BIO-OPTICS FOR OCEAN COLOR REMOTE SENSING

OF THE BLACK SEA

(Black Sea Color)

TN8 Analyses and QA of AOP and IOP data

Workpackage:	*3*	*Data analysis and QA*
Author(s):	*V. Slabakova*	*IO-BAS*

This report summarizes the specific data quality methods and analysis that were applied to the AOP and IOP data collected during the BIO-OPT 2019 cruise (15th- 28th May 2019)

1. Analyses and QA of AOP data

Data products from the free-fall optical profiler include spectral values of: irradiance reflectance, remote sensing reflectance, normalized water–leaving radiance, diffuse attenuation coefficient and the so called Q-factor. The processing and quality assurance of data products were made using the Optical Processor developed at the JRC (D'Alimonte et al., 2002). The processing steps, defined in agreement with consolidated protocols fully documented in Zibordi et al. (2011).

The following data analysis mostly focuses on L_{WN} (or the equivalent R_{RS}) being the key quantity for bio-optical modeling and validation of primary satellite radiometric products.

The in situ radiometric measurements were assessed through quality indices (QI) determined during data processing. These include:

i. temporal changes in illumination conditions as caused by ship roll/pitch or cloudiness (quantified through the standard deviation of $E_d(0^+,\lambda,t)$ at each λ, and differences between $E_d(0^-,\lambda, t_0)$ and $E_d(0^+,\lambda, t)$;

ii. potential difficulties in the determination of subsurface extrapolated quantities (flagged by the number of measurements per unit depth in the extrapolation layer and differences in data products determined at different depths);

iii. poor illumination conditions as resulting from high sun zeniths or cloudiness (quantified through the value of the diffuse to direct ratio of the above-water downward irradiance).

These QIs are recorded as an integral part of the radiometric data set and their use can be defined on an application-by-application basis.

Sample spectra of quality controlled L_{wn} determined from a Satlantic mcroPRO free-fall optical profiler during Black Sea BIO-OPT 2019 cruise are shown of Figure 1. The data exhibit mean maxima of L_{wn} at 490 nm and minima at 665 nm with average values of and 1.48 [1] and 0.15 $mWcm^{-2}\mu m^{-1}sr^{-1}$, respectively (see Table 1).

Table 1. Basic statistic of L_{wn} (λ), [mW $cm^{-2}\mu m^{-1}sr^{-}1$] determined from in-water radiometric profiles collected during Black Sea BIO-OPT 2019 cruise

	$L_{wn}(412)$	$L_{wn}(443)$	$L_{wn}(490)$	$L_{wn}(510)$	$L_{wn}(555)$	$L_{wn}(665)$	$L_{wn}(684)$
Mean	0.75	1.12	1.48	1.34	1.21	0.15	0.16
SD	0.34	0.54	0.65	0.51	0.34	0.05	0.06
Min	0.20	0.27	0.44	0.51	0.50	0.06	0.06
Max	1.84	2.58	3.00	2.45	1.95	0.34	0.35

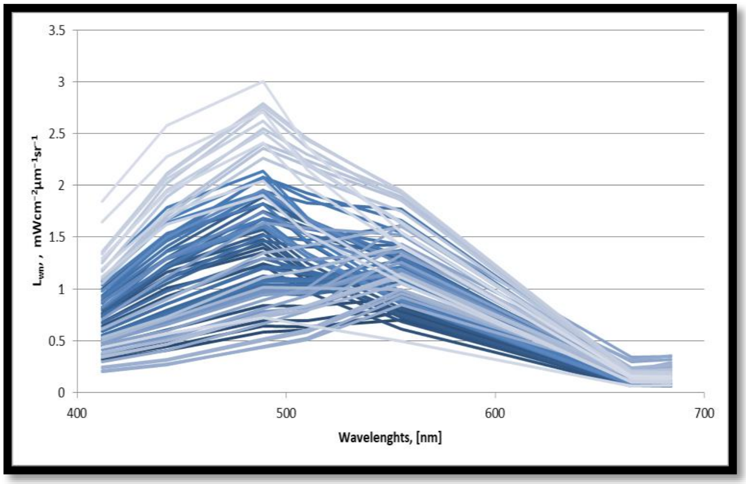

Figure 1. Sample spectra of L_{wn} determined from in-water radiometric profiles during the Black Sea BIO-OPT 2019 cruise

The special distribution of K_d (λ) determined from free fall optical profiler measurements during BIO-OPT cruise at surface layer is presented on Figure 2. The highest values of the diffuse attenuation coefficient are observed in front of Danube delta

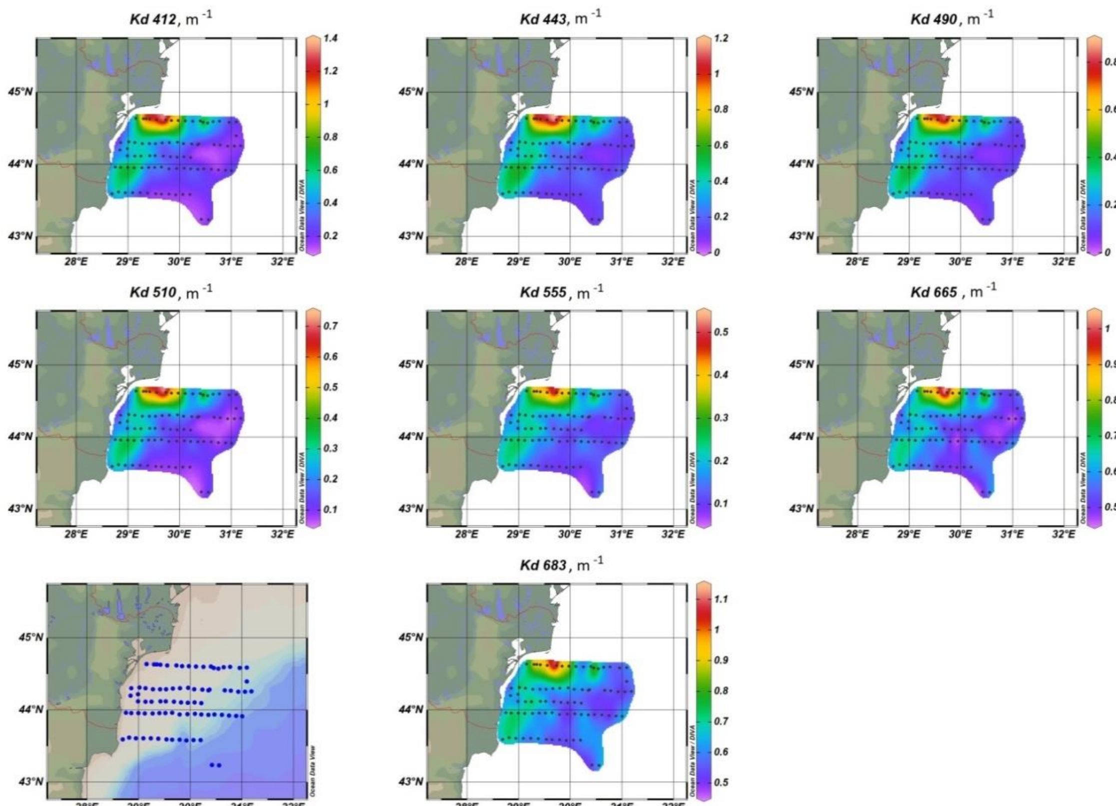

Figure 2. Distribution of K_d (λ) determined from free fall-optical profile measurements performed during BIO-OPT 2019 cruise

2. Analyses and QA of IOP data

2.1 Total beam attenuation c (λ) and absorption a (λ) data

The total (except water) beam attenuation and absorption coefficients c(λ) and a(λ) both in units [m^{-1}], performed with a WET Labs (Philomath, USA) "AC-9" at the nominal wavelengths (λ) 412, 440, 488, 510, 555, 630, 650, 676 and 715 nm. The particulate scattering coefficient b(λ) is determined as c(λ)-a(λ). Data processing and QA of AC-9 data measured during the BIO-OPT 2019 campaign were done according to the protocol described in Zibordi et al. (2002). The absolute calibration of AC-9 was performed by WETLabs before the cruise. Additionally, several calibrations with Mili Q water were carried out during the BIO-OPT campaign. Offset between WETLabs and onboard calibrations were used for correcting the c (λ) and a (λ) due to changes in instrument sensitivity (see Zibordi et al., 2002).

Spectra of total a(λ) and b(λ) measured during the Black Sea Bio-Opt 2019 cruise are shown on Figure 3.

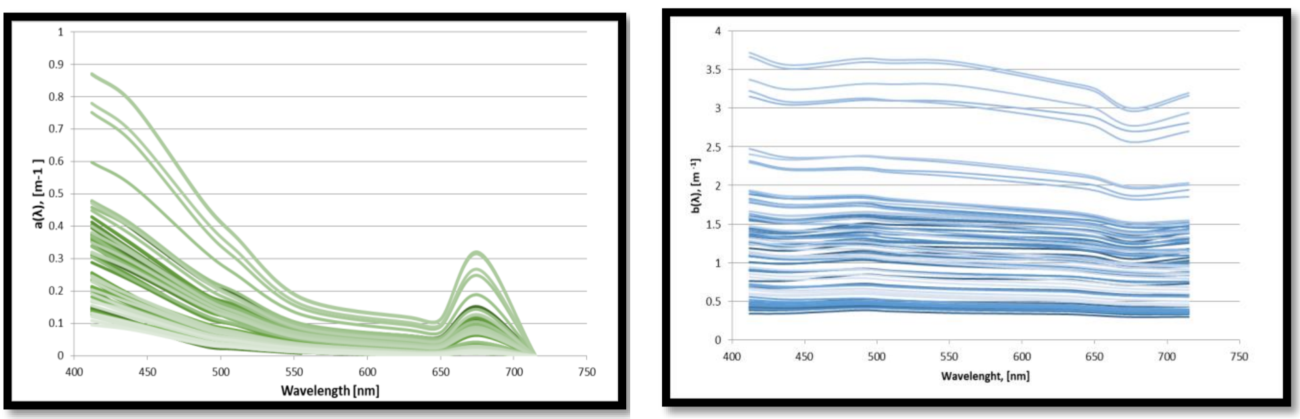

Figure 3. Spectra of total absorption a(λ) and particulate scattering b (λ) coefficients determined during the Black Sea Bio-Opt 2019

2.2 Absorption coefficients of pigmented, a_{ph} (λ) and non-pigmented, a_{dp} (λ), particulate matter

Light absorption by particles is obtained by seawater filtration and spectrophotometric techniques (see Zibordi et al., 2002, and references therein). Depending on the particle concentrations, different volumes of seawater are filtered on glass fiber filters with nominal pore size 0.7µm at low vacuum pressure and immediately frozen in liquid nitrogen for later spectrophotometric analysis. The absorption coefficients of pigmented, a_{ph} (λ) and non-pigmented, a_{dp} (λ), particulate matter between 400 and 750 nm are determined with a Perkin Elmer Lambda – 900 dual beam spectrophotometer. The quality of a_{ph} and a_{dp} (λ) data has been documented through analysis of replicated water samples (see Zibordi et al., 2002).

2.3 Absorption coefficient of colored dissolved organic matter, a_{ys} (λ)

Light absorption by colored dissolved organic matter (CDOM), a_{ys} (λ) is determined through spectrophotometric analysis (see Zibordi et al., 2002, and references therein). Seawater samples are filtered through 0.22µm cellulose filters and then refrigerated at 4° C for later laboratory analysis. Measurements of CDOM spectral absorption, a_{ys} (λ), between 350 and 750 nm with 1 nm resolution are obtained using Perkin Elmer Lambda – 10 dual beam spectrophotometer. The quality of a_{ys} (λ) data has been documented through analysis of replicated water samples (see Zibordi et al., 2002).

Absorption coefficients of non-pigmented (a_{dt} (λ)) and pigmented (a_{ph}(λ)) particulate matter and CDOM determined form water samples collected during the BIO- OPT 2019 are shown on Figure 4. Typical maxima at 443 nm reflect the absorption properties of the main photosynthetic pigment—chlorophyll a. The average value of a_{ph}(λ) is 0.144 m^{-1} (Table 2). CDOM spectral curves show strong absorption features at 412 nm, and decrease to near zero in the red and near infrared portion of the spectrum. CDOM absorption coefficient at 412 nm varies between 0.072 to 0.417 m^{-1}, and the average value is 0.2 m^{-1}. The a_{dt} (λ) data exhibit maxima at 412 nm with mean value of 0.032 m^{-1}.

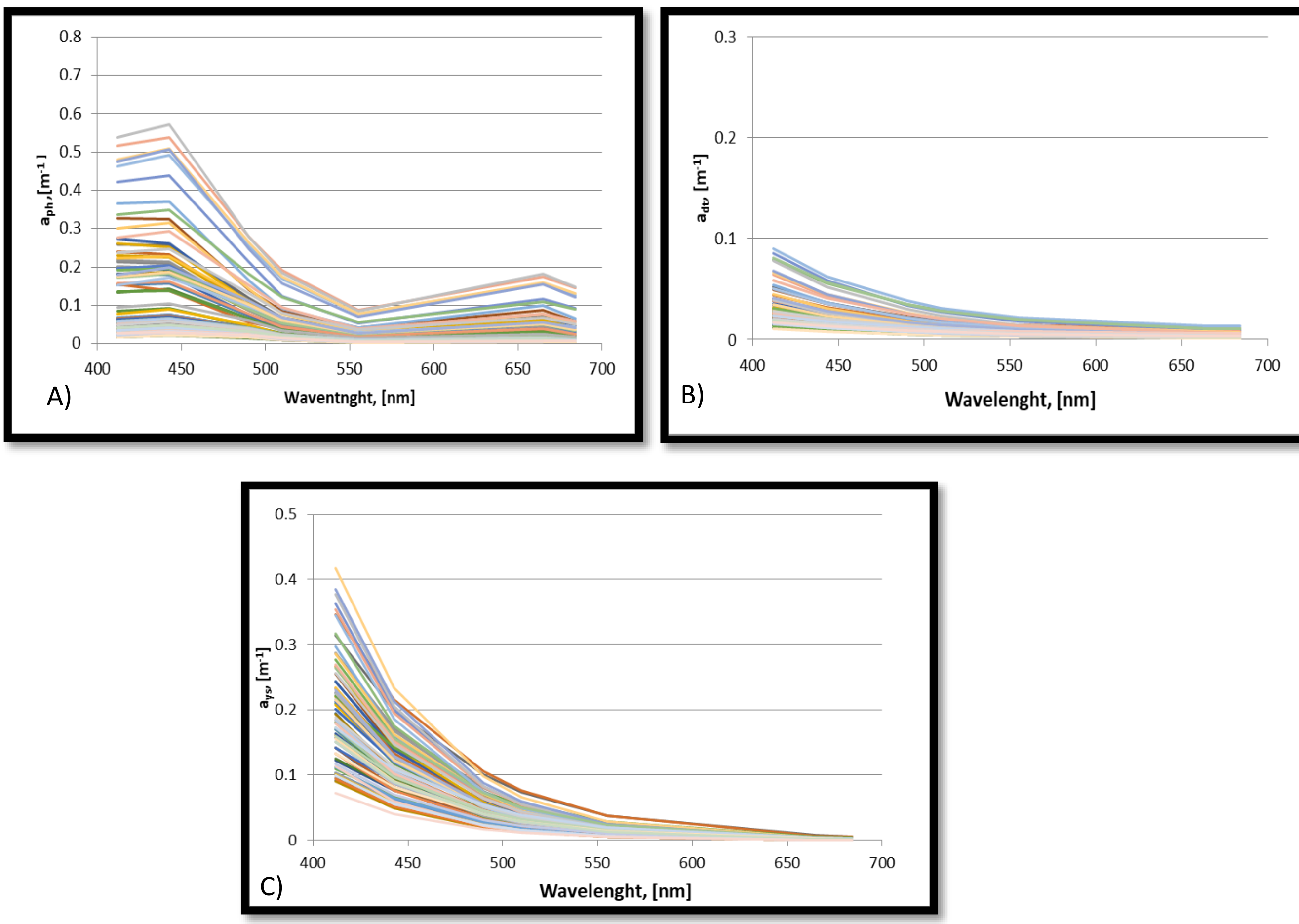

Figure 4. Absorption spectra by pigmented (A) and non-pigmented (B) particulate matter and CDOM (C) at surface layer during BIO-OPT 2019 cruise 412-684 nm

Table 2. Basic statistics of absorption coefficient by pigmented particles at 443 nm, absorption coefficients by non- pigmented particles and CDOM at 412 nm

	a_{ph}(443), m^{-1}	a_{dt}(412), m^{-1}	a_{ys}(412), m^{-1}
Mean	0.144	0.032	0.199
SD	0.140	0.019	0.082
Min	0.023	0.010	0.072
Max	0.571	0.090	0.417

Figure 6 presents the different distribution of the main optical components collected during BIO-OPT cruise and their contribution to the absorption budget in the blue (412 and 443 nm).

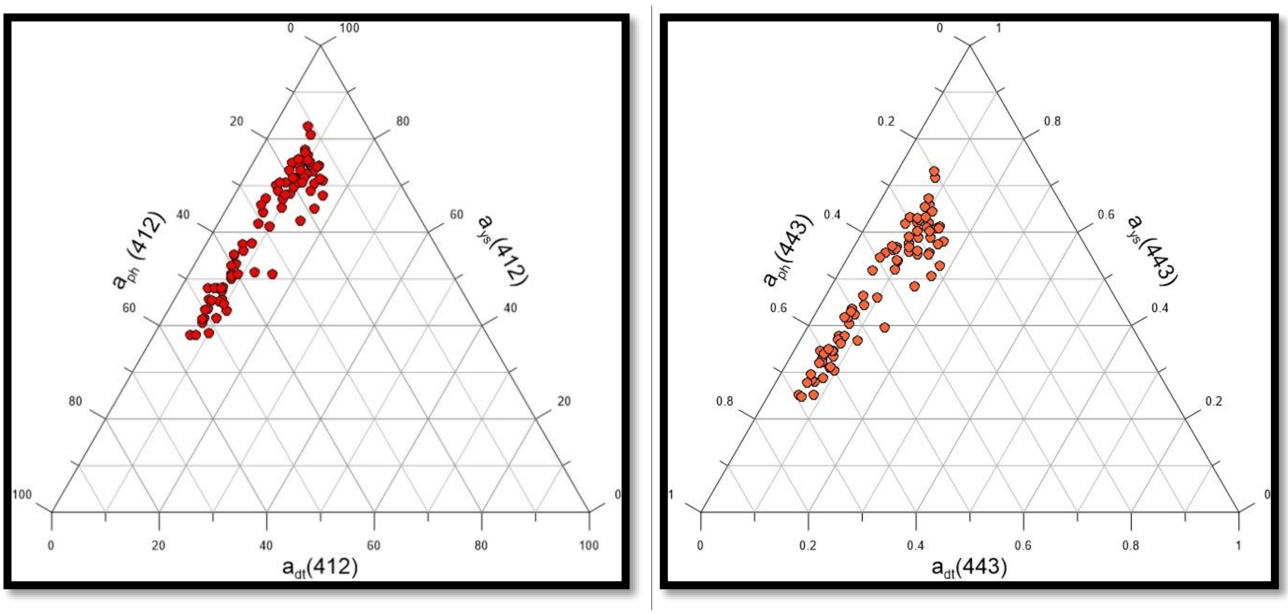

Figure 6 Ternary plot (%) of the three main optical components of the absorption at 412 and 443 nm

The distribution of the data shows that absorption by CDOM represent about 60% of the total at 412 nm and around 48% at 443 nm. While absorption by pigmented particulate matter a_{ph} contribute approximately 30% and 40% at 412 and443 nm, respectively.

ACKNOWLEDGMENTS

We would like to express our sincere thanks to Dr. Giuseppe Zibordi and Dr. Jean–Francois Berthon from JRC for providing us the IOP data and to help with the processing of AOP data, and for their continued support to the implementation of the project activities.

References

1. G. Zibordi, J.-F. Berthon, F. Mélin and D. D'Alimonte. (2011). Cross-site consistent in situ measurements for satellite ocean color applications: the BiOMaP radiometric dataset. Remote Sensing of Environment,115, 2104–2115.
2. D'Alimonte, D., Zibordi, G. &Berthon, J.-F. (2002).The JRC processing system. In In results of the second SeaWiFS data analysis roundrobin, March 2000 (DARR-2000). NASA Tech. Memo. 206892, Vol. 15, 15 pp. (Eds S. B. Hooker and E. R. Firestone). NASA.
3. Zibordi, G., Berthon, J.-F., Doyle, J. P., Grossi, S., van der Linde, D., Targa, C., & Alberotanza, L. (2002). Coastal Atmosphere and Sea Time Series (CoASTS), Part 1: A long-term measurement program (2002). In S. B. Hooker, & E. R. Firestone (Eds.),NASA Tech. Memo. 2002-206892, Vol. 19, Greenbelt, MD: NASA Goddard Space Flight Center 29 pp.

Symbols

L_{wn} (λ) – Normalized water- leaving radiance

R_{rs} (λ) – Remote sensing -sensing reflectance

$E_d(0^+,\lambda)$ – Above –water downward irradiance

$E_d(0^-,\lambda)$ –Subsurface downward irradiance

SD- Standard deviation

c(λ) –Total seawater beam attenuation coefficient

a(λ) – Total sweater absorption coefficient

b(λ)- Total seawater scattering coefficient

a_{ph} (λ)- Pigmented particulate matter absorption

a_{dt} (λ) –Non-pigmented particulate matter absorption coefficient

a_{ys} (λ) – Colored dissolved organic matter absorption coefficient