BIO-OPTICS FOR OCEAN COLOR REMOTE SENSING

OF THE BLACK SEA

(Black Sea Color)

TN 17: Evaluation of regional ocean color products

Workpackage:	*4*	
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1. Objectives

Validation of the various ocean color products in open-sea and coastal waters is a critical element of satellite ocean color missions (Hooker et al., 2000). The uncertainties in retrieval of concentration of seawater optically significant constituents from satellite data may challenge the results of marine environmental and climate studies in the Black Sea as well as to have an impact in the use of ocean color products in primary production models, in validation and tuning of ecosystem modeling and especially in the Black Sea data assimilation systems.

The aim of this report is to evaluate the performance of regional ocean color product develop for OLCI sensor. The accuracy of geophysical products were assessed on the base of independent *in situ* datasets collected in the Bulgarian Black Sea waters during different national and international scientific campaigns.

2. Data and Method

To quantify the uncertainty of the regional ocean color products, we compared OLCI remotely sensed R_{rs} ratio (i.e., input for the algorithms) and bio-optical parameters (output) with corresponding *in situ* measurements which were independent from the data utilized for algorithms development.

The OLCI Level-2 data full-resolution (FR 300 m/pixel), mode “Non Time Critical” over the western Black Sea were obtained from EUMETSAT Data Centre (https://archive.eumetsat.int/usc/). The atmospherically corrected OLCI water-leaving reflectance (ρ_w, dimensionless) was converted into R_{rs} dividing it by π. For the matchup analyses we used the quality controlled *in situ* data (see for details deliverables TN# 7 and 8) - Chlorophyll a (CHL), Total Suspended Matter (TSM), absorption coefficient by non-pigmented particles and colored dissolved organic matter at 443 nm (ADG443) and diffuse attenuation coefficient (K_d) at 490 nm collected in the Bulgarian Black Sea waters in the period 2016 to 2019.

In order to verify the impact of the regional with respect to the OLCI standard products, the global and the regional algorithms were used to retrieve the CHL, TSM, ADG 443 and K_d490 from OLCI data and subsequently compared with the *in situ* co-located measurements. The assessment was performed based on the methodology described in deliverable TN #12.

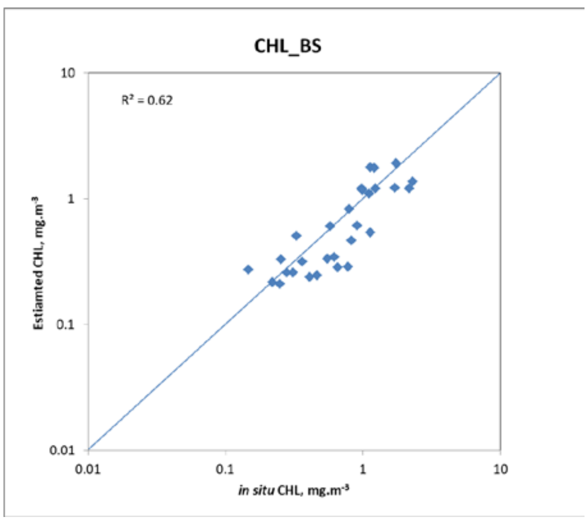
3. Results

3.1 Assessment of the regional algorithms for chlorophyll a (CHL) retrieval from OLCI data

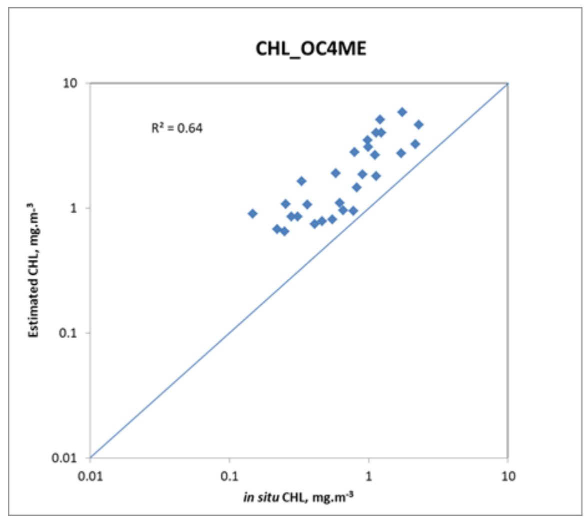
The comparison between OLCI derived pigments concentration form regional two band algorithm (named CHL_BS, TN14) and global (OC4ME, Morel et al.,2007 and OC_NN, Doerffer and Schiller, 2007) algorithms and independent *in situ* CHL data were based on 29 matchups. The *in situ* CHL values used in the analysis ranged between 0.15 and 2.3 mg m^{-3}, with mean concentration 0.84 mg m^{-3}.

The results related to the assessment of OLCI chlorophyll products (regional and global) in respect to the *in situ* data are summarized in Table 1, while the scatter plots are presented on Figure 1.

The derived scatter plots confirm that the OLCI CHL global algorithms overestimate the *in situ* concentrations. R^2 coefficients do not significantly vary for BS_CHL and OC4ME (0.62 and 0.64), while CHL_NN presents a low coefficient of determination (R^2 =0.24).



A)



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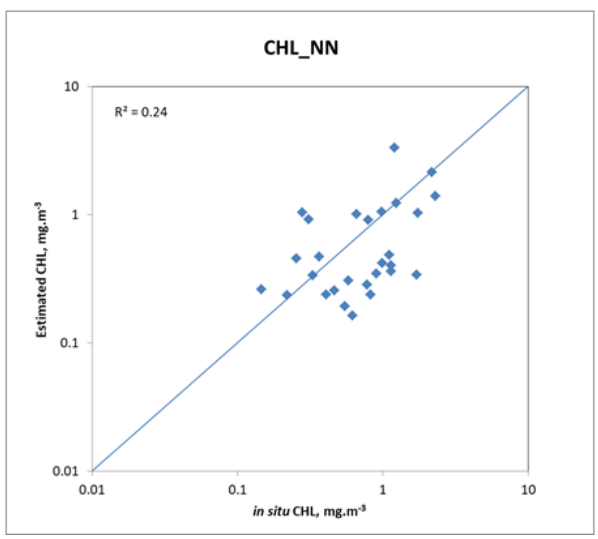

C)

Figure 3. Scatter plot of OLCI regional and global CHL products versus *in situ* data: A) OLCI CHL_BS ocean color product vs. *in situ* data; B)OLCI CHL_OC4ME ocean color product vs. *in situ* data and C) OLCI CHL_NN ocean color produst vs. *in situ* data

Table 1. Validation of the OLCI CHL products produced using the regional and global algorithms

Product	MPD, %	MAPD,%	RMSE, $mg.m^{-3}$	R^2
CHL_BS	-9.15	31.65	0.20	0.62
CHL_OC4ME	174.43	174.43	0.44	0.64
CHL_NN	14.5	75.03	0.38	0.24

RMS ranges from 0.20 mg m^{-3}, for BS_CHL, to 0.44 mg m^{-3} for OC4ME. The comparison between *in situ* measurements and BS_CHL -derived chlorophyll reveals a low negative MPD of -9.15% .The MAPD improves from OC4ME (174.43%) to CHL_NN (75.93%) and to BS_CHL (31.65%). In summary, BS_CHL shows the best accuracy (MAPD = 31.65%), fewer underestimations (MPD =−9.15%), a good correlation coefficient (R^2=0.62) indicating that the regional algorithm is more effective in reproducing *in situ* chlorophyll for this range of concentrations in the Bulgarian Black Sea waters. For further validation exercises of the OLCI CHL products in the Black Sea more *in situ* data with improved spatial and temporal coverage is critically needed.

3.2 Assessment of the regional algorithm for absorption coefficient by non-pigmented particles and colored dissolved organic matter at 443 nm (ADG 443 nm) retrieval from OLCI data

The comparison between ADG443 ocean color products derived from regional (named ADG443_BS, TN#14) and global (ADG_NN, Doerffer and Schiller 2007) algorithms and independent *in situ* ADG443 data were based on the limited number of matchups (N=7). The *in situ* ADG443 used in the analysis ranged between 0.0737 and 0.2581 m^{-1}, with average value of 0.1615 m^{-1}. The results of assessment of OLCI ADG443 products (regional and global) in respect to the *in situ* data are summarized in Table 2, while the scatter plots are presented on Figure 2.

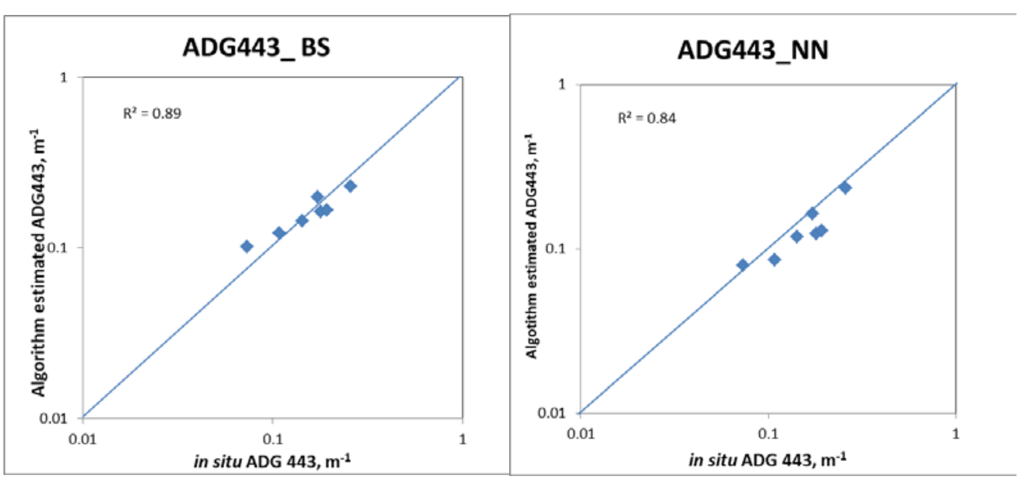

Figure 2. Scatter plots of OLCI ADG443_BS and ADG 443_NN products versus *in situ* $a_{ys}(443)+a_{npp}(443)$ data

The scatterplot of ADG443_BS versus *in situ* data for 7 co-located measurements (Fig. 4) shows a better agreement (R^2=0.89) than this of the ADG443_NN (R^2 =0.84) which is also confirmed by the statistics in Table 4.

Table 2. Validation of the OLCI ADG443 products produced using the regional and global algorithms

Product	MPD,%	MAPD, %	RMSE, m^{-1}	R^2
ADG 443_BS	4	14.09	0.07	0.89
ADG 443_NN	-15.68	17.82	0.11	0.84

The overall statistical performance indicate that ADG 443 values derived from the regional empirical algorithm has lower RMES (0.07 m^{-1}), MPD (4%) and MAPD (14.09%) comparing to the standard OLCI ADG443_NN data product (RMSE=0.11 m^{-1}, MDP=-15.68% and MAPD=17.82%). Both products meet the 30%-uncertainty of SENTINEL 3 Mission Requirements (MRTD, 2007). However, the assessment results are obtained from few matchups that require future validation exercises.

3.3 Assessment of the regional algorithms for the diffuse attenuation coefficient (K_d) retrieval from OLCI data

The comparison between OLCI diffuse attenuation coefficient at 490 nm derived from regional (named Kd490_BS, TN#14) and global (OK2-560, Morel et al.,2007) algorithms and independent *in situ* $K_d(490)$ data were based on the limited number of matchups (N=8). The *in situ* K_d 490 data used in the analysis ranged between 0.07 and 0.36 m^{-1}, with mean value of 0.19 m^{-1}. The results of assessment of OLCI $K_d(490)$ products (regional and global) in respect to the *in situ* data are provided in Table 3, while the scatter plots are presented on Figure 3.

Table 3. Validation of the OLCI K_d (490) products produced using the regional and global algorithms

Product	MPD,%	MAPD, %	RMSE, m^{-1}	R^2
K_d(490)_BS	10.47	16.75	0.08	0.91
K_d(490)_OK2-560	-23.43	25.68	0.11	0.90

Generally, there is a high correlation between OLCI derived K_d (490) estimated from both algorithms and *in situ* data. For the two algorithms, the points of the scatterplots are mainly distributed around the 1:1 line, indicating that most of the satellite-derived K_d (490) values appear to agree with the *in situ* data.

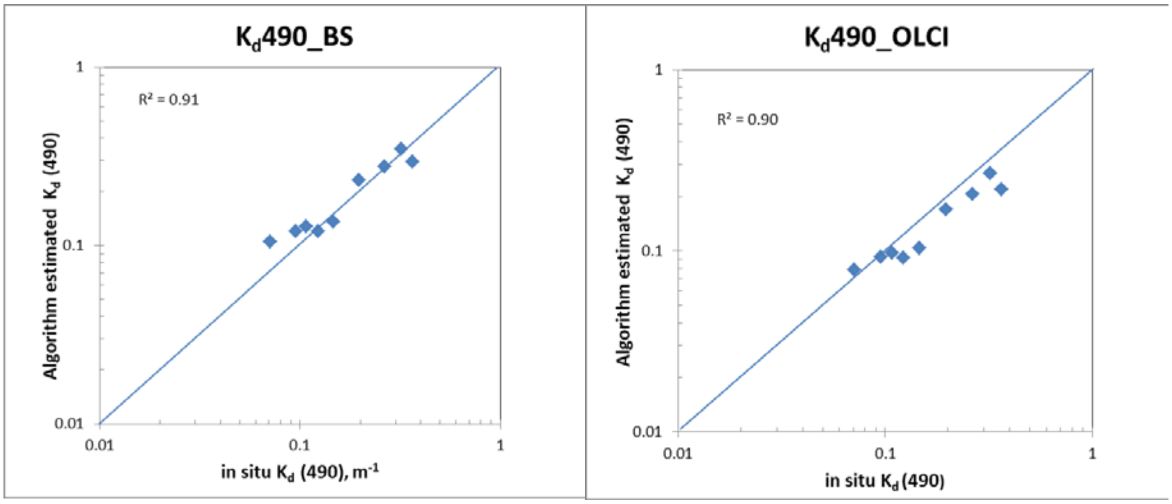

Figure 3. Scatter plots of satellite K_d(490)_BS and K_d(490)_OLCI products versus *in situ* data

The regionally tuned K_d(490)_BS algorithm exhibited the relatively low errors (RMSE=0.08, and MAPD=16.75%) compared to the global. The global K_d (490) algorithm tends to underestimate the *in situ* data (MPD=-23.43%) in contrary to the regional which slightly overestimate the *in situ* records (10.47%). The statistical analysis show that the regional algorithm performed better for K_d (490) estimations in the Bulgarian Black Sea water comparing to the global. The validation results are obtained from limited matchup dataset which makes the statistics barely significant. Further validation exercises are required to continue monitoring of performance of the K_d (490) algorithms in the Black Sea.

3.4 Assessment of the regional algorithm for Total Suspended Matter (TSM) retrieval from OLCI data

The comparison between TSM ocean color products derived from regional (named TSM_BS, TN#14) and global (TSM_NN, Doerffer and Schiller 2007) algorithms and independent *in situ* TSM data are based on a limited number of matchups (N=9). The *in situ* TSM data used in the matchup analysis ranged between 0.13 and 1.94 mg l^{-1} with mean value of 1.04 mg l^{-1}. The results of assessment of OLCI TSM products (regional and global) in respect to the *in situ* data are provided in Table 4, while the scatter plots are presented on Figure 4.

Table 4. Validation of the OLCI TSM products produced using the regional and global algorithms

Product	MPD,%	MAPD, %	RMSE, m^{-1}	R^2
TSM_BS	26.58	59.10	0.28	0.58
TSM_NN	176.61	179.56	0.44	0.31

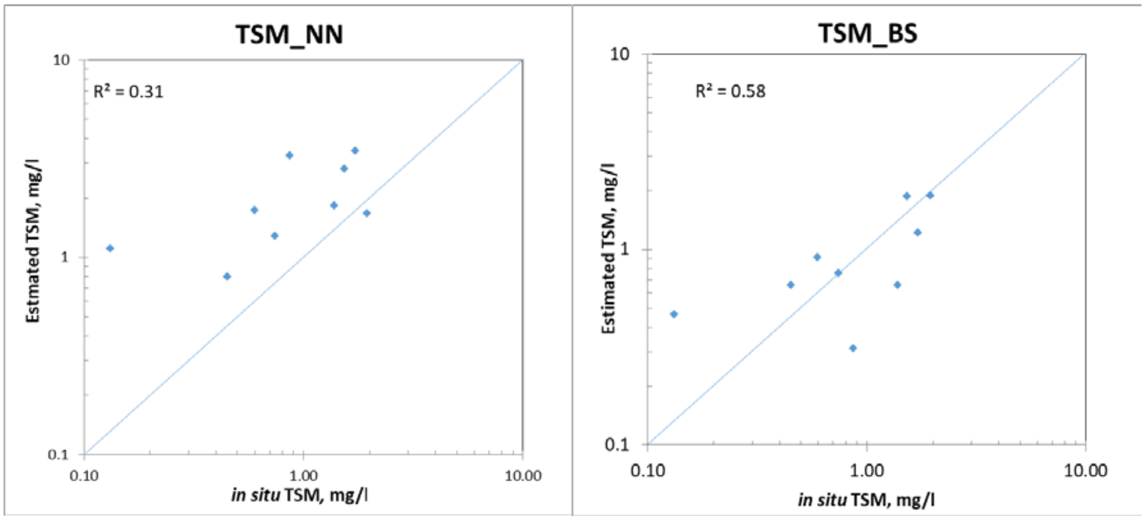

Figure 4. Scatter plots of OLCI TSM_NN and TSM_BS products versus in situ data

The coefficient of determination R^2 varies from 0.31 for TSM_NN to 0.58 for TSM_BS. The TSM values derived from both algorithms overestimate the *in situ* measurements but with different rate. The estimated MPD decreases from TSM_NN (176.6%) to TSM_BS (26.5%). Similarly, MAPD improves from TSM_NN (179.6%) to TSM_BS (59.10%) indicating that the regional algorithms are more effective in reproduction *in situ* TSM for this range of concentrations. RMS ranges from 0.28 mg l^{-1} (TSM_BS) to 0.44 mg l^{-1} for TSM_NN. Although better statistical results were obtained for the regional algorithm, it exhibits uncertainty levels in the TSM estimation, which are incompatible with the expected requirements of the OLCI mission (30%-uncertainty) and user needs. However, the validation results are determined from limited matchup dataset and further validation exercises are required to continue monitoring of performance of the TSM algorithms in the Black Sea.

4. Conclusions

The assessment of regional ocean color products indicates:

- The regional chlorophyll *a* algorithm performed better than the standard operational OLCI algorithms. The higher accuracy (MAPD = 31.65%), fewer underestimations (MPD =−9.15%), a good correlation coefficient (R^2=0.62) confirms the enhancement in retrieving chlorophyll concentrations in the Black Sea based on the regional empirical algorithm.
- The regional ADG 443 empirical algorithm shows lower RMES (0.07 m^{-1}), MPD (4%) and MAPD (14.09%) comparing to the standard OLCI ADG443 algorithm (RMSE=0.11 m^{-1}, MDP=-15.68% and MAPD=17.82%) indicating that the regional empirical algorithm is more effective in reproducing *in situ* absorption coefficient by non-pigmented particles and colored dissolved organic matter at 443 nm (ADG 443 nm) in the Bulgarian Black Sea waters.

- The regionally tuned K_d (490) algorithm performed better than the standard operational OLCI algorithm. The higher accuracy (MAPD=16.75%), lower overestimation (MPD =−10.47) and correlation coefficient close to 1 (R^2=0.91) confirm that the regional empirical algorithm is more effective in reproducing *in situ data.*
- Although better statistical results were obtained for the regional TSM algorithm, it exhibits uncertainty levels in the TSM estimation (MADP=59%), which are incompatible with the expected requirements of the OLCI mission (30%-uncertainty) and user needs.

Results of validation show satisfactory levels of performance of the regional bio-optical algorithms. However, more *in situ* data with improved spatial and temporal coverage is critically needed for further validation exercises of the OLCI ocean color products in the Black Sea.

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Deliverable # TN12: Satellite ocean color data validation, 2020.

Deliverable # TN14: Algorithm development

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