Programme for European Cooperating States (PECS)
ESA contract №4000123951/18/NL/SC

BIO-OPTICS FOR OCEAN COLOR REMOTE SENSING OF THE BLACK SEA (Black Sea Color)

TN10: Analysis and QA of GALATA AERONET-OC data

Workpakage:	*3*	*Data analysis and QA*
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Document Log

Date	*Author*	*Changes*	*Version*	*Status*
04.01.2020	***Slabakova***		***V1.0***	***Draft***
14.01.2020	***Slabakova***	***Revisions***	***V1.1***	***Draft***
21.02.2020	***Slabakova***		***V1.2***	***Completed***

This report summarizes the data quality methods and analyses that were applied to the Galata AERONET–OC data. Additionally, the preliminary results from matchup analysis of OLCI L2 and Galata radiometric data products for the period April 2016 to October 2018 are presented. The validation activities will continue and specific report TN12 "Report on satellite ocean color data validation" planned for reporting period T0+17 will be prepared.

Abbreviations

AERONET - Aerosol Robotic Network

NASA - National Aeronautics and Space Administration

GSFC - Goddard Space Flight Center

Lwn(λ) – normalized water-leaving radiance

QC – Quality Control

FR – Full Resolution

NTC - Non Time Critical

OLCI - Ocean and Land Colour Instrument

RMSE - Rood Mean Square Error

ADP - Absolute Percent Difference

RDP - Relative Percentage Difference

EC- European Commission

1. Background

AERONET-OC is the Ocean Color component of the Aerosol Robotic Network (AERONET, Holben et al. 1998), a federated instrument network and data archive managed by the Goddard Space Flight Center (GSFC) of the U.S. National Aeronautics and Space Administration (NASA), has been developed to support aerosol investigations through standardized instruments and methods (Holben et al. 2001). Similar to AERONET, AERONET-OC (Zibordi et al. 2009a) relies on NASA's commitment for field instruments calibration, data processing and archiving. These activities are complemented by independent actions focused on establishing and maintaining CE-318 modified sun-photometers at coastal sites of interest for individual investigators or research institutions.
Both AERONET and AERONET-OC (Holben et al., 1998; Smirnov et al., 2000; Zibordi et al., 2009a) rely on:

- the use of identical instruments and of a unique measurement protocol;
- the calibration of network radiometers by applying a sole method and laboratory;
- the reduction and quality control of measurements by using a single processing code.

The primary data product of AERONET-OC is L_{wn} at wavelengths suitable for satellite ocean color applications. Key features of AERONET-OC are: 1) near-real time data collection and processing (i.e., within a few hours); 2) use of standardized instruments, calibration procedure and data processing; 3) open access to measurements and products through a specified data policy.
The total number of globally distribute AERONET – OC sites is 26. Two of them (Gloria 44.60N, 29.36 E and Galata 43.045N, 28.193E) are located in the Western part of the Black Sea, which is the region exhibiting the highest environmental stress and range of variability of bio-optical features. Both systems are operated and managed by Joint Research Center of EC, in collaboration with Romanian and Bulgarian research institutions. The present report is focused on data obtained from Galata AERONET–OC site.

2. Glalata AERONET-OC

The AERONET-OC site denominated Galata Platform (see Fig. 1) was established in April, 2014 in the Bulgarian Western Black Sea shelf waters to create time-series of in situ reference data for the continuous validation of satellite ocean color products. The site, operated by JRC in collaboration with the Institute of Oceanology of the Bulgarian Academy of Sciences, is set up on a fixed gas exploration platform owned and managed by Petroceltic Bulgaria, Ltd. The platform is located on the Bulgarian shelf, at approximately 26 km south-east of city of Varna in an average water depth of 30 m (lat.43.045 N, long 28.193E).

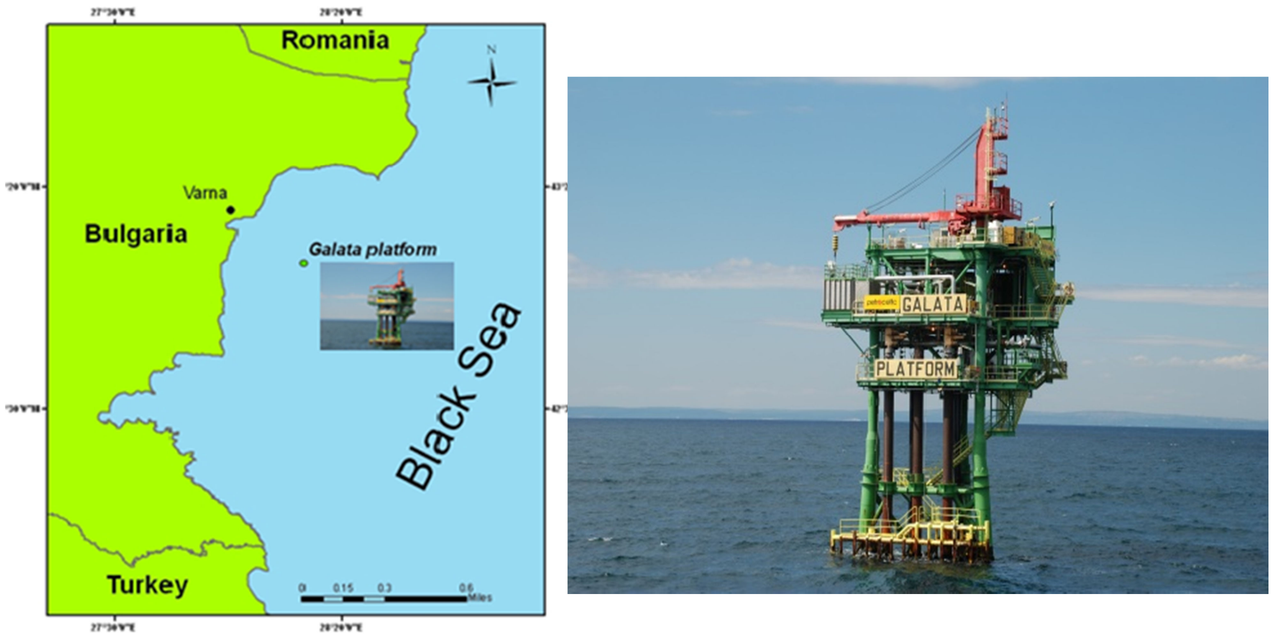


Figure 1. Location of the Galata Platform. The picture illustrates the Galata Platform infrastructure.

3. Galata AERONET OC data QC

The processing and quality control of the data from Galata site are performed in agreement with the scheme presented in Zibordi et al. (2009a).

Data products from AERONET–OC sites determined at different center wavelengths λ in the 412–1020nm spectral region (nominally, 412, 443, 488, 531, 551, 667, 870 and 1020nm), are available at three levels of quality control:

- Level 1.0 – L_{wn} determined from complete in situ measurement sequences;
- Level 1.5 are derived from Level 1.0 data for which:
  - cloud screened aerosol optical thickness data exist;
  - replicate sky and sea radiance measurements exhibit low variance;
  - empirical thresholds are satisfied (e.g., exceedingly negative values or high reflectance in the near infrared).
- Fully quality controlled Level 2.0 data derived from Level 1.5 for which:
  - pre- and post-deployment calibration coefficients exhibit differences within 5%;
  - Level 2 aerosol optical thickness data exist;
  - checks of individual data records according to the algorithm described by D'Alimonte and Zibordi (2006);
  - final spectrum-by-spectrum screening is passed to determine the consistency of $L_{wn}(\lambda)$ spectral shapes.

Level 1.0 and Level 1.5 data are accessible in near real time through AERONET web site (https://aeronet.gsfc.nasa.gov/new_web/ocean_color.html). Level 2 data products are generally available within approximately 1 year by the end of each deployment.

The estimated overall uncertainties affecting AERONET-OC L_{wn} according to the Zibordi et al. (2009a) is 5% in the 412-551 nm spectral range and 7.8 % at 667 nm because of the higher impact of wave perturbations in the red and near-infrared regions.

The quality controlled data obtained from Galata for the period November, 2018 - August, 2019 kindly provided by Dr. G. Zibordi, PI of the Galata AERONET–OC site is presented on Figure 2.

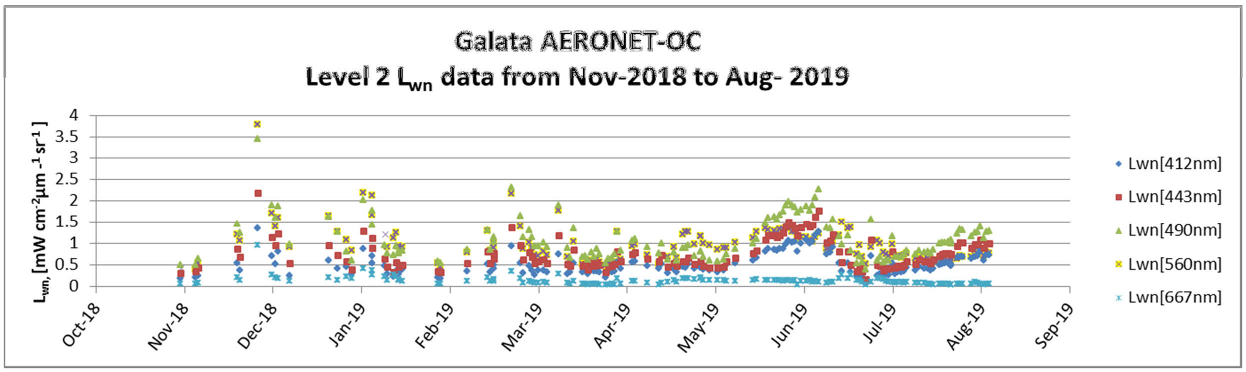


Figure 2. Time series of quality controlled Galata AERONET-OC data for the period November, 2018 – August 2019

4. Assessment of OLCI L2 radiometric data products

In this report the accuracy of OLCI Level-2 radiometric products were assessed based on the in situ data obtained from Galata AERONET OC site for the period April 2016 to October 2018.

4.1 OLCI Data

For the match-up analysis Level-2 data full-resolution (FR 300 m/pixel), mode "Non Time Critical" Processing Baseline 2.23 for the period 26 April 2016 – 29 November 2017 and operational OLCI Level 2 full-resolution (FR 300 m/pixel), mode "Non Time Critical" data after 30 November 2017 to October 2018 over the western Black Sea was downloaded from Copernicus Online Data Access (CODA; REProcessed, https://codarep.eumetsat.int/#/home).

The OLCI spectral reflectance data ρ_w were converted to normalized water-leaving radiance L_{wn} according to

$$L_{wn}=\rho_w E_0/\pi$$

where E_0 is mean extraterrestrial solar irradiance (Thuiller et al., 2003)

4.2 . Galata Aeronet OC data

The data analysis included in this study is based on data obtained from AERONET Ocean Color web site (https://aeronet.gsfc.nasa.gov/new_web/ocean_color.html). All the matchup analyses are based on AERONET-OC Level 2.0 data.

4.3 Methods

The comparison between the two data sets benefitted of 72 matchups for the period 26 April - 29 November 2017 and 40 for the period after 30 November to the end of 2018. The comparison is based on the arithmetic average of valid OLCI full-resolution data calculated over the 3 × 3 – image elements centered on the Galata platform location within time difference of ± 3 h between in situ measurements and satellite overpass. These averages have been retained when data were not affected by any of the main OLCI exclusion flags (EUMETSAT, 2018b).

OLCI L2 primary products were evaluated by means of standard statistical quantities including coefficient of determination R^2, rood mean square error (RMSE), relative percentage difference (RPD) and absolute percent difference (ADP).

The values of RDP and APD are calculated through

$$RPD = \left(\frac{1}{n} \sum_{i=1}^{n} \frac{X_i - Y_i}{Y_i} \times 100 \right)$$

$$APD = \left(\frac{1}{n} \sum_{i=1}^{n} \left| \frac{X_i - Y_i}{Y_i} \times 100 \right| \right)$$

where X_i correspond to satellite data and Y_i indicate the reference Galata AERONET-OC data, while n is the number of match up data points. The RMSE quantifies the error of OLCI data, the relative RPD estimates the deviation between two data sets, and coefficient of determination R^2 indicates the determination coefficient of the linear regression between satellite and in situ data.

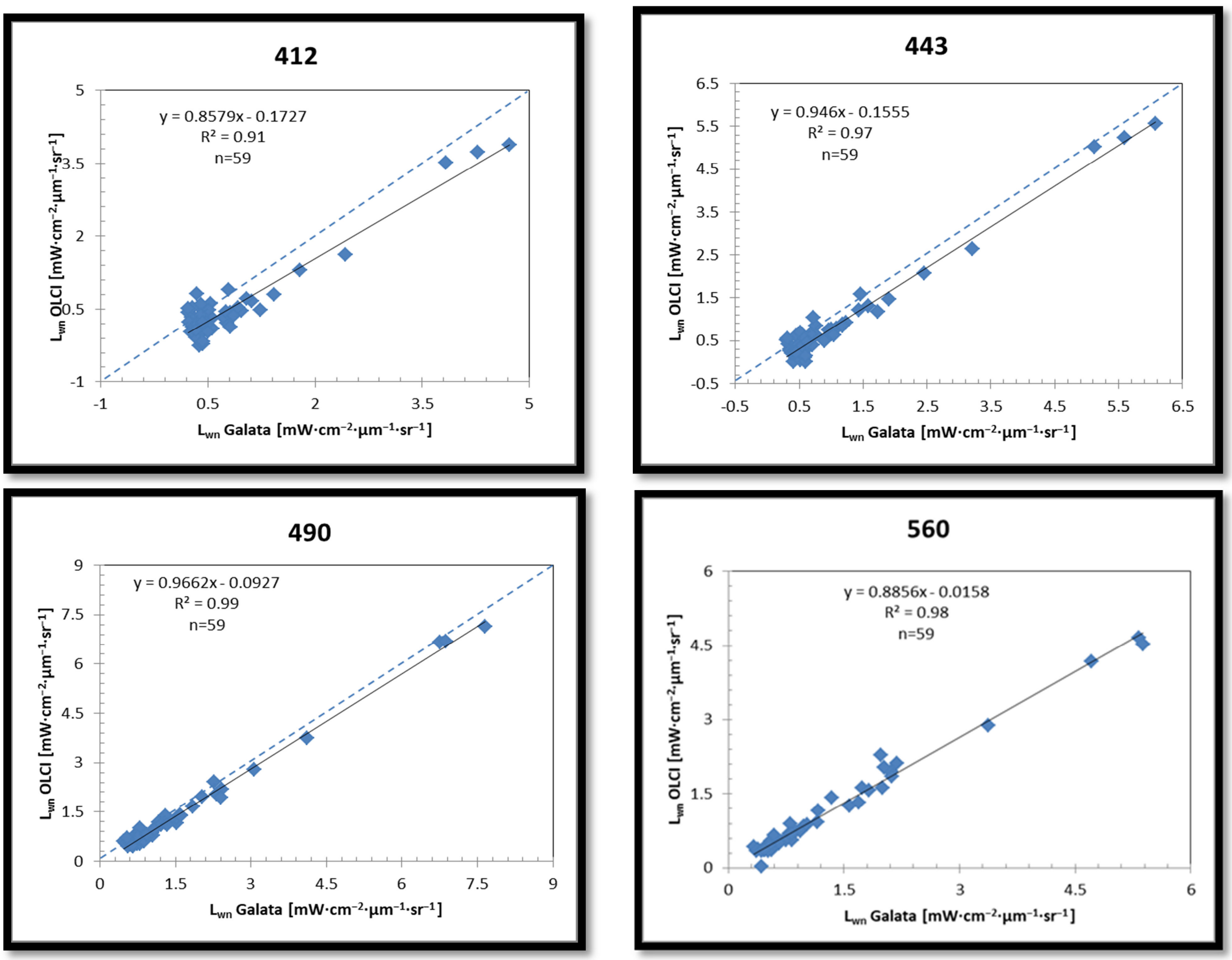
5. Results

The comparison of in situ and satellite L_{wn} spectra have been restricted to the bands for which in situ data exist (i.e., those identified by the center wavelengths at 412, 443, 490, 560, and 665 nm). Two time periods are considered:

I. The reprocessed archive covering from April 2016 to November 2017 time period
II. The period successive to November 2017 up to the end of October 2018.

The results related to the assessment of OLCI primary ocean color radiometric products are summarized in Table 1 and 2, while the scatter plots for each spectral band of OLCI FR data versus in situ AERONET-OC data are presented in Figures 3 and 6.

In general, there is a good correlation between OLCI L_{wn} and Galata records for all the wavelengths for the 1st period. The coefficient of determination R^2 varies from 0.91 at 412 nm to 0.99 at 490, indicating that most of the OLCI data products appears to agree with the in situ data. Still, a significant number of OLCI negative L_{nw} values are observed at 412, 443 and 665 nm. This indicates that OLCI L_{wn} data are likely underestimated. The highest RMSE of 0.0.39 mW $cm^{-2}\mu m^{-1}sr^{-1}$ is determined for L_{wn} at 412nm that considerably decrease to 0.07 for L_{wn} at 665 nm, in agreement with the lower L_{wn} values. The time series of Galata and OLCI radiance data (see Fig. 4) show exceptionally high L_{wm} values for both in situ and satellite data during June 2017 (see Fig. 5). The phytoplankton data collected on 23.05.2017 during an IO-BAS monitoring cruise in the area around Galata platform confirmed the presence of coccolithophore *Emiliana huxleyi* with abundance of 2 265 120 cells/l during the initial phase of the bloom. The full development of the *Emiliana huxleyi* bloom during late spring of 2017 in the Black Sea is clearly visible in the OLCI RGB images (see Fig. 5).



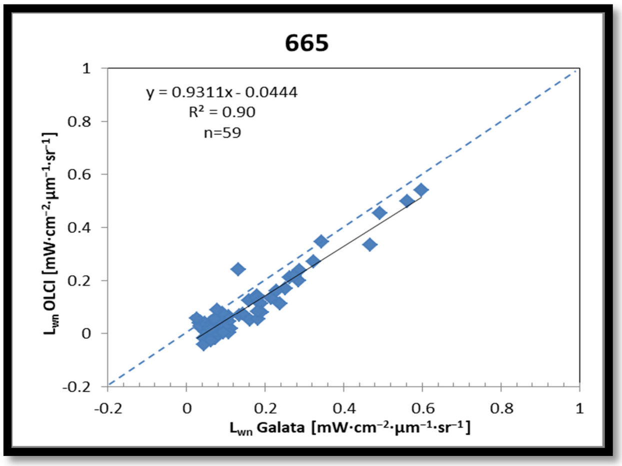
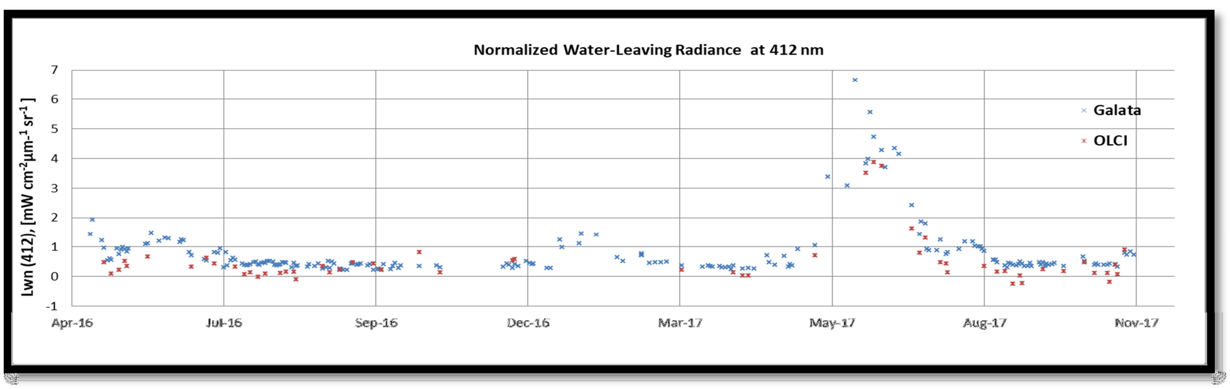
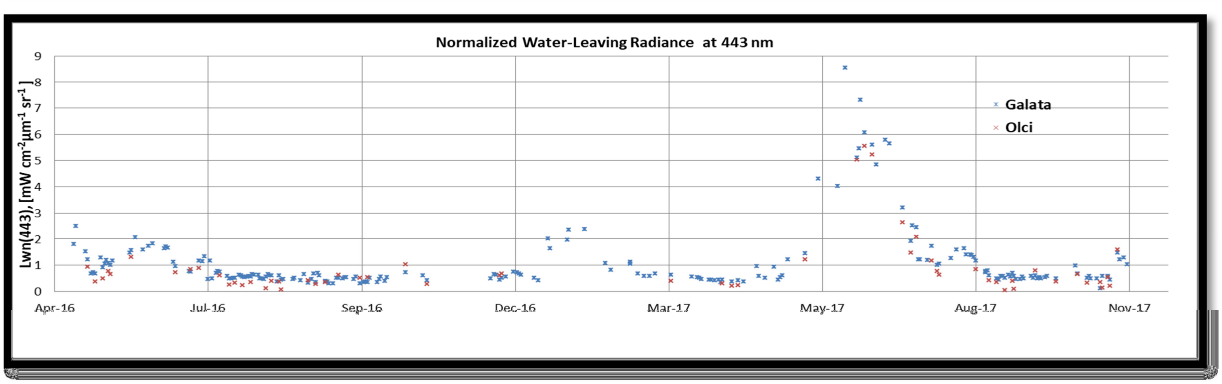


Figure 3. Scatter plots of OLCI and Galata AERONET OC L_{wn} matchup data at 412, 443, 490, 560, and 665 nm for the period 26 April 2016 – 29 November 2017

Table 1. OLCIL L_{wn} reprocessed data statistics over time period April 2016 – November 2017

λ	RPD	APD	RMSE	R^2
12	-42	61	0.39	0.91
443	-23	34	0.28	0.97
490	-11	15	0.19	0.99
560	-14	17	0.23	0.98
665	-48	56	0.07	0.90





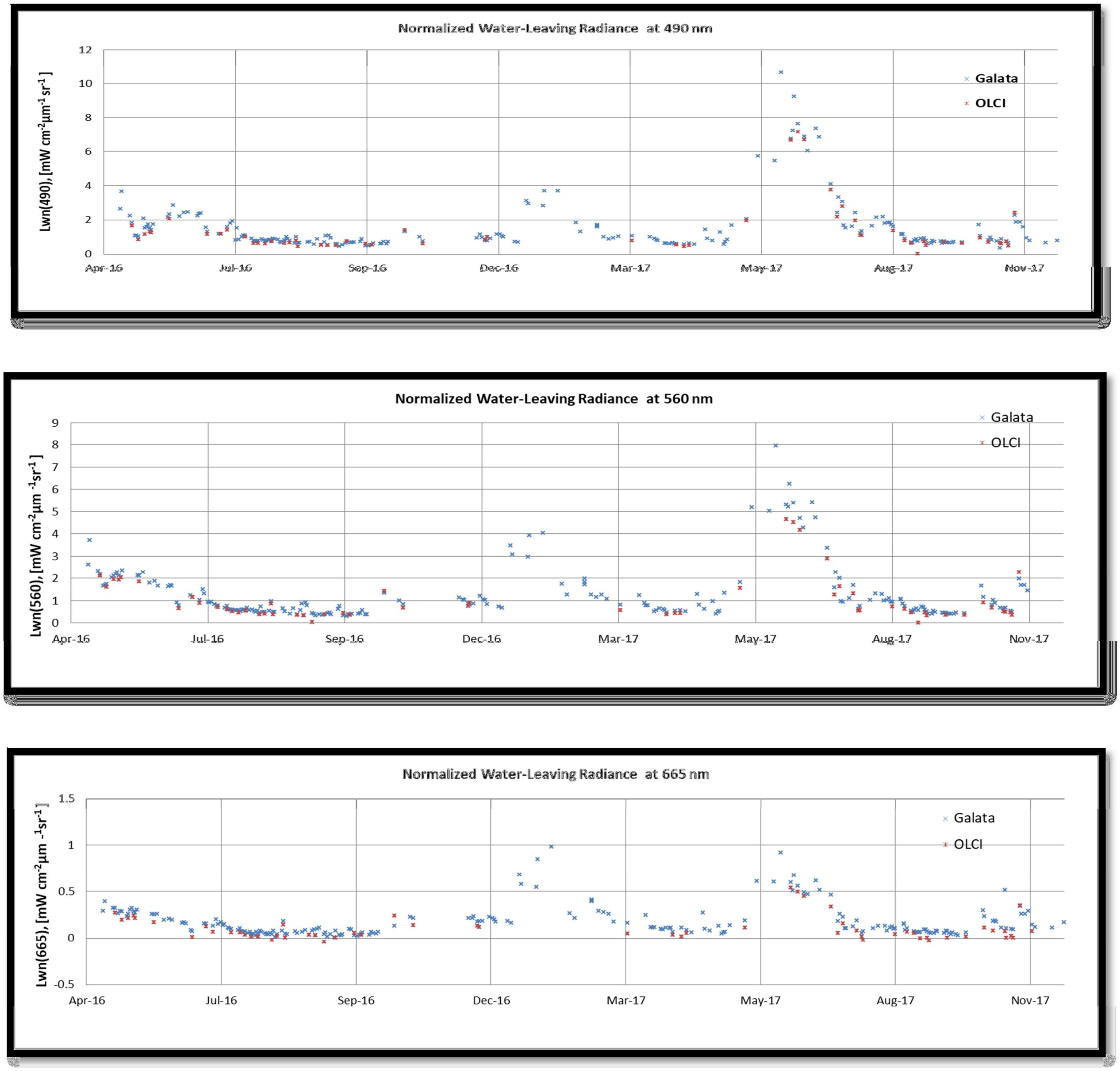
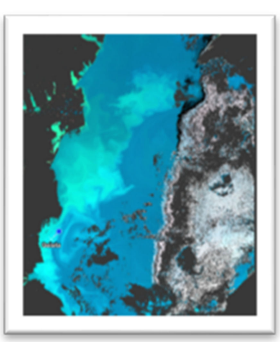
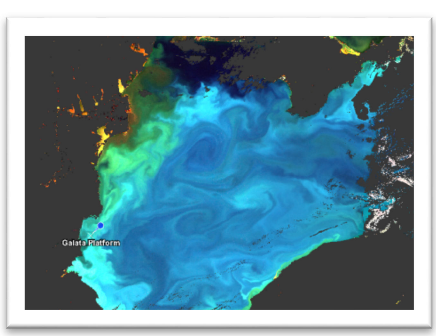
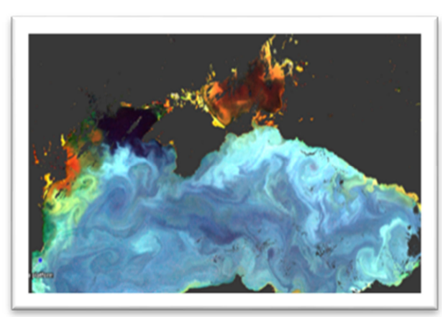


Figure 4. Time series of Galata and OLCI L_{wn} (λ) data

23.05.2017	12.06.2017	13.06.2017
		

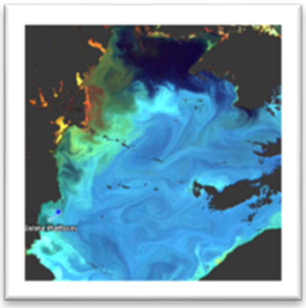
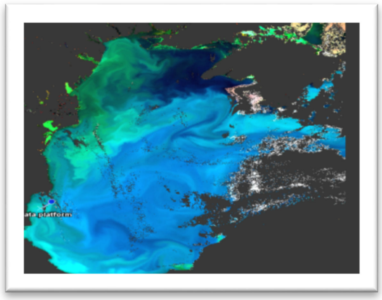
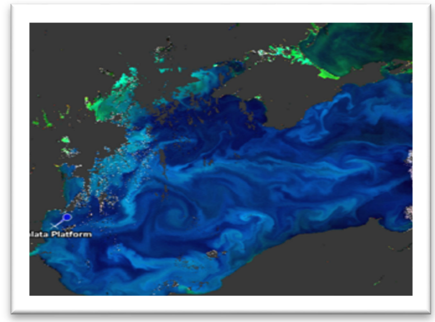
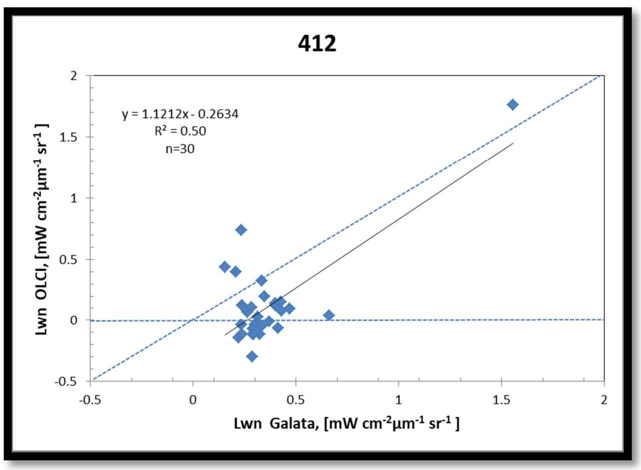
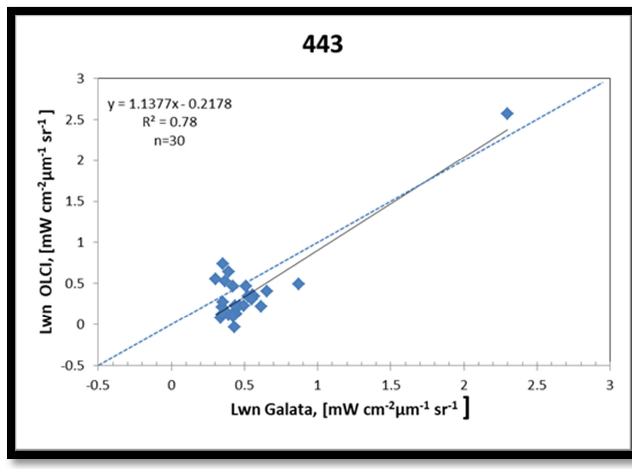
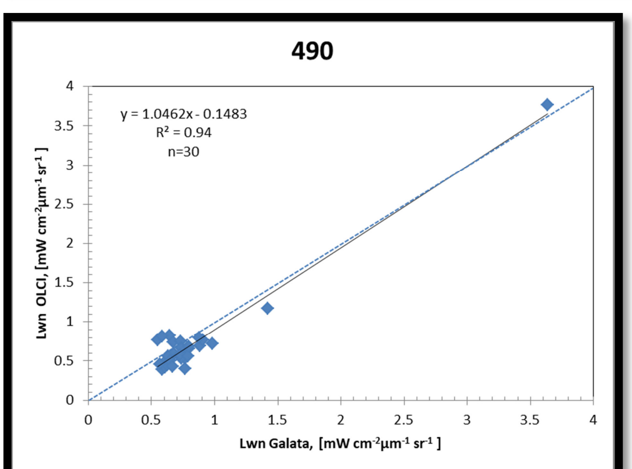
20.06.2017	27.06.2017	13.07.2017
		

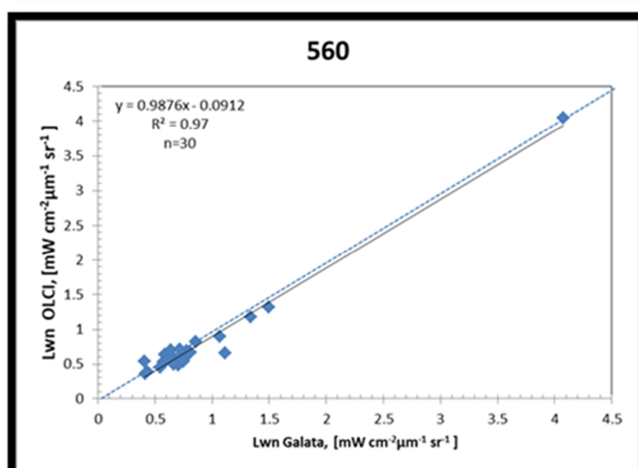
Figure 5. Sentinel-3 OLCI RGB images for 23.05.2017, 12, 13, 20, 27.06.2017 and 13.07.2017

For the second period evaluated in this study, the statistical results from the match up analysis of OLCI and Galata L_{wn} data at 490, 560, and 665 nm are similar to those obtained for the 1st period. The apparent larger differences observed for blue spectral bands (see Tab. 2 and Fig. 5) may result from the high weight of some value.









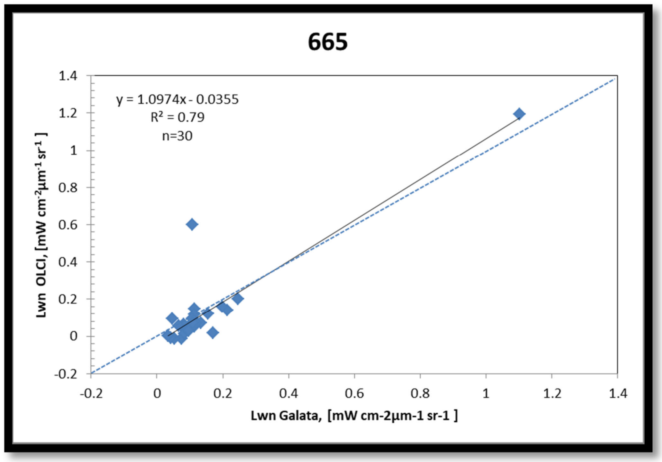


Figure 6. Scatter plots of OLCI and Galata AERONET OC L_{wn} matchup values at 412, 443, 490, 560, and 665nm for the period November 2017 - October 2018

The RPD and ADP values determined from the OLCI L_{wn} matchups at 412 nm is almost 2 times higher from those estimated for the 1st period. The estimated RMSE gradually decreases from 0.35 $mW \cdot cm^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$ at 412 nm to 0.11 $mW\ cm^{-2}\ \mu m^{-1} sr^{-1}$ at 665 nm.

Table 2. OLCI L_{wn} data statistics over time period November 2017 to October 2018

λ	RPD	APD	RMSE	R^2
412	-71	104	0.35	0.50
443	-32	54	0.26	0.78
490	-14	22	0.18	0.94
560	-12	16	0.15	0.97
665	-25	66	0.11	0.79

In general, for both periods the OLCI normalized water-leaving radiances appear underestimated with respect to the in situ data from Galata AERONET-OC site: this is more significant is at 412, 443, and 665 nm.

ACKNOWLEDGMENT

I would like to express my sincere thanks to Dr. Giuseppe Zibordi for providing the quality controlled data from Galata AERONET-OC site and for his continued support and help.

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