EUROLAG9
VENICE 2020

Development and validation of ocean color algorithms for highly complex and dynamic coastal lagoons (Berre and Bolmon) as part of the DCS4COP project

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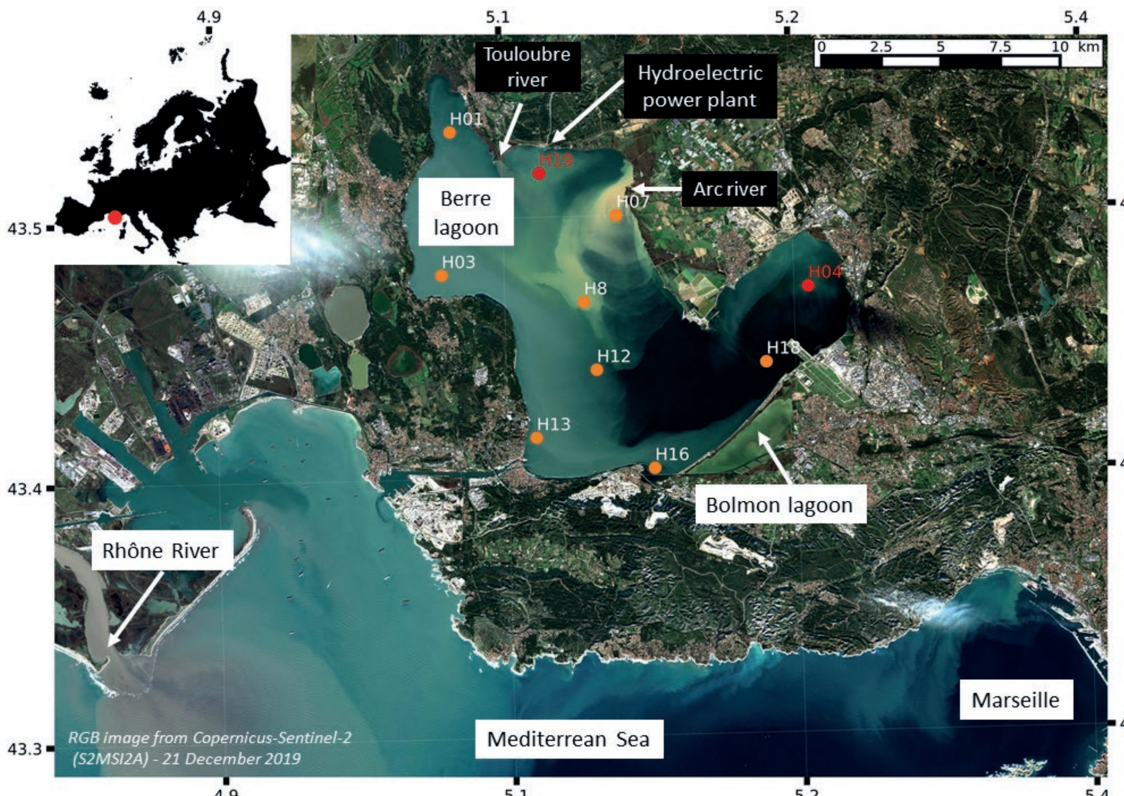

Figure 1: Study area

INTRODUCTION/OBJECTIVES

Satellite ocean color observations are one of the important tools used in water quality monitoring at high spatial and temporal scales. These ocean color products are well-validated in open ocean waters. Due to the complexity of the optically active substances prevailing in coastal and inland waters, the estimation of ocean color products fails frequently. **In the present study, we attempt to specifically design and validate key ocean color products such as concentrations of Chlorophyll-a (Chl-a), suspended particulate matter (SPM) and water Turbidity for costal lagoons, by coupling in situ and satellite data.** This work was conducted in the framework of the DCS4COP project (EU-H2020).

The test sites are two highly complex and sensitive brackish coastal lagoons (Berre and Bolmon) located in the south-east of France. They have been strongly impacted by human-induced pollution and Berre lagoon also receives massive freshwater (containing nitrates and silts) inputs from a hydropower plant. Bolmon lagoon is considered as hypertrophic since many years. Berre lagoon was hypertrophic before 2000, but is on **a restauration trajectory** and now could be characterized as mesotrophic. The water quality of Berre lagoon is monthly monitored by field measurements since 1994 (GIPREB): time series of SPM and Chl-a show the **large temporal and spatial variability** usual in this kind of ecosystem (Figure 3).

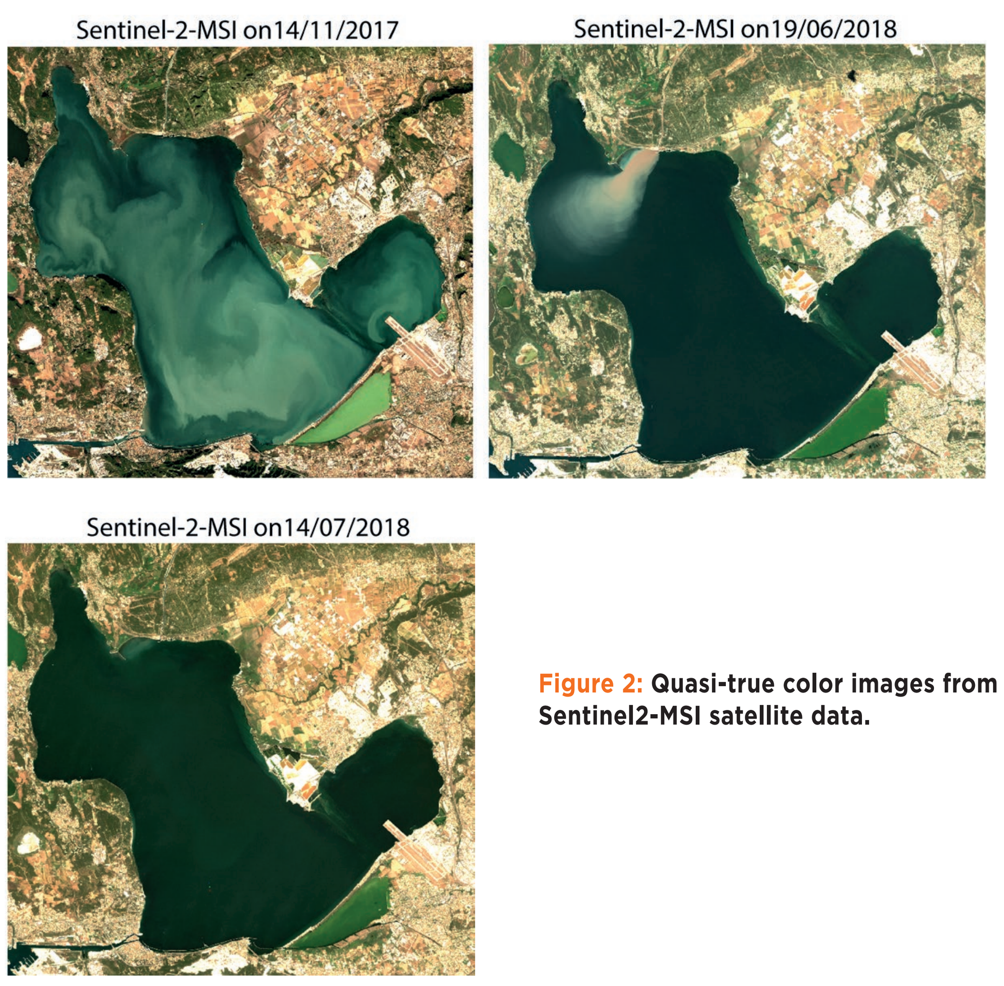

Figure 2: Quasi-true color images from Sentinel2-MSI satellite data.

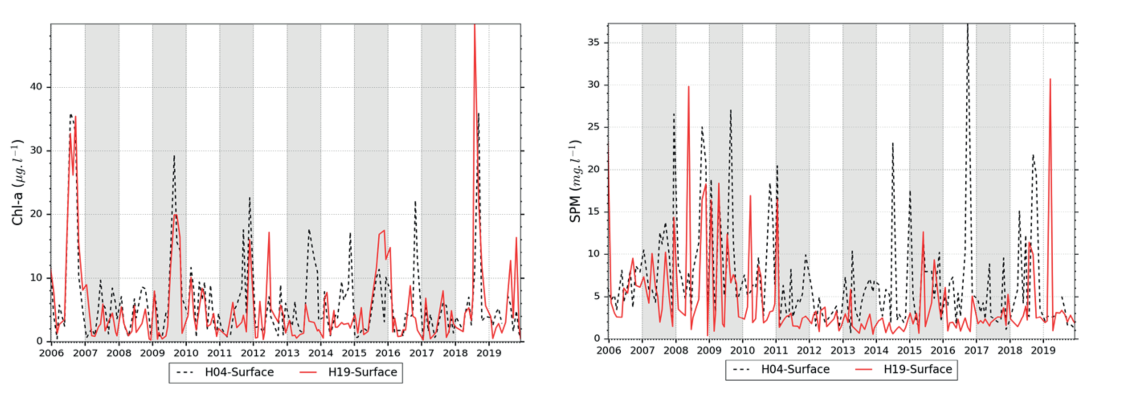

Figure 3: Time series of SPM (mg.l^{-1}) and Chl-a (µg.l^{-1}) concentrations from the monthly sampling data of GIPREB Syndicat Mixte at two different stations (see Figure 1).

DATA AND METHODS

The satellite products were generated from Landsat-8-OLI (NASA), Sentinel-2-MSI (ESA) and Sentinel-3-OLCI (ESA) satellite data (Table 1) considering the ACOLITE-DSF (Vanhellemont, 2019), C2RCC (Brockmann et al. 2016), POLYMER (Steinmetz et al. 2016) and L2-BAC (Moore et al. 2017) algorithms.

In situ data included field measurements of the hyperspectral water reflectance signal (R_{rs}, in sr^{-1}, measured using TriOS RAMSES radiometers), water Turbidity (in Formazin Nephelometric Units (FNU)), Chl-a and SPM concentrations within surface waters (data used to establish regional relationships between these parameters), notably during satellite overpasses for **match-ups** (for the validation of satellite products).

Satellite sensors	Spatial Resolution (m)	Number of spectral bands	Swath width (km)	Revisit delay on Berre
S2-MSI	20	13	290	4 days
S3-OLCI	300	21	1440	1 day
L8-OLI	30	9	185	9 days

Table 1: Satellite specifications.

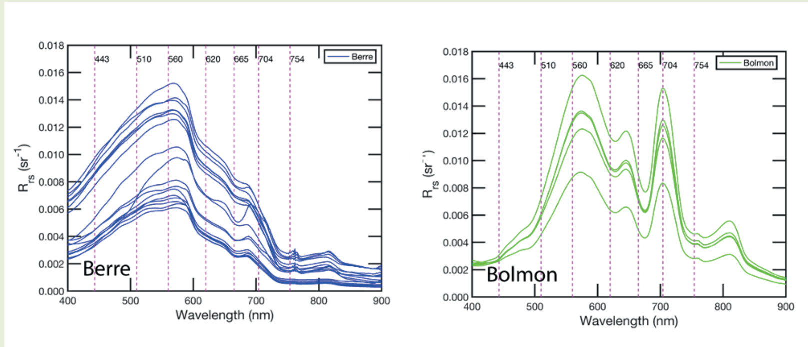

Figure 4: Remote sensing reflectance spectra measured from the Berre and Bolmon from 03/12/2018 to 05/12/2018.

RESULTS

Preliminary results show the failure of standard ocean color products (atmospheric corrections (AC), Chl-a and SPM concentrations, water turbidity, as shown by H2020 SWOS project). Therefore, **regular field bio-optical measurements** are used to successively assess the validity of several atmospheric correction algorithms and develop **regional inversion relationships.**

For S2-MSI, C2RCC and Polymer perform better validation results compared with in-situ R_{rs}. For S3-OLCI, the BAC algorithm shows comparable R_{rs} values with the in-situ data in Berre and Bolmon (figure 5). Based on field measurements, a linear relationship has been developed between SPM and Turbidity (figure 6- A); linear relationships between Turbidity and R_{rs} have been established for S2-MSI (figure 6-B) and S3-OLCI (figure 6-C).

The linear relationships are applied to different satellite data (Sentinel-3-OLCI and Sentinel-2-MSI) recorded on different days after applying atmospheric corrections. BAC (OLCI) and POLYMER (MSI) atmospheric correction algorithms **provide satisfactory and consistent results** in Berre and Bolmon (figure 7).

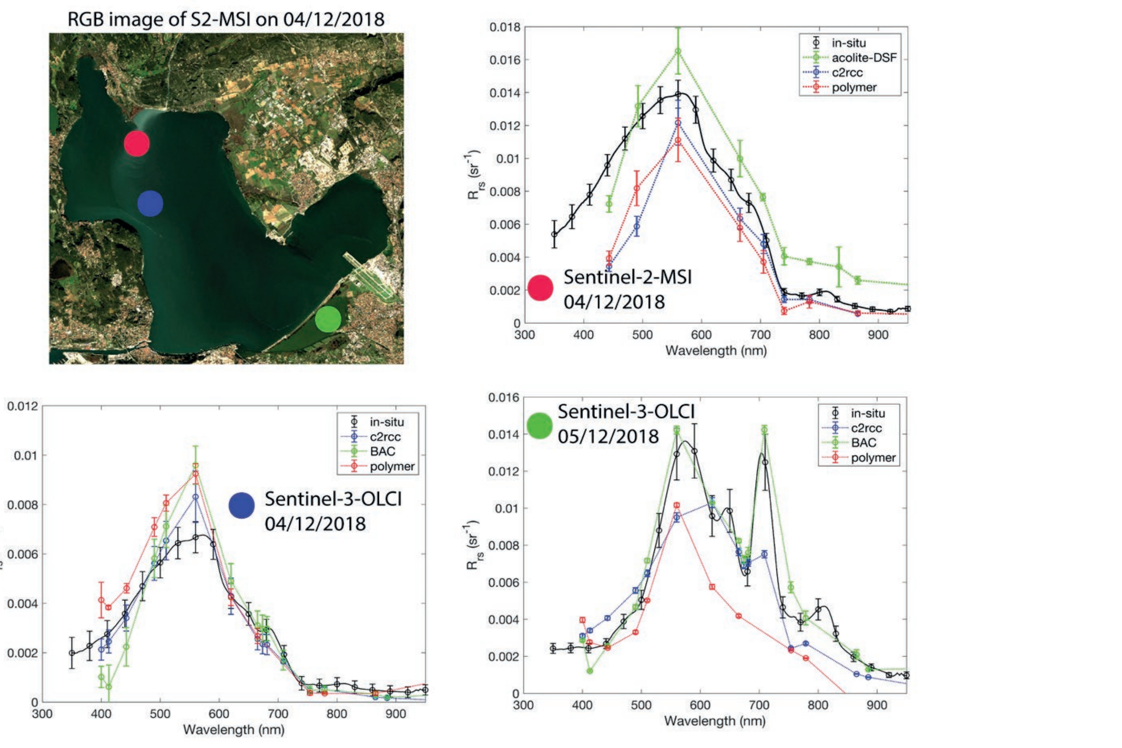

Figure 5: Examples of validation of atmospheric correction algorithms based on match-ups between S3-OLCI and S2-MSI satellites and in-situ radiometer.

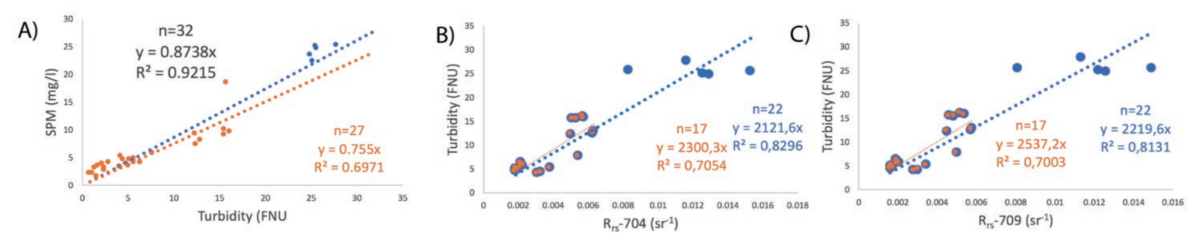

Figure 6: Local empirical relations (SPM vs Turbidity and Turbidity vs R_{rs} (704 and 709 nm)). The blue dots are the points from Berre and Bolmon and orange dots are the points from Berre.

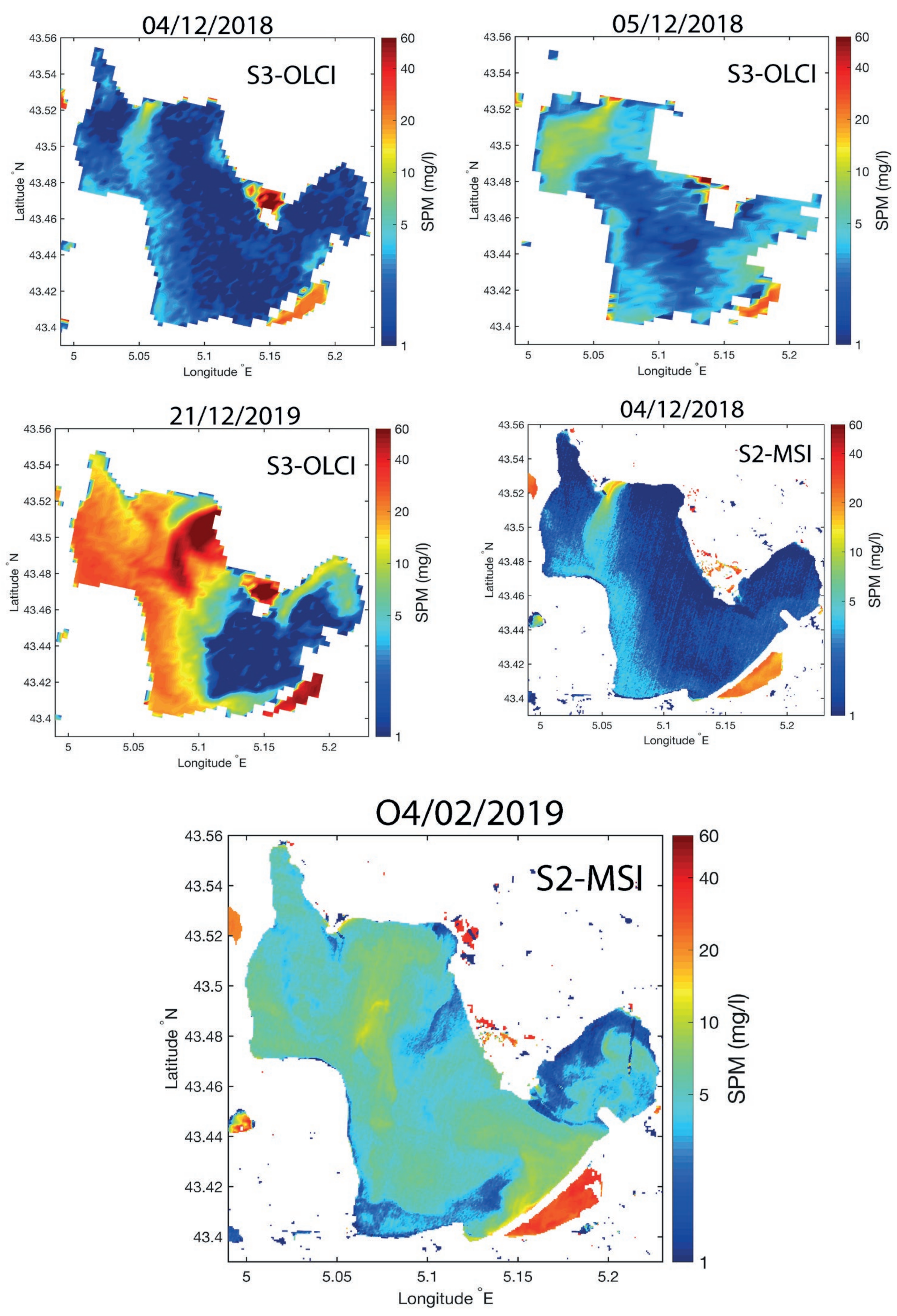

Figure 7: SPM (mg.l^{-1}) maps retrieved from Sentinel-3-OLCI (Baseline Atmospheric Correction) and Sentinel-2-MSI (Polymer Atmospheric Correction) satellite data.

CONCLUSIONS

- Based on match-ups with in situ water reflectance measurements, **the best atmospheric correction algorithms were identified** in the complex Berre and Bolmon lagoons: BAC for S3-OLCI and POLYMER for S2-MSI.
- A turbidity algorithm (turbidity versus water reflectance) has been developed for both Berre and Bolmon lagoons (with 22 data points) ; turbidity and SPM show a linear relationship. This work therefore **allows generating spatial maps of SPM concentrations and water turbidity** in these lagoons using S2-MSI and S3-OLCI satellite data.
- For the moment, no satisfactory algorithm for Chl-a concentration was established (not enough data).
- An important conclusion of this work: for accurate retrievals of satellite ocean color products in complex lagoon waters, **standard ocean color algorithms require a regional adaptation, taking into account the variability of the water bio-optical properties in each lagoon** (i.e. considering the nature of suspended particles, phytoplankton diversity, and the ratio between algal and non-algal-particles).

PERSPECTIVES

- More in-situ data and a larger range of turbidity and Chl-a values will improve the calibration of regional algorithms in these coastal lagoons.
- A validation work will be conducted with in situ data from GIPREB monitoring and all available satellite data.
- One the main goals of the **DCS4COP project** (www.dcs4cop.eu) will be to provide to end-users multi-sensors satellite products previously **validated** (i.e, products associated to minimum and well-documented uncertainties), useful for the **operational monitoring of sensitive coastal zones.**

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