Water quality of lakes over Europe using Sentinel-2; Atmospheric Correction and Validation

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Plan

- Rationale and motivation
- Atmospheric Correction (AC) – final algorithms
- Secchi disk depths, turbidity and Chlorophyll-a derivation
- Impact of AC on Chl-a retrieval
- Conclusions/perspectives
Main targets for continental waters monitoring

• Environmental regulations (National, Water Framework Directive, MFSD, BW..)
• Fresh water management / Water energy management

Sentinel-2 opens the door to « ocean colour » at suitable spatial scale (water surfaces less or equal 0,5 km2)

Challenges
Atmospheric corrections, optical properties retrieval in very different waters, land/water optical contamination, ...

In preparation to S2, ACRI-ST (and partners; Veolia, EDF, NA countries…) is working with Landsat 7/8 for Coastal Zones and Inland Waters

Thematic works are done within
• SIRHYUS project led by Veolia (support :French Industry Ministry) - IW
• FP7-MEDINA project – CW

IT works are done within FP7-SenSyf project
Atmospheric Correction (AC) – final algorithms

Surface reflectance

Rayleigh

Aerosol

Wavelength (μm)

Reflectance

B G R NIR MIR

Diffusion - Rayleigh

\[ \rho_{\text{Rayleigh}}(\lambda) = \rho_{\text{Rayleigh}}(\lambda_0) \times \left(\frac{\lambda}{\lambda_0}\right)^{-1} \]

Diffusion - Aerosol

\[ \rho_{\text{Aerosol}}(\lambda) = \rho_{\text{Aerosol}}(\lambda_0) \times \left(\frac{\lambda}{\lambda_0}\right)^{-\epsilon} \]
\[ \rho_{\text{abs,corr}} - \rho_{\text{Ray}} = \rho_{\text{aero}} + t_d \cdot \rho_{\text{surf}} \]

### Sea Side
- No (surface) marine signal in the PIR
- \( \rho_{\text{abs,corr}} - \rho_{\text{Ray}} = \rho_{\text{aero}}(\text{PIR}) \)
- \( \rho_{\text{aero}}(\lambda) \) estimated from 2 bands
- Blind fit on a classical \( \lambda^{-\varepsilon} \) law (e.g. GOMOS) mixed with marine signal

### Land Side
- Dark pixel in the blue and
- guess-estimate of \( \rho_{\text{aero}}(\lambda) \) law (Chavez 88)
- Dark Dense Vegetation + knowledge of \( \rho_{\text{aero}}(\lambda) \) dependency for 2 wavelengths (Remer, SMAC, MACCS..)
- Spatial consistency (QUAC)
- Temporal variability over stable targets (Hagolle)
- Radiative Transfer Computations FLAASH
Atmospheric Correction (AC) – final algorithms

\[ \rho_{\text{abs_corr}} - \rho_{\text{Ray}} = \rho_{\text{aero}} + t_d \cdot \rho_{\text{surf}} \]

Sea Side

- No (surface) marine signal in the PIR

Land Side

- Dark pixel in the blue and guess-estimate of \( \rho_{\text{aero}}(\lambda) \) law
- Dense Vegetation + knowledge of \( \rho_{\text{aero}}(\lambda) \) dependency for 2 wavelengths (Remer, SMAC, ...)
- Temporal variability over stable targets (Hagolle)
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Coastal/inland waters

1. **Screening** of the whole scene to find out the darkest MIR pixel (Percentile 1)
2. **Building** of each \( \varepsilon \)-power law spectrum with the reference MIR pixel and the darkest pixel of each band
3. **Selection** of the minimum spectrum (no band is overcorrected)

Make use of the variability of the landscape
Verification has been done on the « étang de Thau » area that offers a variety of landscape.

Identification of stable targets after atmospheric correction.

Red: stable
Blue: unstable

Selection of targets for AC evaluation.
Atmospheric Correction (AC) – final algorithms evaluation

Target stability

One target with AC applied to Landsat 7

Same target with AC applied to Landsat 8

Very good stability

Low level of « unstability » (here for instance with B2)
Algorithm for Chlorophyll-a has been derived after a complete data analysis (data has been provided by EDF and ONEMA – some from Veolia in the frame of Sirhyus project):

First, 110 matchups of Secchi disk depths have allowed to derive formulae for three classes:

- **Class 1.1**: G level high
- **Class 1.2**: (G+R) level high
- **Class 1.3**: G level low

**Secchi disk depth**

**Estimation de la profondeur du disque de Secchi**

\[ R^2 = 0.808 \]
Second, 68 matchups of turbidity (NTU) have allowed to derive formulae for two classes:

\[
turbidity = f(\text{classe, visible bands (B,V,R,NIR), lake depth, Secchi disk depth})
\]
Lastly, 156 matchups of Chlorophyll concentrations have allowed to derive formulae for three classes:

\[ \text{Chla} = f(\text{classe, visible bands (B,V,R,PIR), turbidity}) \]
Application of AC+ Chlorophyll retrieval

Lac de Sainte-Croix

No visible adjacency effects

Lac de Sainte-Croix
Elements of validation on Carcès lake

Carcès lake is the water reservoir for Toulon managed by Véolia

**Image Sat: 01-07-2007**

**Mesure: 30-06-2007**

Veolia: 7,47 μg/L

**Image Sat: 05-08-2009**

**Mesure: 30-07-2009**

Veolia: 7 μg/L

Veolia: 6 μg/L

Veolia: 6 μg/L

Veolia: 6 μg/L

**Image Sat: 17-03-2010**

**Mesure: 18-03-2010**

Veolia: 2 μg/L

Veolia: 1 μg/L

Veolia: 4 μg/L

Veolia: 3 μg/L

Veolia: 2 μg/L

Veolia: 10,49 μg/L

Veolia: 8 μg/L

Veolia: 6 μg/L

Veolia: 6 μg/L

Veolia: 2 μg/L
**Summary**

- **Atmo. Corr. 1**: All wavelengths used
- **Atmo. Corr. 2**: Two wavelengths used
- **Secchi depth**, **Turbidity**, **Chlorophyll**: Propagation of errors

**Diagram:**

- Wavelengths: B (Blue), G (Green), R (Red), NIR (Near Infrared), MIR (Mid Infrared)
- 0.4 to 2.0 um wavelength range
The fluctuations in AC has been propagated into the algorithm of Chlorophyll determination.

The fluctuations in AC impacts by about 10% the chlorophyll retrieval.
Availability
from May 2013 – updated every day

Spatial coverage
presently limited to 650 lakes/reservoirs for testing purpose

Data used
Landsat 7/8 (in preparation to Sentinel-2)

Algorithms
Atmospheric correction
Surface Chlorophyll concentration (4 types of waters) – ACRI-ST

Eye_On_Water: http://eyeonwater.eu

- Display and navigation are supported by Open Street Map
- Largest symbols point toward a more recent information (from which iso-value contours are computed)
Color codes are following the standards state/pressure from De Bortoli et Argillier (2008)

Quality levels are depending on surface chlorophyll concentrations and lakes depths
The tool is presently used for validation to detect temporal and/or spatial artifact.
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Conclusions

Atmospheric correction
• Use of the mixed landscape (water + land) to derive (robust) atmospheric correction
• Reasonable assumption is stability of aerosols over one scene
• Aerosols absorption not considered
• Adjacency effects not considered (has to be evaluated and considered in a quality indicator)

Chlorophyll derivation
• Already operational and under large scale evaluation
• Adaptation to Landsat-8 done
• Quality of in situ data needs to be better described

Operational system
• Fully (and easily) adaptable to Sentinel-2
Validation
We are in a process of setting up a validation “club” for the eyeonwater.eu open to
• Scientists
• Institutions in charge of WQ monitoring
• Large public
To get feedback on the site, validation material, in situ truth

If you are interested you are welcome ! (send a mail from the site)

Operational system
We are fully open to implement and run other algorithms (AC and WQ) for cross-evaluation
and improvements of the system.

For both aspects, if you are interested you are welcome !
(send a mail from the site)
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Thank you for attention

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