark offset* is the dark reading in millivolts, and *scale [wet]* is the wet calibration scale factor in volts per quanta • cm^{-2} s^{-1}.

Calibration scale factors and conditions information can be found on the Biospherical Instruments calibration sheet and are part of the instrument-specific metadata.

Reference: PAR Instrument User's Manual (see section 2.4)

Note that several QC routines are carried out on these data after the L1 data product has been produced, as shown in the PARAD Processing Flow document (DCN 1342-00720). Specifically we perform a global range test (DCN 1341-10004); a local range test (DCN 1341-10005) based on latitude, longitude, and depth; and a trend test (DCN 1341-10007) to check for the absence of exponential decay with depth in the data. Note that this trend test will automatically catch data that erroneously increase with depth, another sign that the data are suspect and should be flagged. Additional QC that are sometimes performed on these types of data sets, but that are NOT performed on OOI OPTPARW data, include checking near-surface data (0 - 5 m depending on wave height) for wave focusing and defocusing and horizontal light effects.

4.4 Outputs

The output of the OPTPARW computation is

- Photosynthetically Active Radiation in µmol photons • $m^{-2} s^{-1}$ as a fixed-point number with two (2) decimal places, displayed as %.2f.

Metadata that must be included with the output are:

- Latitude, longitude of the observation
- Depth of the observation

Note that instrument output data 2 and 3 (the circuit board temperature and supply voltage) may be useful as metadata for trouble-shooting purposes but not required for OPTPARW processing.

See Appendix B for a discussion of the accuracy of the output.

4.5 Computational and Numerical Considerations

4.5.1 Numerical Programming Considerations

There are no numerical programming considerations for this computation. No special numerical methods are used.

4.5.2 Computational Requirements

Computation estimate not required for algorithms that are not computationally intensive.

4.6 Code Verification and Test Data Set

The code will be verified using the test data set provided, which contains the computation inputs and their associated correct outputs. CI will verify that the code is correct by checking that the output, generated using the test data inputs, is identical to the test data output. Table 1 and 2 contain test data sets that provide a few data points within the range of water column values.

Table 1. Input (instrument reading) and output (PAR) data from the Biospherical Instruments PAR QSP-2100 series instrument. Values for the dark offset and wet calibration scale factor from a BSI Calibration Certificate for Model QSP-2155.

dark offset = 0.0101 volts
scale [wet] = 5.897E-04 volts per µmol photons • $m^{-2} s^{-1}$

instrument reading (instrument output)	PAR (data product output)
volts	µmol photons • $m^{-2} s^{-1}$
1.016793	1707.13
0.599800	1000.00
0.452400	750.00
0.305000	500.00
0.187000	300.00
0.178900	286.25
0.069100	100.00

0.039600	50.00
0.010100	0.00

Table 2. Input (instrument reading) and output (PAR) data from the Biospherical Instruments PAR QSP-2200 series instrument. Values for the dark offset and wet calibration scale factor from a BSI Calibration Certificate for Model QSP-2200.

dark offset = 10.1 millivolts
scale [wet] = 9.7957E-18 volts per quanta • cm $^{-2}$ s $^{-1}$

instrument reading (instrument output)	PAR (data product output)
millivolts	µmol photons • m^{-2} s^{-1}
1016.793	1707.13
599.800	1000.00
452.400	750.00
305.000	500.00
187.000	300.00
178.900	286.25
69.100	100.00
39.600	50.00
10.100	0.00

Appendix A Output Accuracy

The accuracy of the OPTPARW (PAR) data calculated as described herein is a function of the accuracy of the input (i.e., signal) voltage. Digital output resolution is 24-bit ADC data, 9600 baud, 8 data bits, 1 stop bit, no parity (9600,N81).

The following specifications are stated in referenced Biospherical Instruments User's Manual and Application Note. This information shall be recorded as metadata.

PAR dynamic range: 0.14 – 4,700 µmol photons • $m^{-2} s^{-1}$

QSP Directional Response: Each instrument's directional response is optimized before final calibration. The response is a constant ±7% between 0^{o} to approximately 135^{o} in zenith angle, with response falling off to zero as the light field is obscured by the instrument housing. Individual detector response plots can be furnished by the vendor.

Spectral Response: Equal (better than ±10%) quantum response from 400 nm to 700 nm with response sharply attenuated above 700 nm and below 400 nm. Spectral response induced errors will cause less than 5% errors in naturally occurring light fields.

Calibration: The QSP-2100 series is calibrated using a National Institute of Standards and Technology (NIST)-traceable 1000-watt type-FEL Standard of Spectral Irradiance. Calibration factors are imbedded within the sensor housing as nonvolatile memory. Annual recalibration is recommended.

Biospherical Instruments stated accuracy in dry air is <± 5% for output values in the stated dynamic range for PAR (0.14 – 4700 µmol photons • $m^{-2} s^{-1}$).

The OOI Level 2 (L2) requirement for PAR accuracy (L2-SR-RQ-3673) states that PAR shall be measured with an accuracy of ±5%.

Appendix B Sensor Calibration Effects

The PAR sensor should be calibrated using a NIST-traceable lamp with a known spectral response or sent back to the manufacturer for calibration. Calibration accuracy is ± 5% NIST Traceable (in air).

The PAR sensor must be placed on mobile platforms (profiler, glider, and AUV) so that it is clear of any shadows, reflections, or obstruction of surface light. Profilers, gliders, or AUVs may be equipped to produce data bearing on pitch, roll, and or heading (e.g., ADCPA instrument class). These data could be used to correct PAR sensor values for tilt.

Upon deployment, the PAR sensor may be field validated using another PAR sensor on a CTD cast, as well as profiles using absorption and transmissometer instruments. Beam attenuation may be used to estimate diffuse attenuation and then PAR values. Comparison with other PAR sensors should show the same relative pattern with depth, but the spectral response may differ. Scalar PAR sensor values should be similar within ±5%.