



DATA PRODUCT SPECIFICATION FOR DOWNWELLING SPECTRAL IRRADIANCE

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Consortium for Ocean Leadership
1201 New York Ave NW, 4th Floor, Washington DC 20005
www.OceanLeadership.org

in Cooperation with

University of California, San Diego
University of Washington
Woods Hole Oceanographic Institution
Oregon State University
Scripps Institution of Oceanography
Rutgers University

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Signature Page

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

OOI Senior Systems Engineer:



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

OOI CI Signing Authority: _____

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Table of Contents

1	Abstract	1
2	Introduction	1
2.1	Author Contact Information	1
2.2	Metadata Information	1
2.3	Instruments.....	2
2.4	Literature and Reference Documents	2
2.5	Terminology.....	3
3	Theory.....	4
3.1	Description	4
3.2	Theory	5
3.3	Known Theoretical Limitations	5
3.4	Revision History	5
4	Implementation	6
4.1	Overview	6
4.2	Inputs.....	6
4.3	Processing Flow	13
Appendix A	Example Code.....	14
Appendix B	Output Accuracy.....	15
Appendix C	Sensor Calibration Effects.....	16

1 Abstract

The purpose of this document is to provide OOI programmers, product developers, reviewers and users with an overview of the theoretical and practical algorithm information (scientific, mathematical and computational) that is used by the Ocean Observatories Initiative (OOI) to derive downwelling spectral irradiance (SPECTIR) using data collected with a Satlantic Inc. OCR-507.

SPECTIR is a measure of the spectral irradiance, which is the power of electromagnetic radiation per unit area incident on a surface. The spectral irradiance measurements are cosine corrected and integrated over 2π steradians). The spectral irradiance is used directly for a range of science questions (e.g., heating of water and photosynthetic potential) and can provide inputs to derive a suite of data proxies (e.g., phytoplankton biomass using ocean color algorithms). One example of derived parameter used by many in the science community is the diffuse attenuation coefficient, which can be calculated from a vertical profile of measured light intensity. The irradiance is measured for discrete wavelength bands that were chosen when the sensor was purchased.

SPECTIR is an L1 product, but is subject to instrument specific calibration coefficients and dark current corrections. The procedures described herein assume that the sensors are calibrated and free of confounding effects of instrument drift and biofouling.

2 Introduction

2.1 Author Contact Information

Please contact the Data Product Specification lead (DPS@lists.oceanobservatories.org) for more information concerning the algorithm and other items in this document.

2.2 Metadata Information

2.2.1 Data Product Name

The OOI Core Data Product Name for this data product is

- SPECTIR

The OOI Core Data Product Descriptive Name for this data product is

- Downwelling Spectral Irradiance

2.2.2 Data Product Abstract (for Metadata)

SPECTIR is the spectral irradiance calculated from measurements made by silicon photodiodes. There are 7 specific wavebands measured, nominally 10 or 20 nm in width, that are defined by the selection of specific interference filters when the instrument is purchased. The measurements are cosine corrected to provide an integrated measurement over all angles of the hemisphere above the sensor.

2.2.3 Computation Name

Not required for data product algorithms.

2.2.4 Computation Abstract (for Metadata)

SPECTIR is the spectral irradiance measured for specific wavebands at any given time. The irradiance within each specified waveband is calculated using vendor-supplied calibration coefficients that transform instrument voltage to scientific units.

2.2.5 Instrument-Specific Metadata

There are no instrument-specific metadata that need to be added for the other the specific instrument calibration files provided during annual servicing of the sensors. The instrument serial number and calibration coefficients are provided in the data header.

2.2.6 Synonyms

Synonyms for this data product are

- Spectral Irradiance
- Spectral Downwelling Irradiance (as the sensors will be facing the sea surface they provide measurements of the downward flux of light)
- E_d

2.2.7 Similar Data Products

Similar data products that SPECTIR may be confused with:

- Radiance (light intensity per solid angle as a function of view direction)
- Scalar irradiance (light intensity integrated over a hemisphere, but not cosine corrected)
- Diffuse Attenuation (the rate of change in irradiance as a function of path length)
- K_d

2.3 Instruments

The primary instrument (SPKIR) is the Satlantic OCR-507 which is a silicon diode radiometer outfitted with a series of interference filters to provide measurements at 7 user defined specific wavebands. The bandwidth of the specific wavebands varies with wavelength but nominally are 10 or 20 nm, however the measurements are usually reported as the spectral irradiance measurement for the center of the bandwidth. There are 22 SPKIR instruments that will be deployed throughout the OOI construction, with sensors integrated into the Pioneer, Endurance, Regional and Global arrays. They are deployed at fixed depths (near-surface, mid-water column and sea floor) and on moored profilers.

SPECTIR is an L1 product. Data are derived from the sensor and the manufacturer supplied calibration coefficients. The instrument also typically provides a sensor-specific dark current correction that may be applied to the data. For the OCR, this is based on the calibration files. Additionally, data for applying a dark current correction may be collected by shuttering the collector or by collecting data under very low light conditions, e.g., very deep within the water column or at night with a new moon. Calibration procedures are available through the vendor (Satlantic Inc, 2007).

2.4 Literature and Reference Documents

General sensor information available from the vendor can be found at the following link:

<http://www.satlantic.com/ocr500>

The Technical Report from which the information in Section 4 came can be found stored on Alfresco under REFERENCE>Data Product Specification Artifacts (1341-00730_SPECTIR) as SPECTIR_OCR-50_Data_Format.pdf.

General references:

Radiometry Theory and measurement considerations

Mueller J. L., Morel A., Frouin R., Davis C., Arnone R., Carder K., Lee Z. P., Steward R. G., Hooker S., Mobley C. D., McLean S., Holben B., Miller M., Pietras C., Knobelspiesse K. D., Fargion G. S., Porter J., Voss K. 2003. Ocean Optics Protocols For Satellite Ocean Color Sensor Validation, Revision 4, Volume III: Radiometric Measurements and Data Analysis Protocols. Mueller J. L., Fargion, G. S., McClain C. R. (Eds). NASA/TM-2003-21621/Rev-Vol III

Mobley, C.D. (1994). Light and Water. San Diego, CA: Academic Press.

Some literature using spectral irradiance data:

Zibordi, G.; Berthon, J.F.; Melin, F.; & Alimonte, D.D. (2010) Cross-site consistent in situ measurements for satellite ocean color applications: The BiOMaP radiometric dataset. *Remote Sensing of Environment*. doi:10.1016/j.rse.2011.04.013

Kowalczuk, P, Durako, M.J., Cooper, W.J., Wells, D, Souza, J.J. (2006) Comparison of radiometric quantities measured in water, above water and derived from seaWiFS imagery in the South Atlantic Bight, North Carolina, USA. *Continental Shelf Research* 26: 2433-53.

Bergmann, T, Fahnenstiel, G, Lohrenz, S, Millie, D, Schofield, O. (2004) Impacts of recurrent resuspension event and variable phytoplankton community composition on remote sensing reflectance. *Journal of Geophysical Research* doi:109: C10S15, DOI: 10.1029/2002JC001575.

O'Reilly, J.E., Maritorena, S., Mitchell, B.G., Siegel, D.A., Carder, K.L., Garver, S.A., Kahru, M., and McClain, C. (1998). Ocean color chlorophyll algorithms for SeaWiFS, *Journal of Geophysical Research* 103, 24,937-24,953.

Morel, A. (1991). Light and marine photosynthesis: a spectral model with geochemical and climatological implications. *Progress in Oceanography* 26, 263-306.

Gordon, H.R. (1987). Bio-optical model describing the distribution of irradiance at the sea surface resulting from a point source embedded in the ocean. *Applied Optics* 26, 4133-4148.

2.5 Terminology

2.5.1 Definitions

The following terms are defined here for use throughout this document. Definitions of general OOI terminology are contained in the Level 2 Reference Module in the OOI requirements database maintained on a Dynamic Object Oriented Requirements System tool (DOORS).

Spectral Irradiance (E_d): The rate of light energy per unit area incident on a surface per unit of time. The units for spectral irradiance are $\mu\text{W cm}^{-2} \text{ nm}^{-1}$. Since irradiance is a function of λ , the descriptor is typically appended to the term only when spectral dependency is referenced, e.g., $E_d(\lambda)$.

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 (DOORS).

2.5.3 Variables and Symbols

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

E_d Spectral downwelling irradiance SPECTIR ($\mu\text{W cm}^{-2} \text{ nm}^{-1}$)

E_o Spectral scalar irradiance ($\mu\text{W cm}^{-2} \text{ nm}^{-1}$)

L Radiance ($\mu\text{W cm}^{-2} \text{ nm}^{-1} \text{ sr}^{-1}$)

T Internal instrument temperature ($^{\circ}\text{C}$)

q energy of a photon (J)

- h Planck's constant (6.626×10^{-34} J s)
- c speed of light, (2.998×10^8 m s⁻¹)
- λ Wavelength (nanometers, nm)
- Φ azimuthal angle (degrees)
- θ zenith angle; the angle between light propagation direction and vertical (degrees)

3 Theory

3.1 Description

Downwelling spectral “vector” irradiance $E_d(\lambda)$ is a measure of the integrated intensity of downwelling light as a function of wavelength weighted by the cosine of its propagation direction relative to vertical (zenith angle). Thus, while it is a measure of the quantity of light illuminating a surface of unit area, it is sensitive to instrument orientation relative to the light field as well as the distribution of light within the light field (Figure 1). In oceanography, irradiance sensors are typically oriented horizontally and facing the surface, i.e., measuring downwelling irradiance, or horizontally and facing away from the surface, thus measuring upwelling irradiance. All OOI SPECTIR instruments will measure downwelling irradiance, hence the subscript “d”.

Another quantity of irradiance often measured in oceanographic studies is scalar irradiance, $E_o(\lambda)$, where the measured light is not weighted according to zenith angle. Thus, it represents a measure of the total photon flux passing through a point in space. Like the vector counterpart, scalar irradiance sensors may be configured to measure only one hemisphere or, unlike the vector quantity, may integrate over the entire 4π steradians of directions surrounding a point. While scalar irradiance sensors are readily available, these sensors are not currently part of the OOI core suite of sensors and this document does not apply to them.

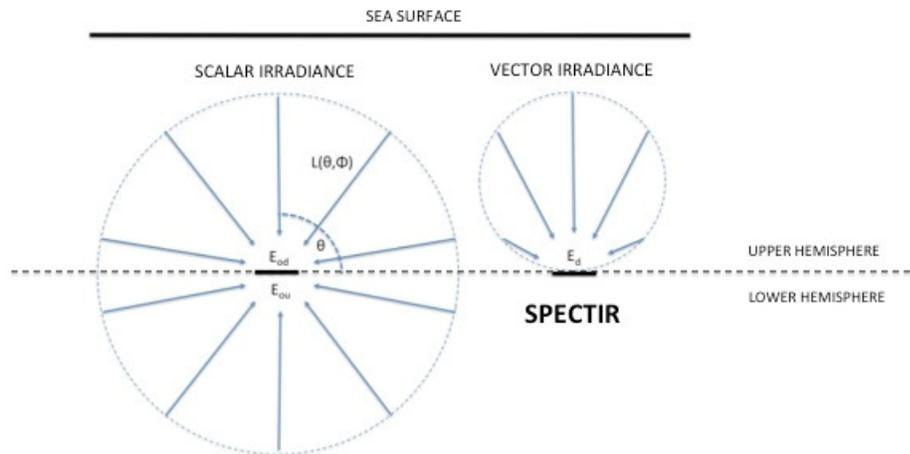


Figure 1. The different types of measurements made by radiometers. The bold horizontal lines specify the respective detector surfaces. The circles represent the light fields sensed by the respective detectors.

Spectral irradiance is a critical measurement for defining important ocean processes, such as the radiant heating rate, and sets the energy available to drive a range of biological and chemical processes in the ocean. The vertical profiles of irradiance are also used to study light-dependent processes as a function of depth and the rate of change in light intensity with depth is parameterized as the diffuse attenuation coefficient, K_d (m⁻¹).

3.2 Theory

The energy in a beam of light can be measured in units of joules ($J = 1 \text{ kg m}^2 \text{ s}^{-2}$), or power units of watts ($W = 1 \text{ J s}^{-1}$). Alternatively, we could speak of light as individual packets called photons or quanta. An einstein is equal to one mole of photons ($1 \text{ Einst} = 6.023 \times 10^{23}$ photons; a more recently accepted nomenclature is $1 \text{ mol quanta} = 1 \text{ Einst}$). These properties of light are related by the wavelength, the speed of light, and Planck's constant:

$$q = hc/\lambda \quad (1)$$

where q is equal to the energy of a photon; h is Planck's constant = $6.626 \times 10^{-34} \text{ J s}$; c is the speed of light = $2.998 \times 10^8 \text{ m s}^{-1}$; and λ is the wavelength (in meters; note that c is given in m s^{-1} ; usage of this formula requires that wavelength and speed of light have the correct units.) of interest.

Radiance L is operationally defined as:

$$L = \frac{\Delta Q}{\Delta t \Delta A \Delta \Omega \Delta \lambda} \quad (2)$$

and states that radiance is the amount of light energy ΔQ , received in a time interval Δt , by a detector of area ΔA , which is viewing a solid angle $\Delta \Omega$, and whose wavelength filter passes a wavelength band of size $\Delta \lambda$. The measurement of a solid angle is given in steradians (sr) and refers to the equivalent surface area of a sphere of unit radius subtended by a set of radii from the sphere's center. Purely vertical downwelling light has a propagation direction (zenith angle) θ of 0° . As the propagation direction moves off vertical, the zenith angle changes in a positive direction, such that when horizontal the zenith angle would be 90° . The result of the integration of the energy of all downward-traveling photons over cosine-weighted zenith angles from 0 to 90 degrees and all azimuthal angles is called downwelling irradiance, E_d .

The origin of the cosine factor arises because the sensitivity of the flat detector is dependent on the zenith angle θ . Consider a uniform collimated beam of light looking straight down onto a circular detector (zenith angle, θ , of 0 degrees) whose beam exactly fits onto the detector. Now consider the same beam propagating at a $\theta=45^\circ$ angle to the detector. In the plane of the detector the beam will be spread out into an oval, and the detector will see only a fraction of the total light, proportional to $\cos\theta$.

3.3 Known Theoretical Limitations

The spectral irradiance is a function of the geometric light field. Therefore most of the practical considerations for measurements are focused on avoiding the shading of the sensor detectors, and thus an artificial change in the observed radiance distribution. Clearly, the measurements can only be done in daylight hours.

3.4 Revision History

No revisions to date.

4 Implementation

4.1 Overview

The spectral irradiance algorithm is a multi-step process: 1) read raw, uncorrected signal and reference light levels delivered from the OCR-507 instrument. 2) Apply calibration constants. While the vendor does supply stand-alone software for processing OCR data, the procedures within this document assume that each step will be coded into the cyberinfrastructure and that vendor-supplied applications will not be used.

4.2 Inputs

- Inputs to the Algorithm are L0 data packets from SPKIR sensor containing reference and raw downwelling irradiance measurements and internal instrument temperature measurements. All Satlantic sensors provide the data in a fixed length binary format (the format is described in the Satlantic RD1 reference folder (RD1. OCR-507 Operation Manual, Satlantic LP, SAT-DN-0027, Rev E 2011-12-30).

An example of a data packet is provided below:

Offset (h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..Š.€.í€€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€.Š@€.–@.ÿ}@.€
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.c€...

Below is a sample calibration file. Note that a “#” character at the beginning of a line indicates that the line is a comment and can be ignored by any processing software.

```

# Satlantic model # OCR-507 ICSW s/n 0225 SATNET
# [customer] / [project number] / with Bioshutter
#####
#####
###
# Calibration History
# Date      |Operator |SW Version |Rev |Type |Light Data  |Dark Data  |
Lamp      |Target   |Immersion Param |Distance | Comments
#-----
-----
# 2012-04-11 |Jenn    |1.7.2_1   |A   |ED   |DI7225fa2-0225_2012-04-11_13-39-
59_raw |DI7225da2-0225_2012-04-11_13-36-30_raw |F985      |
March 2003   |50.0     | Initial Calibration

INSTRUMENT SATDI7 '' 6 AS 0 NONE
SN 0225 '' 4 AS 0 NONE

# Time since commencement of normal operation
TIMER NONE 'sec' 10 AF 0 COUNT

# Sample Delay
DELAY SAMPLE 'ms' 2 BS 0 COUNT

# Wavelength Data

ED 412.50 'uW/cm^2/nm' 4 BU 1 OPTIC2
2148377867.8    2.09023117662e-007    1.368
    
```

```

ED 443.80 'uW/cm^2/nm' 4 BU 1 OPTIC2
2148218092.4    2.06543624674e-007    1.410

ED 489.70 'uW/cm^2/nm' 4 BU 1 OPTIC2
2147607229.7    2.12484770952e-007    1.365

ED 510.00 'uW/cm^2/nm' 4 BU 1 OPTIC2
2147789959.1    2.07241106309e-007    1.354

ED 555.40 'uW/cm^2/nm' 4 BU 1 OPTIC2
2148047456.7    1.99358530187e-007    1.372

ED 670.10 'uW/cm^2/nm' 4 BU 1 OPTIC2
2147335412.8    2.06033896796e-007    1.404

ED 682.80 'uW/cm^2/nm' 4 BU 1 OPTIC2
2146998228.4    2.14806273478e-007    1.347

# In-head ancillary measurements
VS NONE 'Volts' 2 BU 1 POLYU
0 0.03

VA NONE 'Volts' 2 BU 1 POLYU
0 0.03

TEMP PCB 'Celsius' 2 BU 1 POLYU
-50.0 0.5

# Frame Counter (Data Integrity)
FRAME COUNTER '' 1 BU 0 COUNT

# Check Sum (Data Integrity)
CHECK SUM '' 1 BU 0 COUNT

# Frame Terminator
CRLF TERMINATOR '' 2 BU 0 NONE
    
```

A breakdown of the files is provided below:

INSTRUMENT FIELD: The instrument field indicates that the frame begins with the 6-character SATD17 ASCII string. This is shown below for the example provided above.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A				

The SERIAL NUMBER field indicates that the next 4 bytes in the data are in the instrument serial number in ASCII string format, in the case above it is 0225. This is highlighted in the figure below.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..Š.€.í€€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€.Š@€.-@.ý}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.€€...

The TIMER field displays the time operation began in seconds with 0.01 s resolution, as zero-padded 10-byte ASCII floating point number. This is highlighted below for the example provided.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..Š.€.í€€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€.Š@€.-@.ý}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.€€...

The value used in the TIMER field is created when ADCs are ready to read out. However, the delta-sigma ADCs have a finite conversion time. For the OCR-507, the DELAY field contains the nominal conversion time for the ADC, multiplied by -1, in the binary signed format. For the OCR-507, this is 133 ms. Below highlights SAMPLE DELAY field in the sample data frame. Note the hexadecimal value for this field is 0xFF7B, which is Satlantic binary signed notation is -133 ms.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..Š.€.í€€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€.Š@€.-@.ý}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.€€...

The optical channel fields contain the raw 32-bit ADC counts. However, the calibration coefficients must be applied to this data to yield the desired output. The calibration file provides the first coefficients and describes how to apply them to the data. The first line is the sensor definition (for the example above) and consists of:

The TYPE field, ED, indicates that this is a downwelling irradiance sensor.

The ID field, in the case above is the wavelength 412.50 (in nanometers), indicates the center wavelength for the optical measurement.

The UNITS are uW/cm^2/nm.

The FIELD LENGTH is 4 bytes.

The DATA-TYPE is BU (binary unsigned).

The number of lines with calibration coefficients immediately following the current sensor definition line is 1.

The FIT-TYPE indicating the type of processing needed to convert the field value to physical units is OPTICS2. The second line is the calibration line, formatted for OPTICS- fit-type. The coefficients are a0, a1, and lm, where a0 is the offset (dark) value, a1 is the scale factor, and lm is the immersion coefficient. The lm should be set to 1.0 if the sensor is not immersed. The coefficients are applied as:

$$Y = lm * a1 * (x-a0)$$

where x is the raw ADC counts and y is the calibrated output. For the example above, the hexadecimal value for this field is 0x800D8A00, which as a binary unsigned integer is 2148370944 ADC counts is highlighted below.

Offset (h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..Š.€..í€€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€..Š@€€.-@.ÿ}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.ø€...

Applying the calibration coefficients from the calibration file (an example of the calibration file is provided above):

Applying the calibration coefficients from the calibration file:

$$Y = 1.368 * 2.09023117662e-007 * (2148370944 - 2148377867.8) = -0.00198 \text{ uW/cm}^2/\text{nm}$$

Note that this value is slightly negative, indicating that the optical channel was not observing light at the time of the measurement, and was a measurement of noise.

After the ED 412.50, each of the next 6 subsequent grouping of 4 bytes contain the ED 443.80, ED 489.70, ED 510.00, ED 670.10, and ED 682.80 nm optical numbers. It should be noted that these wavelengths can be changed by the customer.

The Vin SENSE field is described in the calibration file by the following two lines:

VS NONE 'Volts' 2 BU 1 POLYU

0 0.03

The TYPE field, VS, is meant to indicate that this is a measurement of the “supply voltage”.

The ID field is set to NONE

The UNITS are Volts.

The FIELD-LENGTH is 2 bytes.

The DATA-TYPE is BU (binary unsigned)

The number of lines with calibration coefficients immediately following the current sensor definition line is 1.

The FIT-TYPE, indicating the type of special processing needed to convert the field value to physical units is POLYU.

The second line is the calibration line, formatted for the POLYU fit-type with the coefficients a0 and a1. These coefficients are applied as follows:

$$Y = a0 * x^0 + a1 * x^1$$

Where x is the raw ADC counts, and y is the calibrated output. Below the VS field is highlight in the data frame. The hexadecimal value for this field is 0X0120 which as a binary unsigned value is interpreted as 288 counts.

Offset (h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..Š.€..í€€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€..Š@€€.-@.ÿ}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.ø€...

Note that this measurement is nominally 8.8 V over an external supply voltage range of about 9.1 – 22 V. Below about 9.1 V, measurement roughly tracks the external supply voltage with a -0.25 V offset. This is applied to the calibration file

$$y = 0 \cdot 288^0 + 0.03 \cdot 288^1 = 8.64 \text{ V}$$

The Va SENSE field is described in the calibration file by the following two lines:

VA NONE 'Volts' 2 BU 1 POLYU

0 0.03

The TYPE field, VA, is meant to indicate that this is a measurement of the “analog voltage”/

The ID field is set to NONE.

The UNITS are Volts.

The FIELD-LENGTH is 2 bytes

The DATA-TYPE is BU (binary unsigned).

The number of lines with calibration coefficients immediately following the current sensor definition line is 1.

As above the FIT-TYPE is the POLYU function with the coefficients a0 and a1. These coefficients are applied as follows:

$$y = a0 \cdot x^0 + a1 \cdot x^1$$

where x is the raw ADC counts, and y is the calibrated output. Note that this measurement is nominally 5.0 V. The hexadecimal value for this field here is 0x00B1, which as a binary unsigned value is 177 counts. The VA field from the data sample (above) is shown below.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{€..š.€..í€.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:€€..š@€.-@.ý)@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.€€...

Applying the coefficients from the calibration file:

$$y = 0 \cdot 177 + 0.03 \cdot 177^1 = 5.31 \text{ V}$$

The INT. TEMP. (internal temperature) field is described in the calibration file by the following two lines:

TEMP PCB 'Celsius' 2 BU 1 POLU

-50.0 0

The TYPE field, TEMP, is meant to indicate that this is a temperature

The ID field is set to PCB, indicating that this measurement is on a printed circuit board.

The UNITS are Celsius.

The FIELD-LENGTH is 2 bytes

The DATA-TYPE is BU (binary unsigned).

The number of lines with calibration coefficients immediately following the current sensor definition line is 1.

As above the FIT-TYPE is the POLYU function with the coefficients a0 and a1. These coefficients are applied as follows:

$$y = a0 \cdot x^0 + a1 \cdot x^1$$

where x is the raw ADC counts, and y is the calibrated output.

Below is the TEMP PCB field in the sample data frame. Here the hexadecimal value for the field is 0x00A2, which as a binary unsigned number is 162 counts.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{e.š.e.íee.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:ee.š@e.-@.ý}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.e€...

Applying the coefficients from the calibration file:

$$y = -50.0 \cdot 162^0 + 0.5 \cdot 162^1 = 31C$$

The FRAME Counter field is denoted as

Frame Counter (Data Integrity) FRAME COUNTER ‘ ‘ 1 BU 0 COUNT

The FRAME COUNTER field is a single byte that increments by 1 for each frame sent by the OCR-507, starting at 0 and rolling over at 255. This field can be used for data integrity checks. The FRAME COUNTER field is illustrated in the field below. Here the hexadecimal value is 0x80, which as a binary unsigned number is 128.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{e.š.e.íee.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:ee.š@e.-@.ý}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.e€...

The CHECK SUM field is denoted by:

Check Sum (Data Integrity)
CHECK SUM ‘ ‘ 1 BU 0 COUNT

The CHECK SUM field is a single byte that causes the sum of all bytes in the frame up to and including the CHECK SUM field to be 0. It is highlighted in the data frame below, and is in the 0x0F frame here. In the sample frame the sum of all the bytes up to the CHECK SUM field is 0xF1 (only the least significant byte is added); adding the CHECK SUM byte (0x)F sums to 0x00 (0xF1 + 0x0F = 0x00). This field is used for data integrity checks.

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33	SATDI70225000023
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02	2.77ÿ{e.š.e.íee.
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8	:ee.š@e.-@.ý}@.ø
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A					ÓÀ. .±.e€...

The terminator field is denoted by:

Frame Terminator
CRLF TERMINATOR ‘ ‘ 2 BU 0 NONE

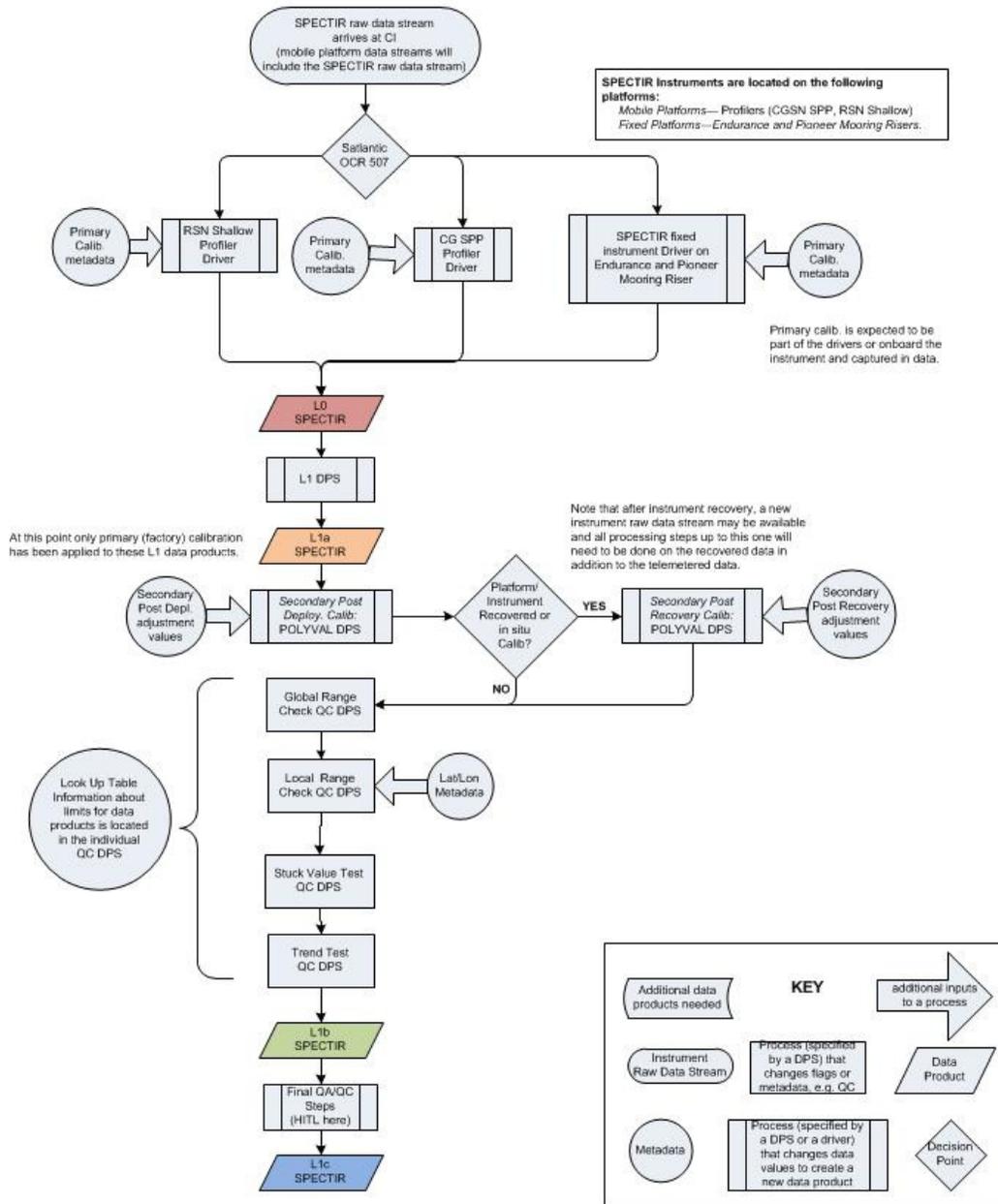
The TERMINATOR field is simply a carriage return and line feed pair (0X0D and 0X0A respectively), indicating the end of the data frame. The TERMINATOR field of the sample frame is provided below.

Offset (h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00000000	53	41	54	44	49	37	30	32	32	35	30	30	30	30	32	33
00000010	32	2E	37	37	FF	7B	80	0D	8A	00	80	0A	CE	80	80	02
00000020	3A	80	80	04	8A	40	80	08	97	40	7F	FD	7D	40	7F	F8
00000030	D3	C0	01	20	00	B1	00	A2	80	0F	0D	0A				

4.3 Processing Flow

The processing flow for the SPKIR is comprised of two steps; 1) unpack the binary data records and 2) convert raw beam intensities to scientific values with instrument temperature correction applied.

Data Processing Flow for SPECTIR L0 and L1 Data Products from SPKIR Instrument



4.4 Outputs

The file outputs should provide the physical units. The Ed measurements will be provided in $\mu\text{W}/\text{cm}^2/\text{nm}$ for each of the wavebands that are included on the OOI sensors. These physical measurements shall be complemented with associated metadata. The metadata shall include the sensor serial number, platform it is mounted upon, depth, and time of day. The data of last calibration, link to the sensor's latest calibration file. The metadata should provide the precision for the sensor. Based on visual inspection by Qc inspection by OOI Project Scientists, data should be flagged for instrument drift and biofouling should be flagged.

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.

4.6 Computational Requirements

There are no large computational requirements for this sensor.

4.7 Code Verification and Test Data Set

Appendix A Example Code and Test Data Set

No Example Code.

The fabricated dataset used in the unit tests of the coded DPA can be found stored on Alfresco under REFERENCE>Data Product Specification Artifacts (1341-00730_SPECTIR) as SPKIR_SPECTIR_unit_test.xlsx.

Appendix B Output Accuracy

The following requirements in the DOORS database (Version_2.29_(NSF-CCB-2012-07-03)) describe downwelling spectral irradiance accuracy and precision requirements.

Downwelling spectral irradiance shall be measured with an accuracy of $\pm 5\%$. <L2-SR-RQ-3527>
>. For this sensor the precision is 3% based on the cumulative error budget for our calibration facility.

Downwelling spectral irradiance shall be measured with a precision of 0.01 micro mol photons $m^{-2} s^{-1}$. <L2-SR-RQ-3781>. For this sensor the precision will vary $0.25 \mu W cm^{-2} nm^{-1}$, which is below the project precision requirements per channel.

Appendix C Sensor Calibration Effects

<None>