



# DATA PRODUCT SPECIFICATION FOR OPTICAL ABSORPTION COEFFICIENT

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Consortium for Ocean Leadership  
1201 New York Ave NW, 4<sup>th</sup> Floor, Washington DC 20005  
[www.OceanLeadership.org](http://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:

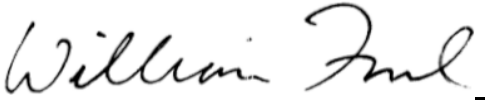


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Date: 27 Feb 2012

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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## 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 optical absorption coefficients as a function of wavelength (OPTABSN) using data collected with a WET Labs ac-s spectral absorption and attenuation meter. The procedures for reading raw data from the instrument, converting from raw signal to data with units  $\text{m}^{-1}$  and correcting for environmental factors are covered in detail within the vendor-supplied users manual (Revision J, February 9, 2009a) and a companion document, *ac-s Protocol Document* (Revision P, December 2009b). Example processing code is also presented in the protocol document.

OPTABSN is the optical absorption coefficient resulting from the combined effects of all water impurities;  $a_{pd}(\lambda)$  [ $\text{m}^{-1}$ ], where  $\lambda$  denotes wavelength (nm) within the approximate spectral range from 400 to 750 nanometers (nm). Impurities include all particulate and dissolved matter of optical importance. OPTABSN is the difference between the total absorption of the water mixture ( $a$ ) and that of pure seawater ( $a_w$ );  $a_{pd} = a - a_w$ .

OPTABSN is a L2 product since it requires independent measures of ambient water temperature and salinity in order to correct for these effects on the absorption of seawater as well as optical beam attenuation in order to correct for light scatter from suspended matter. Corrected data therefore requires coincidental and collocated measurements of OOI data products water temperature (TEMPWAT) and practical salinity (PRACSAL) and ac-s (OPTAA) measurements of optical beam attenuation (OPTATTN).

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](mailto: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

- OPTABSN

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

- Optical Absorption Coefficient (all water impurities only)

#### 2.2.2 Data Product Abstract (for Metadata)

OPTABSN is the absorption coefficient for all water impurities and is computed using data collected with a reflecting tube type ac-s meter and co-located and synchronized observations of ambient water temperature, salinity and optical beam attenuation.

#### 2.2.3 Computation Name

Not required for data product algorithms.

#### 2.2.4 Computation Abstract (for Metadata)

OPTABSN is the absorption coefficient for all water impurities and is computed using vendor-supplied algorithms that transform instrument voltage to scientific unites and corrected for internal instrument temperature and ambient water temperature, salinity and light scatter from particulate matter using community accepted procedures.

#### 2.2.5 Instrument-Specific Metadata

Instrument specific factory calibration data, passed to CI and stored as part of an instrument's metadata, are required to convert the raw absorption reference and signal counts (OPTAREF and OPTASIG) to absorption (a).

#### 2.2.6 Synonyms

There are no synonymous terms.

#### 2.2.7 Similar Data Products

There are no data products that are similar.

### 2.3 Instruments

The primary instrument (OPTAA) is the WET Labs ac-s spectral absorption and attenuation meter . The instrument provides a 75 wavelength output from approximately 400–750 nm with approximately 4 nm steps. Individual filter steps have a full-width half maximum response that range between about 10 to 18 nm. There are a total of 35 OPTAA instruments deployed throughout the initial OOI construction and integrated into the Pioneer, Endurance, Regional and Global arrays. They are deployed at fixed depths (near-surface, mid-water column and sea floor) and installed on moored profilers.

The ac-s performs concurrent measurements of the water attenuation and absorption by incorporating a dual optical path configuration in a single instrument. Each optical path contains separate optics and detectors appropriate to the given measurement. Absorption is derived from a measure of light transmitted through a tube with highly polished sides. This data product specification only addresses the computation of OPTABSN.

OPTABSN is a L2 product in that computation requires the raw signals emanating from a properly calibrated and configured instrument as well as water temperature (TEMPWAT) and practical salinity (PRACAL) derived from a co-located and synchronized CTD. While small corrections for salinity are available at visible wavelengths ( $\lambda < 700$  nm), temperature and salinity corrections are more significant at infrared wavelengths ( $\lambda > 700$  nm) and must be performed on both the absorption and attenuation (OPBATTN) signals. Detailed procedures for correcting ac-s data for temperature and salinity are outlined within a separate protocols document available through the vendor (WET Labs Inc., 2009b).

### 2.4 Literature and Reference Documents

- WET Labs, Inc. 2009a. Spectral Absorption and Attenuation Meter ac-s User's Guide, Rev. J.  
WET Labs, Inc. 2009b. ac Meter Protocol Document, Rev. P.  
W. Scott Pegau, Deric Gray, and J. Ronald V. Zaneveld. 1997. Absorption and attenuation of visible and near-infrared light in water: dependence on temperature and salinity. *Appl. Opt.* 36: 6035-6046.  
Sullivan, J.M., M.S. Twardowski, J.R. V. Zaneveld, C.M. Moore, A.H. Barnard, P.L. Donaghay and B. Rhoades. 2006. The hyperspectral temperature and salt dependencies of absorption by water and heavy water in the 400 - 750 nm spectral range. *Appl. Opt.*, 45:5294-5309.

Mueller, J. L., G. S. Fargion, C. R. McClain, S. Pegau, J. R. V. Zaneveld, B. G. Mitchell, M. Kahru, J. Wieland and M. Stramska. 2003. Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 4, Volume IV: Inherent Optical Properties: Instruments, Characterizations, Field Measurements and Data Analysis Protocols. NASA/TM-2003-211621, Volume IV, Issue May 2002.

## 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 the Dynamic Object Oriented Requirements System tool (DOORS).

**Absorption coefficient (*a*):** The fraction of a light beam transmitted upon traversal of a pathlength *r* which is attenuated only by absorption is given by  $\exp(-ar)$  where *a* is the absorption coefficient. Since absorption is a function of  $\lambda$ , the descriptor is typically appended to the term only when spectral dependency is referenced, e.g.,  $a(\lambda)$ . Subscripts identify the component of the water mixture that absorption refers to, such as pure water ( $a_w$ ) or water particulate and dissolved impurities ( $a_{pd}$ ). This specification describes the derivation and computation of absorption pertaining to all water impurities corrected for water temperature and salinity and particulate scattering effects.

### 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). The following acronyms and abbreviations are defined here for use throughout this document.

ITS-90 International Temperature Scale of 1990

### 2.5.3 Variables and Symbols

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

<i>a</i>	Absorption coefficient of water as associated suspended and dissolved impurities ( $m^{-1}$ )
$a_{pd}$	Absorption coefficient of suspended and dissolved impurities ( $m^{-1}$ )
$a_{pd;ts}$	Absorption for water impurities corrected for temperature and salinity effects ( $m^{-1}$ )
$a_{pd;ts;s}$	Absorption for water impurities corrected for t, s, and light scatter effects ( $m^{-1}$ )
$a_{off}$	Clean water offset value determined during pre-deployment calibration ( $m^{-1}$ )
$a_w$	Absorption coefficient for clear water ( $m^{-1}$ )
<i>b</i>	Scattering coefficient of water and associated impurities ( $m^{-1}$ )
$b_b$	Coefficient for light scattered into the backward direction ( $m^{-1}$ )
$b_f$	Coefficient for light scattered into the forward direction ( $m^{-1}$ )
$\bar{b}_b$	Fraction of scattered light directed into the backward direction
<i>c</i>	Beam attenuation of water and associated impurities ( $m^{-1}$ )
$c_{pd}$	Beam attenuation for all particulate and dissolved water impurities ( $m^{-1}$ )
$c_{pd;ts}$	Beam attenuation for water impurities corrected for temperature and salinity effects ( $m^{-1}$ )
$A_{ref}$	Raw absorption reference data (wavelength-specific, uncalibrated) (counts)
$A_{sig}$	Raw absorption signal data; measured amount of light that reached the a detector (wavelength-specific, uncalibrated) (counts)
$I_o$	Initial light intensity
$I_r$	Light intensity after having propagated a distance <i>r</i>
<i>r</i>	Path length (m)
<i>s</i>	Water salinity (psu)
<i>t</i>	Water temperature ( $^{\circ}C$ )

$t_r$	Reference water temperature recorded during pre-deployment calibration (°C)
$T$	Internal instrument temperature (°C)
$\lambda$	Wavelength (nm)
$\lambda_{ref}$	Reference wavelength (nm)
$\Delta_T$	Correction for internal instrument temperature from vendor-supplied table ( $m^{-1}$ )
$\Psi_T$	Correction constant for water temperature
$\Psi_{sa}$	Absorption correction constant for water salinity

### 3 Theory

#### 3.1 Description

Absorption,  $a(\lambda)$ , is a fundamental inherent optical property of water and defined as the rate that the intensity of a beam of light will decrease in response to the absorption (removal) of light energy as a function of propagation distance. The reflecting tube approach to measuring absorption is designed to measure as much of the transmitted light as possible, including light scattered by water and suspended particles (Figure 1). Since most of the light scattered by particles is in the forward direction,  $b_f$ , any observed decrease in light intensity is attributed primarily to absorption. However, the design does not measure a small portion of light scattered into the backward direction,  $b_b$ . Unless corrected for, this lost energy will be interpreted as absorption, thus yielding an overestimation of absorption.

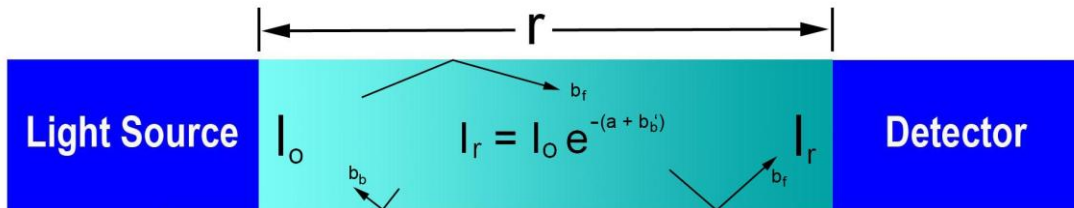


Figure 1. Diagram showing a reflecting tube absorption meter design.

#### 3.2 Mathematical Theory

The absorption coefficient,  $a(\lambda) m^{-1}$ , expresses the rate of decrease in the intensity of a light beam as it propagates through a volume of water as a result of light energy removal and subsequent conversion to another form of energy (e.g., heat and chemical bonds). The rate of intensity decrease is a function of the absorption properties of pure water and the properties and concentration of particulate and dissolved matter;

$$I_r = I_0 e^{-(a)r}$$

Rearrangement of this equation yields a simple expression for absorption:

$$a = -\ln \left[ \frac{I_r}{I_0} \right] / r$$

where  $I_0$  is the reference beam intensity, and  $I_r$  is the beam intensity after having propagated through a water path of length  $r$ .

In order to measure a directly, it is necessary to account for all of the light transmitted into the interrogation compartment of the ac-s meter, including light scattered out of the original beam by



water and any particles suspended within the sample. The instrument is designed to accomplish this with highly polished sides of the absorption tube that directs as much of the light scatter into the forward detector as possible. Since most light scatter from marine particles is in the near-forward direction, this method accounts for most of the scattered light. However, a small portion of light scattered into the backward direction,  $b_b$ , is not detected. Thus, the measured light decrease is a combination of light absorption and backscatter:

$$a + b_b = -\ln \left[ I_r / I_o \right] / r$$

This is accomplished by parameterizing  $b_b(\lambda)$  as a function of beam attenuation,  $c(\lambda_{ref})$ , and the measured absorption signal,  $a_m(\lambda_{ref})$ , at a reference wavelength where absorption due to water impurities is assumed to be negligible and subtracting the result from the measured absorption signal. (Note: the term  $b_b$  used in this document is not the true definition of backscatter, but simply that portion of light scatter not detected by the ac-s instrument, most of which is scattered into the backwards direction.)

The following governing equation applies to raw data emanating from the ac-s (see discussion of equation 8 in user's manual):

$$a_{pd} = \left( a_{off} - r^{-1} \left[ \ln \left( \frac{A_{sig}}{A_{ref}} \right) \right] \right) - \Delta_T$$

where  $a_{pd}$  is the wavelength-specific absorption coefficient ( $m^{-1}$ ) for water impurities (particulate and dissolved),  $a_{off}$  is the wavelength-specific water offset provided by the vendor for each instrument,  $r$  is the instrument path length (0.25 m) and  $A_{sig}$  and  $A_{ref}$  are wavelength-specific signal and reference light intensity, respectively. The final term on the right side,  $\Delta_T$ , is a correction factor for the internal instrument temperature based on vendor-supplied, instrument-specific calibration table (see discussion regarding equation 7 in user's manual);

$$\Delta_T = \Delta_{T1} + \frac{(T - T_1)}{(T_2 - T_1)} \times (\Delta_{T2} - \Delta_{T1})$$

where  $T$  is the internal instrument temperature at the time of data collection,  $T_1$  and  $T_2$  are the two bracketing temperature bins within the calibration table or device file (\*.dev) and  $\Delta_{T1}$  and  $\Delta_{T2}$  are the respective correction values.

After correcting for internal instrument temperature,  $a_{pd}$  must next be corrected for effects of water temperature and salinity. The temperature and salinity corrections discussed here are different than the instrument temperature correction. These corrections relate to physical changes in the absorption properties of clear water,  $a_w$ , due to changing dissolved salt content and temperature. These corrections are quite small in the visible portion of the spectrum ( $\lambda$  between 400 nm and 700 nm) but can be significant within the near infrared portion of the spectrum ( $\lambda > 700$  nm). The temperature and salinity corrected beam attenuation,  $a_{pd:ts}$ , is computed as:

$$a_{pd:ts} = a_{pd} - (\Psi_t * (t - t_r) + \Psi_{sa} * s)$$

where  $\Psi_t$  and  $\Psi_{sa}$  are corrections constants for water temperature ( $t$ ) and salinity ( $s$ ), respectively, and  $t_r$  is the reference water temperature recorded at the time of pre-deployment instrument calibration. Values for  $\Psi_t$  and  $\Psi_{sa}$  are presented in Appendix A. Intermediate values must be interpolated:

$$\Psi_t = \Psi_{t1} + \frac{(\lambda - \lambda_1)}{(\lambda_2 - \lambda_1)} \times (\Psi_{t2} - \Psi_{t1})$$

$$\Psi_{sa} = \Psi_{sa1} + \frac{(\lambda - \lambda_1)}{(\lambda_2 - \lambda_1)} \times (\Psi_{sa2} - \Psi_{sa1})$$

where subscripts 1 and 2 refer to the two bracketing wavelengths and associated temperature and salinity correction factors.

Finally, the measured signal must be corrected for light scatter not measured by the instrument. The method to be used assumes a reference wavelength where absorption due to all water impurities is negligible. Thus, any measured signal at that wavelength is due solely to undetected light scatter. Given the assumption of a stable volume scattering function, the fraction of light scattered in the backward direction,  $\widetilde{b}_b$ , at the reference wavelength and thus not detected is for all wavelengths is:

$$\widetilde{b}_b = \frac{a_{pd;ts}(\lambda_{ref})}{c_{pd;ts}(\lambda_{ref}) - a_{pd;ts}(\lambda_{ref})}$$

Thus, the amount of light scatter not detected by the ac-s instrument at any wavelength is simply the product of  $\widetilde{b}_b$  and the difference between the corrected  $c_{pd;ts}$  (OPTATTN) and  $a_{pd;ts}$  at that wavelength:

$$a_{pd;ts;s}(\lambda) = a_{pd;ts}(\lambda) - \widetilde{b}_b [c_{pd;ts}(\lambda) - a_{pd;ts}(\lambda)]$$

The reference wavelength is roughly 715 nm. While the ac-s may not measure beam attenuation and absorption centered directly on 715 nm, the values representing the closest wavelengths will suffice since the spectral difference should be no more than +/- 2 nm.

### 3.3 Known Theoretical Limitations

Absorption is a bulk optical measure and, therefore, is the result of the combined effects of a water volume and associated impurities. Therefore, the accuracy of  $a$  is dependent upon assumptions regarding the homogeneity and distribution of impurities within the sample volume. No attempt is made to correct for these effects.

There is a degree of uncertainty regarding the adjustment of the measured signal to account for backscatter. Over the years, several approaches have been proposed with various assumptions, measurement requirements and associated uncertainties (see Wet Labs Inc., 2009b). All assume that the shape of the volume scattering function for the population of particles is stable with respect to wavelength.

The prescribed approach is based on the best available knowledge and community standards. The OOI will consider future approaches as they become available.

### 3.4 Revision History

Revisions to test data as a result of correcting mathematical equations.

## 4 Implementation

### 4.1 Overview

The absorption algorithm is a multi-step process: 1) adjust raw, uncorrected signal for changes in internal instrument temperature, 2) apply a pre-deployment instrument calibration referenced to clean water, 3) correct the initial attenuation values for ambient water temperature and salinity, and 4) apply a light scatter correction (see processing flow diagram, Figure 2, Section 4.3). While

the vendor does supply stand-alone software for processing ac-s 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. Since absorption due to clear water is subtracted from the signal, the resulting absorption is due to all water impurities (particulate and dissolved matter);  $a_{pd}(\lambda)$ . Example code may be found in WET Labs ac-s *Protocol Document* (Revision P, December 2009).

#### 4.2 Inputs

- Data packets from OPTAA sensor containing reference (OPTAREF) and signal (OPTASIG) absorption and internal instrument temperature (OPTTEMP) measurements
- Co-located, synchronized measurements of water temperature (TEMPWAT) and salinity (PRACSAL).
- Simultaneously measured spectral beam attenuation from the OPTAA sensor (OPTATTN)

#### 4.3 Processing Flow

After receiving and parsing the raw data files as described in the ac-s user’s manual (Revision J, 2009), the data processing flow for the OPTABSN is comprised of 4 steps (Figure 2); 1) adjust raw, uncorrected signal for changes in internal instrument temperature, 2) apply a pre-deployment instrument calibration referenced to clean water, 3) correct the initial absorption values for ambient water temperature and salinity using observations from a co-located CTD, and 4) apply a light scatter correction using simultaneous measurements of beam attenuation.

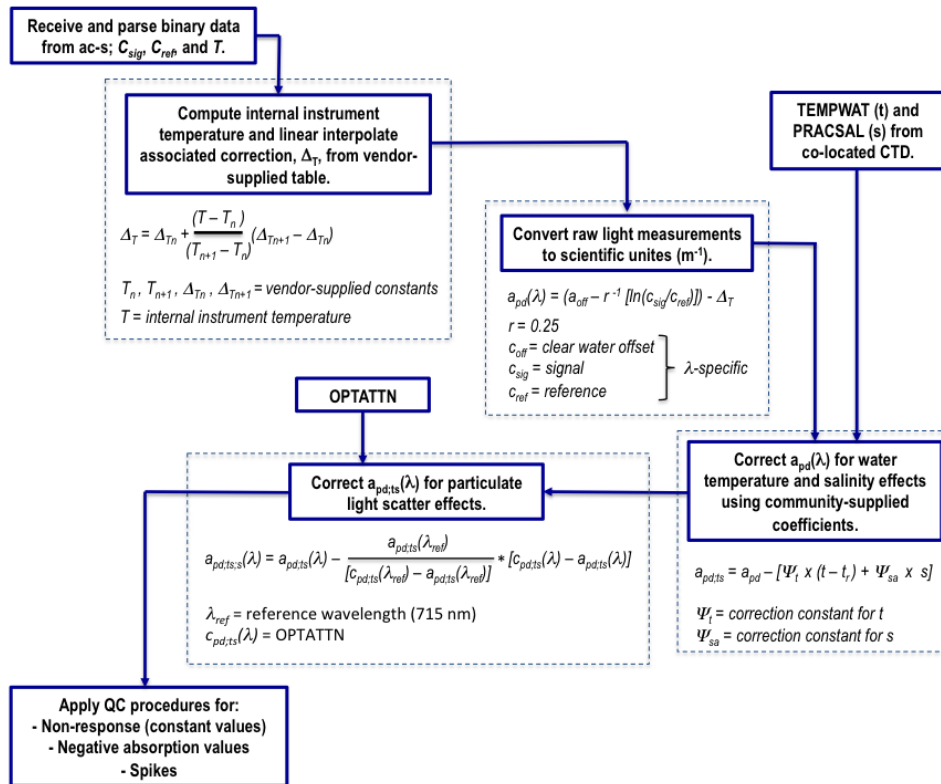


Figure 2. Data processing flow for OPTABSN.

#### 4.4 Outputs

The output of the OPTABSN algorithm is optical absorption coefficient representing the combination all water impurities. The units are inverse meter, expressed as a double precision floating point number. To obtain total absorption of the water mixture, the user would need to add the constant absorption value for clear water at the wavelength of interest (e.g., see Mueller et al., 2003). This calculation is not a part of the product computation. OPTABSN only refers to the component of absorption pertaining to water impurities.

#### 4.5 Code Verification and Test Data Sets

A test data set below (Table 1a, 1b, and 1c) provides a few data points over the expected range of absorption values;  $a_{pd;ts} = .01 - 10$  assuming a 0.25 m path length instrument. The offset for pre-deployment, clear-water calibration is constant and the correction based on internal instrument temperature is allowed to vary over a reasonable range. These data are only presented as an example for testing the coded algorithms. Each instrument will have a separate device file containing clear water offsets and internal instrument temperature correction coefficients. However, corrections for ambient temperature and salinity (Appendix A) apply to all data streams after correcting for internal temperature and clear water offset.

Note that these Tables are useful for checking simplified OPTAA data product calculations but that in reality there will be on the order of 80 'a' wavelengths and on the order 35 internal temperature bin values for each of these wavelengths. Also, there will be one internal temperature measurement for each OPTAA data packet (suite of wavelengths and counts for each wavelength channel). In addition, there will be one temperature and one salinity value used for each data packet suite of measurements to correct the absorption values for the variation of the absorption of seawater as a function of temperature and salinity.

Note also that the test values for the T,S-corrected absorption and beam attenuation values are unphysical: because  $c=a+b$ , where  $b$  is the scattering coefficient, absorption can never be greater than beam attenuation. The test values result in unphysically negative values for the scatter correction coefficient, which must be trapped out of the calculation.

For realistic OPTAA datasets see the file OPTAA\_unit\_test.xlsx in the data artifact section for OPTABSN on alfresco: Company Home>>OOI>REFERENCE>> Product Specification Artifacts >>1341-00700.

**Table 1a. Test computations of internal instrument temperature correction.**

$\lambda$	$T_i(\text{counts})$	$T_i(^{\circ}\text{C})$	$T_1$	$T_2$	$\Delta T_1$	$\Delta T_2$	$\Delta T$
500	48750	15.00	14.5036	15.5200	-0.004929	-0.004611	-0.0048
550	48355	16.00	15.5200	16.4706	-0.004611	-0.004418	-0.0045
600	47950	17.00	16.4706	17.4833	-0.004418	-0.004355	-0.0044
650	47535	18.00	17.4833	18.4831	-0.004355	-0.004131	-0.0042
700	47115	19.00	18.4831	19.5196	-0.004131	-0.003422	-0.0038
715	46684	20.00	19.5196	20.5565	-0.003422	-0.002442	-0.0030

**Table 1b. Test computations of unit conversion.**

$\lambda$	$A_{sig}$	$A_{ref}$	$r$	$a_{off}$	$\Delta T$	$a_{pd}(\lambda)$
500	50	500	0.25	0.1	-0.0048	9.3151
550	150	500	0.25	0.1	-0.0045	4.9204
600	250	500	0.25	0.1	-0.0044	2.8770
650	350	500	0.25	0.1	-0.0042	1.5309
700	450	500	0.25	0.1	-0.0038	0.5252
715	495	500	0.25	0.1	-0.0030	0.1432

**Table 1c. Test computations of water temperature and salinity correction.**

$\lambda$	$a_{pd}(\lambda)$	$t$	$t_{ref}$	$\Psi_t$	$s$	$\Psi_{sa}$	$a_{pd,ts}(\lambda)$
500	9.3151	4	20	0.00003	10	0.000008	9.3155
550	4.9204	8	20	0.00002	15	0.000005	4.9206
600	2.8770	12	20	0.00098	20	0.000001	2.8848
650	1.5309	16	20	0.00001	25	0.000026	1.5303
700	0.5252	20	20	0.00070	30	-0.000151	0.5297
715	0.1432	24	20	0.00416	35	-0.000206	0.1338

**Table 1d. Test computations of light scattering correction.**

$\lambda$	$C_{pd,ts}(\lambda)$	$a_{pd,ts}(\lambda)$	scatter ratio	$a_{pd,ts;s}(\lambda)$
500	9.2260	9.3155	-1.50185	9.1811
550	4.8312	4.9206	-1.50185	4.7864
600	2.7955	2.8848	-1.50185	2.7507
650	1.4412	1.5303	-1.50185	1.3965
700	0.4406	0.5297	-1.50185	0.3959
715	0.0447	0.1338	-1.50185	0.0000

Scattering correction notes:

For the following 2 occurrences in real data, the scattering correction must be set to 0:

(1)  $c_{\text{ref}} - a_{\text{ref}} \leq 0$ ;

(2)  $a_{\text{ref}} < 0$ .

Note also that the absorption wavelengths and 'c' wavelengths do not have the same values. Therefore, to apply the scattering corrections the values for 'c' must be interpolated onto the absorption wavelength record.

## **Appendix A      Temperature and Salinity Correction Factors**

See the references for values for the Temperature and Salinity Correction Factors.

## **Appendix B      Output Accuracy and Quality Control**

Assuming that impurities are evenly distributed within the sample volume and that the data has been appropriately corrected for ambient water temperature and salinity and light scatter within the absorption tube, WET Labs, Inc. estimates an instrument error of +/- 0.01.

Quality control procedure should be applied after the computation of OPTABSN and should include:

- Global Range (GLBRNG): minimum = 0, maximum = 100
- Stuck Value Test (STUCKVL)
- Spike Test (SPKETST): > 2x the adjacent product values

The following requirements in the DOORS database describe optical absorption accuracy requirements:

- The instrument shall measure spectral absorption with an accuracy within  $\pm 0.01 a(\lambda)/m$  of the true value. <L2-SR-RQ-3532, L4-CG-IP-RQ-226, L4-RSN-IP-RQ-347>
- The instrument shall measure spectral absorption with a precision of  $0.005 a(\lambda)/m$  <L2-SR-RQ-3742, L4-CG-IP-RQ-514, L4-RSN-IP-RQ-567>
- The instrument should measure spectral absorption with a precision of  $10^{-3} a(\lambda)/m$ . This is an objective. <L2-SR-RQ-3743, L4-CG-IP-RQ-515, L4-RSN-IP-RQ-568>

## Appendix C Example Code

The following code corrects ac-s attenuation and absorption data for ambient temperature and salinity (see WET Labs *ac-s Protocol Document*, Revision P, December 2009).

```
function [corrected_data] = acscor(data)

% Corrects ac9 for effects of temperature and salinity.

load TS.cor ;
% Temperature and salinity coefficients file.

Tref = 12.0;
% Reference temperature (temperature at time of calibration).

acs_cal = load('acs010_051006.cor' );
% This is an instrument-specific file supplied by the vendor.

c_wl = acs_cal(:,1);
a_wl = acs_cal(:,3);

acs_Wcal = [acs_cal(:,2)'; acs_cal(:,4)'];
% Transform calibration file to 2x84 (varies with acs) matrix; first
% row is a, second row is c.

% Find temperature and salinity coefficients at wavelengths matching
% acs.
t = zeros(2,length(a_wl));
for k = 1:length(a_wl)
[near_c, t(1,k)] = find_nearest(c_wl(k),TS(:,1));
[near_a, t(2,k)] = find_nearest(a_wl(k),TS(:,1));
end
acs_c_tempcor = TS(t(:,1),2);
acs_a_tempcor = TS(t(:,2),2);
acs_c_salcor = TS(t(:,1),3);
acs_a_salcor = TS(t(:,2),4);

% Column assignments must be corrected for each dataset
temp = data(:,3); % CTD temperature
sal = data(:,5); % CTD salinity column
% In this case, "data" is a merged CTD and ac-s data file

acs_c = data(:,12:95); % c (in ascending wavelengths)
acs_a = data(:,96:179); % a (in ascending wavelengths)

% Correct data to reference temp., 0 PSU, subtract Pure Water Offset.
for z = 1:length(a_wl);
acs_a_cor(:,z) = acs_a(:,z) - ((temp - Tref) * acs_a_tempcor(z))...
- (sal * acs_a_salcor(z)) - repmat(acs_Wcal(1,z),r,1);
acs_c_cor(:,z) = acs_c(:,z) - ((temp - Tref) * acs_c_tempcor(z))...
- (sal * acs_c_salcor(z)) - repmat(acs_Wcal(2,z),r,1);
end

[corrected_data] = [acs_a_cor acs_c_cor];
```

The following code corrects ac-s absorption data for scattering loss within the instrument (see WET Labs *ac-s Protocol Document*, Revision P, December 2009)..

```
function [scat_cor_apg]=scatcor_proportional(acs_a,acs_c,a_wl,c_wl,...
    ref_wl,ag_ref_wl)
% Corrects for absorption tube scattering error using proportional
% method (Zaneveld et al. 1994, method 3). ref_wl is 715.
% ag_ref_wl is the dissolved absorption at the reference wavelength
% (measured with a pre-filter). It should be a column vector with
% the same length as acs_a and acs_c. Using this ensures any small
% absorption in the near IR is not subtracted. Make sure there are no
% negative ag values (use something like the routine below). If this
% measurement doesn't exist, insert 0.

% Find a(ref_wl) for scattering correction
ref_wl = 715
[near, ind_a_ref_wl] = find_nearest(ref_wl,a_wl);

% Ensure apg(ref_wl) is not negative
apg_ref_wl = acs_a(:,ind_a_ref_wl);
i = find(apg_ref_wl < 0);
apg_ref_wl(i) = 0;

% Proportional scattering correction to acs
% First interpolate c values to match a wavelengths.
acs_ci = pchip(c_wl,acs_c,a_wl);

% Find scattering error at ref_wl, ae_ref_wl
ae_ref_wl = apg_ref_wl - ag_ref_wl;

% Calculate apg using proportional method
[scat_cor_apg] = acs_a - repmat(ae_ref_wl,1,length(a_wl)).*...
((acs_ci - acs_a)./repmat(acs_ci(:,ind_a_ref_wl)...
- apg_ref_wl,1,length(a_wl)));
```