Absorption of Colored Dissolved Organic Matter

G2GS

Exported on May 14, 2021

Table of Contents

1 INTRODUCTION 4
1.1 Purpose of This Document 4
1.2 Who Should Use This Document? 4
1.3 Inside Each Section 4
1.4 Related Documents 4
1.5 Revision History 4
1.6 List of Acronyms 5

2 ALGORITHM DESCRIPTION 6
2.1 Algorithm Overview 6
2.1.1 Product Generated 6
2.1.2 Instrument Characteristics 6
2.2 Processing Outline 7
2.3 Algorithm Input 7
2.3.1 Primary Sensor Data 7
2.4 Theoretical Description 7
2.4.1 Physics of the Problem 7
2.4.2 Mathematical Description 8
2.5 Algorithm Product Output 8
2.5.1 aDOM (absorption coefficient of Colored Dissolved Organic Matter) 8
2.5.2 Flags 9

3 TEST DATA SETS AND OUTPUT 10
3.1 Input Datasets – In-situ data 10
3.2 Output from Simulated Datasets 10
3.2.1 Accuracy Estimates 10

4 PRACTICAL CONSIDERATIONS 12
4.1 Numerical Computation Considerations 12
4.2 Programming and Procedural Considerations 12
4.3 Quality Assessment and Diagnostics 12
4.4 Exception Handling 12
4.5 Algorithm Validations 12

5 ASSUMPTIONS AND LIMITATIONS 14
5.1 Performance 14

6 REFERENCES 15

7 APPENDIX 16

Document	a_{dom}440 Algorithm for GOCI-II Data
Initial creation date	2018-12-07
Last update date	2021-05-14
Writer	Korea Ocean Satellite Center of KIOST, Busan, Republic of Korea

1 INTRODUCTION

1.1 Purpose of This Document

This ATBD document is intended to explain the theoretical background of the GOCI-II absorption coefficient of dissolved organic matter at 440 nm (a_{dom}440) estimation algorithm (collectively referred to as a_{dom}440 algorithm). This algorithm has been developed for the purpose of improving performance by utilizing bands added to GOCI-II. This algorithm was implemented and validated through ADE of the G2GS and applied to ODPS.

1.2 Who Should Use This Document?

This document has been prepared for readers of two objectives: 1) A researcher who wants to know the theoretical background of the GOCI-II a_{dom}440 algorithm and how to implement it. 2) A developer who wants to maintain and improve the GOCI-II a_{dom}440 algorithm code.

1.3 Inside Each Section

This document is composed of the table of contents below:

- **Introduction:** A brief description of the output of a_{dom}440 algorithm
- **Algorithm Description:** Input/Output Materials, Physical Theory, and Detailed Descriptions of a_{dom}440 algorithms
- **Test Datasets and Outputs:** Data and results for a_{dom}440 algorithm test
- **Practical Considerations:** For those who regularly maintain and operate a_{dom}440 algorithm S/W, provide guidance such as maturity of the algorithm, information necessary for implementing S/W, evaluation of data quality, and exception processing.
- **Assumptions and Limitations:** Demonstrates the performance of the system and data set up when the algorithm is developed, and the uncertainty of system restrictions and data generated when operating.

1.4 Related Documents

This document is related to the ATBD of GOCI-II as shown below.

- Atmospheric Correction Algorithm for GOCI-II Data

1.5 Revision History

Revision	Date	Revision Description	Page Affected
0.2	2018-08-28	ATBD writing instruction is added and updated	all
0.21	2018-12-06	Translated into English	all
0.3	2021-05-14	Some minor typo errors are corrected	all

1.6 List of Acronyms

The abbreviations associated with this document are summarized in Table 1.

Table 1. Abbreviations

a_{dom}	Absorption coefficient of DOM
a_{dom}440	Absorption coefficient of DOM at 440 nm
CDOM	Colored Dissolved Organic Matter
DOM	Dissolved Organic Matter
GK2	Geostationary KOMPSAT 2
GOCI-II	Geostationary Ocean Color Imager-II
G2CDOM	GOCI-II a_{dom}440 algorithm
LG	[Gain Mode] Low Gain
R_{rs}	Remote sensing reflectance

2 ALGORITHM DESCRIPTION

This section describes the purpose of the GOCI-II a_{dom}440 algorithm and the specificity of the a_{dom}440 algorithm in relation to the final output, GOCI-II system.

2.1 Algorithm Overview

In this chapter, the GOCI-II a_{dom}440 algorithm is briefly referred to as G2CDOM. G2CDOM is an algorithm that adjusts coefficients based on the YOC algorithm (Siswanto *et al.*, 2011). That is, the ratio of remote sensing reflectance of 443 nm and 490 nm of blue wavelengths, 555 nm of green wavelength, and functional form of Tassan (1994).

2.1.1 Product Generated

DOM (Dissolved Organic Matter) refers to organic matter dissolved in seawater and is sometimes called gelbstoff, yellow substance, and gilvin. Among them, dissolved organic materials associated with light-absorption are referred to as Colored Dissolved Organic Matter (CDOM). CDOM in coastal waters are mostly supplied from freshwater, sewage, and sediments and CDOM in open seas are known to be produced mainly from the decomposition of plant plankton by bacteria, animal plankton excrement, animal plankton and other animals' sloppy feeding (Urban-Rich, 1999). CDOM decomposes about 57 to 84 percent by mainly solar radiation (Moran *et al.*, 2000; Zanardi-Lamardo *et al.*, 2002), and plankton are also known to contribute to the decomposition of CDOM (Hessen *et al.*, 1994; Morris and Hargreaves, 1997; Nelson *et al.*, 1998).

The optical properties of CDOM protect the aquatic ecosystem from harmful ultraviolet (UV-A, UV-B) and blue wavelengths, but at the same time reduce photosynthetically available light (PAR), which is a major variable in the marine ecosystem. In general, the absorbent spectrum characteristics of CDOM decrease exponentially with increasing wavelengths. Therefore, the blue wavelength range has a strong absorbent characteristic.

The CDOM algorithm calculates the absorption coefficient values generated at a specific wavelength in the range of blue wavelengths, such as wavelengths 400 nm, 412 nm, and 440 nm. The unit is m^{-1}. The requirements for a_{dom}440 production in GOCI-II data are as shown in Table 2.

Table 2. GOCI-II adom440 production requirements

Product level	Spatial resolution	Temporal resolution	Acc. for case-1 waters
Level-2	300 m	1 hour	60 %
Level-3	1 km	1 day	-

2.1.2 Instrument Characteristics

The calculation of a_{dom}440 is estimated using the ratio of remote sensing reflectance of blue wavelengths with strong absorption of CDOM and green wavelengths with relatively weak absorption. The GOCI-II has four blue bands of 380 nm, 412 nm, 443 nm, and 490 nm, and two green bands of 510 nm and 555 nm so that various forms of algorithms can be applied. In particular, GOCI-II could produce an a_{dom}440 with a new 380 nm blue band not present in GOCI-I, which is slightly more accurate.

2.2 Processing Outline

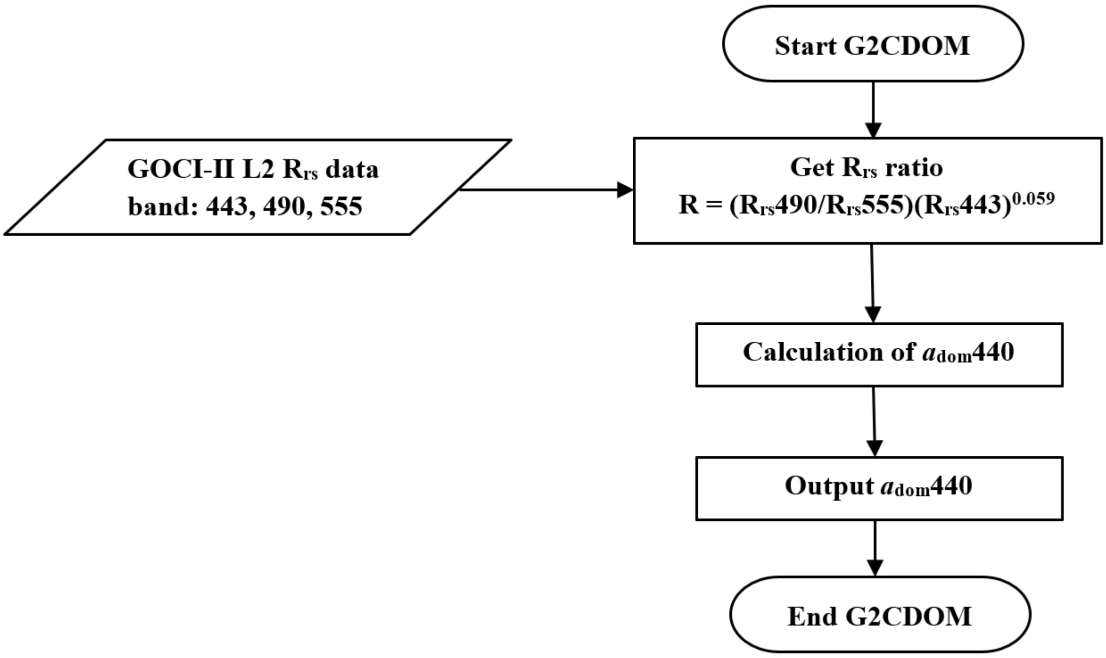

Figure 1. Flow chart of G2CDOM.

2.3 Algorithm Input

The input data are GOCI-II atmospheric correction production, which is remote sensing reflectance data.

2.3.1 Primary Sensor Data

Using remote sensing reflectance (R_{rs})

- Band composition: No.3 Band (443 nm), No.4 Band (490 nm), No.6 Band (555 nm)

- File format: NetCDF-CF

- Data form: 32bit float

- Dimension: 3 bands for a grid size of 2780 pixels * 2780 pixels

2.4 Theoretical Description

2.4.1 Physics of the Problem

The remote sensing reflection (R_{rs}) of seawater is determined by the absorption and scattering characteristics of the underwater constituents. Dissolved organic matters are dissolved and present in seawater, so the characteristics of scattering are not taken into account and only the characteristics of absorption are taken into account. Since the spectrum of the absorption coefficient of dissolved organic matter decreases exponentially with increasing wavelengths, it shows a very strong absorbency in the UV area and in the blue wavelength area of the visible light area, with little or no absorbency characteristic beyond the green wavelength area of the visible light area. Also, dissolved organic matters account for most of the freshwater and sediment rather than marine sources such as the decomposition of plant plankton by bacteria. However, the spectrum of the absorption coefficient of suspended solids is very similar to that of dissolved organic matters, but the slope is gentle compared to dissolved organic materials and the scattering characteristics are very strong. Chlorophyll represents the maximum absorption coefficient near wavelength of 443 nm.

Therefore, suspended solids and chlorophyll are also strongly absorbed in blue wavelengths where dissolved organic matter is strongly absorbed. To minimize the effects of these two components, the ratio of remote reflections in the blue wavelength range of 443 nm, 490 nm, and 555 nm in the green wavelength range was used.

2.4.2 Mathematical Description

2.4.2.1 GOCI-II adom440 Algorithm

Based on the YOC algorithm (Siswanto *et al.*, 2011), the algorithm was derived by adjusting the coefficients as follows:

$$a_{dom}440 = 10^{(a_0 + a_1 log_{10}(R) + a_2 log_{10}(R)^2)} \quad (1)$$

$$R = (\frac{R_{rs}490}{R_{rs}555})(R_{rs}443)^{0.059}, a_0 = -1.23, a_1 = -2.311, a_2 = -2.16 \quad (2)$$

2.5 Algorithm Product Output

2.5.1 aDOM (absorption coefficient of Colored Dissolved Organic Matter)

- File format: NetCDF-CF

- Data form: 32bit float

- Dimension: 2780 pixels * 2780 pixels

(Data form will be changed to 16 bit in the future for better data service by reducing the data size)

Attribute	Precision	Value
_FillValue	float	-999.0
add_offset	float	0.0
long_name	character	Absorption coefficient of dissolved organic matter at wavelength 400, 440, or 443, Tassan aCDOM
scale_factor	float	1.0
standard_name	character	absorption_coefficient_of_colored dissolved_organic_matter
units	character	m^-1

Attribute	Precision	Value
valid_max	float	100.0
valid_min	float	0.0

2.5.2 Flags

flag_masks (Bit)	flag_values	flag_meanings	Descriptions
1	1	Cloud_or_Ice	Cloud or ice
2	2	Land	Land
3	4	AC_Fail	Atmospheric correction failure
4	8	aCDOM_Fail	aCDOM is not calculable
5	16	reserved5	
6	32	reserved6	
7	64	reserved7	
8	128	reserved8	

3 TEST DATA SETS AND OUTPUT

3.1 Input Datasets – In-situ data

For three years from 2015 to 2017, field data collected from the waters around the Korean Peninsula were used. Among the in-situ data collected, the observation points collected together with the remote sensing reflectance and absorption coefficients of dissolved organic matter were selected and used as data for verification purposes. The used observation points are 111 points (Figure 2).

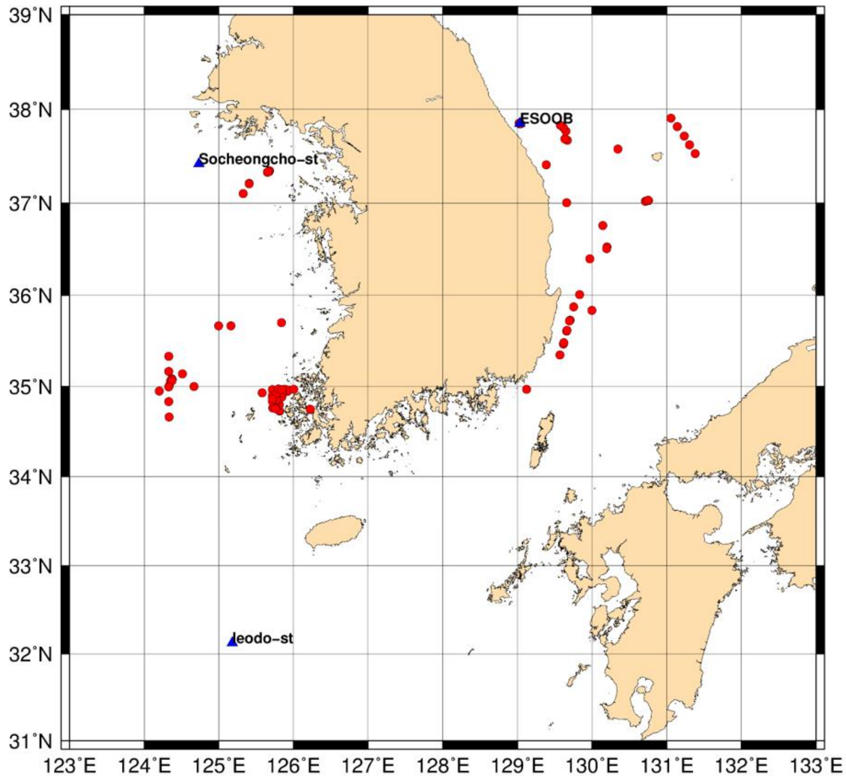

Figure 2. Observation map.

3.2 Output from Simulated Datasets

3.2.1 Accuracy Estimates

As shown in the following formula, APD (absolute percentage difference, %), RMSE (root mean square error), RPD (relative percentage difference, %), and Bias were used. P_{ret} is a value calculated from the algorithm and P_{is} is a in-situ data.

$$\text{APD} = \frac{1}{N}\sum_{i=1}^{N} \left| \frac{P_{ret}-P_{is}}{P_{is}} \right| 100,$$

$$\text{RMSE} = [\frac{1}{N}\sum_{i=1}^{N}(P_{ret} - P_{is})^2]^{\frac{1}{2}},$$

$$\text{RPD} = \frac{1}{N}\sum_{i=1}^{N}(\frac{P_{ret}-P_{is}}{P_{is}})\, 100,$$

$$\text{Bias} = \frac{1}{N}\sum_{i=1}^{N}(P_{ret} - P_{is}),$$

As a result of the verification, the APD for the adom440 algorithm is 40.8 %, the RMSE is 0.031, the RPD is 20.3 %, and the Bias is 1.089. The accuracy calculated from APD is 59.2%.

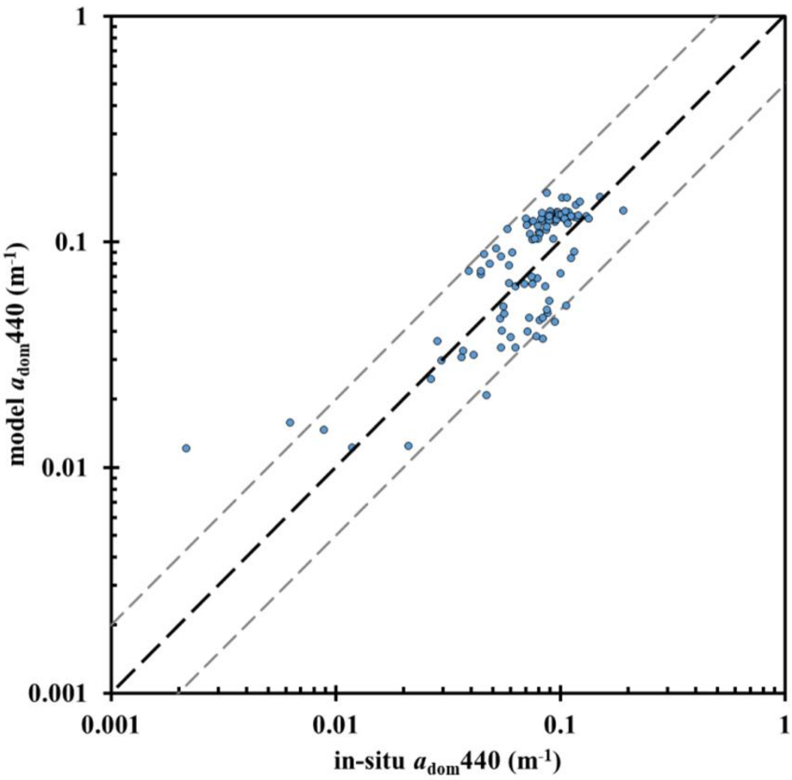

Figure 3. Comparison between the in-situ and retrieved adom440.

4 PRACTICAL CONSIDERATIONS

4.1 Numerical Computation Considerations

The GOCI-II a_{dom}440 algorithm is simple in its construction and does not require a high-end system. The data processing time requirement is within 30 seconds of the ADE. In addition, the system specifications for ADE consist of the dodeca-core 2.5 GHz CPU and the K80 GPU.

It is recommended to free up 2 to 3 times more system memory than required because continuous memory space allocation is required for data processing. Because this algorithm is processed by pixel unit, parallel processing is possible and multi-CPU and GPU processing is supported for this algorithm.

4.2 Programming and Procedural Considerations

The a_{dom}440 algorithm code for all GOCI-II was written in C++ with in-line assembly code, and inheritance by class was not used to facilitate modularization of each subroutine. For the compatibility of the systems, the C++ code used the ANSI specifications and the window system's dependent libraries were not used. Specific descriptions of input/output of all classes and functions are detailed in the header file and variables and function names are set to intuitively understand the role of each variable and function within the code.

All libraries used, except for libraries (OpenCL) for parallel processing of the GOCI-II a_{dom}440 algorithm, were realized directly without open source.

4.3 Quality Assessment and Diagnostics

GOCI-II a_{dom}440 algorithm can have problems during processing due to several factors, and the S/W operator can determine whether data processing successful is based on the list below:

- Normal processing if the sum of ratios of the effective pixels and the mask pixels generated in the metadata is 100%.
- "R_{rs} Warn" on the flag should the quality of a_{dom}440 outputs be reduced as a whole if "No meteorological data warn" warning is issued in the R_{rs} input data.
- The calculated a_{dom}440 should have a value larger than the open ocean as the coastal waters grow, in generally.

4.4 Exception Handling

When processing GOCI-II a_{dom}440 algorithm, various errors can occur depending on the circumstances.

4.5 Algorithm Validations

The guidelines below are provided for the verification of GOCI-II a_{dom}440 algorithm output.

1. An a_{dom}440 image can be determined by comparing the spectral shapes of each major ocean area relative to the model of the a_{dom}440 output of MODIS or VIIRS. The major ocean area are open ocean (North-west Pacific Ocean), East Sea, Bohai Sea, Bay of Gyounggi, waters around Mokpo, Estuary of Yangtze River, and etc.
2. The overall performance of the a_{dom}440 algorithm can be determined by comparing it with the in-site data of a_{dom}400. In-situ data are collected from the Korea Institute of Ocean

Science & Technology's Korea Ocean Satellite Center, and if such data is difficult to obtain, the site data may be used from NASA's SeaBASS data and other agencies.

5 ASSUMPTIONS AND LIMITATIONS

5.1 Performance

The following assumptions have led to the development of algorithms and performance measurements.

1. Weather reanalysis or climate data, which are ancillary input data for data processing every hour, must be available.
2. The geometry and radiative calibration of GOCI-II Level 1B shall be intact
3. The input range of the LUT used for atmospheric calibration shall be within the range of the recording conditions of GOCI-II.

6 REFERENCES

Blough, N.V. and Vecchio, R.D. 2002. 'Chromophoric DOM in the coastal environment', In: Hansell, D.A. and Carlson, C.A. (Eds.), *Biogeochemistry of Marine Dissolved Organic Matter*. Academic Press, SanDiego, CA, pp.509-546.

Bricaud, A., Morel, A., and Prieur, L. 1981. 'Absorption by dissolved organic matter in the sea (yellow substance) in the UV and visible domains', *Limnology and Oceanography*, 26: 43-53.

Hessen, D.O., Nygaard, K., Salonen, K., and Vahatalo, A. 1994. 'The effect of substrate stoichiometry on microbial activity and carbon degradation in humic lakes', *Environment International*, 20: 67-76.

Moon, J., Park, Y., Ryu, J., Choi, J., Ahn, J., Min, J., Son, Y., Lee, S., Han, H., and Ahn, Y. 2012. 'Initial validation of GOCI water products against *in situ* data collected around Korean Peninsula for 2010-2011', *Ocean Science Journal*, 47: 261-277.

Moran, M. A., Sheldon, W. M., and Zepp, R. G. 2000. 'Carbon loss and optical property changes during long-term photochemical and biological degradation of estuarine dissolved organic matter', *Limnology and Oceanography*, 45: 1254-1264.

Morris, D. and Hargreaves, B. 1997. 'The role of photochemical degradation of dissolved organic carbon in regulating the UV transparency of three lakes on the Pocono Plateau', *Limnology and Oceanography*, 42: 239-249.

Nelson, N.B., Siegel, D.A., and Michaels, A.F. 1998. 'Seasonal dynamics of colored dissolved organic material in the Sargasso Sea', *Deep-Sea Research I*, 45: 931-957.

Nelson, N.B. and Siegel, D.A. 2002. 'Chromophoric DOM in the open ocean', In: Hansell, D.A. and Carlson, C.A. (Eds.), *Biogeochemistry of Marine Dissolved Organic Matter*. Academic Press, SanDiego, CA, pp.547-578.

Siswanto, E., Tang, J., Yamaguchi, H., Ahn, Y., Ishizaka, J., Yoo, S., Kim, S., Kiyomoto, Y., Yamada, K., Chiang, C., and Kawamura, H. 2011. 'Empirical ocean-color algorithms to retrieve chlorophyll-*a*, total suspended matter, and colored dissolved organic matter absorption coefficient in the Tellow and East China Seas', *Journal of Oceanography*, 67: 627-650.

Tassan, S. 1994. 'Local algorithms using SeaWiFS data for the retrieval of phytoplankton, pigments, suspended sediment, and yellow substance in coastal waters', *Applied Optics*, 33: 2369-2378.

Urban-Rich, J. 1999. 'Release of dissolved organic carbon from copepod fecal pellets in the Greenland Sea', *Journal of Experimental Marine Biology and Ecology*, 232: 107-124.

Zanardi-Lamardo, E., Clark, C., Moore, C., and Zika, R. 2002. 'Comparison of the molecular mass and optical properties of colored dissolved organic material in two rivers and coastal waters by flow field-flow fractionation', *Environmental Science and Technology*, 36: 2806-2814.

7 APPENDIX

End of Document