Atmospheric correction in the CERTO project

Water Quality Continuum Atmospheric Correction Workshop
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Introduction: the CERTO project

Copernicus Evolution: Research for harmonised Transitional water Observation

- Study and develop harmonized water quality products in transitional waters
- Develop a prototype system designed to be applicable across Copernicus services (Copernicus Marine, Copernicus Climate Change, and Copernicus Land)
- Focus on six case study sites across Europe

Main components of the project:
- In-situ data gathering
- Water optical classification
- Atmospheric correction study and improvement
- Develop indicators that are useful to end-users and stakeholders
- Demonstration to end users

https://certo-project.org/
The Atmospheric Correction WP in CERTO: overview

Objective: evaluate and optimize atmospheric correction in transitional waters, in view of harmonizing the methods from inland to coastal waters (Use of Sentinel-2 MSI and Sentinel-3 OLCI data)

- Evaluation of various atmospheric correction schemes in transitional waters; selection for prototype development
- Improving atmospheric correction
  - Bathymetry effect detection and correction
  - Improve adjacency effect correction
  - Focus on Polymer improvements
  - Involve radiative transfer simulations and in-situ data
In-situ data from CERTO campaigns

+ matchups from the Solar tracking radiometry platform being integrated (automated So-Rad data, PML)

- Tagus estuary: 2 OLCI matchups, 1 MSI matchup
- Curonian lagoon: 3 OLCI matchups, 1 MSI matchup
- Venice lagoon: 7 OLCI matchups, 8 MSI matchup
- Elbe estuary: 0 OLCI matchups, 1 MSI matchup
- Tamar Estuary: 0 OLCI matchups, 0 MSI matchup
Validation exercise

• First validation conducted in 2020 using Aeronet-OC data from Venise AAOT which showed best performance by Polymer
• Now updated with CERTO campaigns data and PML So-Rad data
• Algorithms:
  • C2RCC
  • Polymer with current CERTO modifications (modifications presented later)
  • ACOLITE
  • iCOR not included in this presentation, to be added for final evaluation
• Insufficient matchups for conclusive results; historical data are being added to the analysis
OLCI - CERTO campaigns

- Matchups dominated by Venice lagoon
- Best quality by C2RCC
- Underestimation by Polymer
MSI – CERTO campaigns

• Matchups dominated by Venice lagoon
• Best accuracy by ACOLITE
• Best correlation by Polymer
Polymer updates

• Added an uncertainties propagation mechanism:
  • TOA uncertainties, propagated to water reflectance (equivalent to Monte Carlo uncertainties)
  • Uncertainties induced by model inversion

• Water model update: better account for highly turbid waters
  \( \rightarrow \) Switch to increase of mineral particles when chl > 10mg/m³
  \( \rightarrow \) Avoids introducing a third parameter to the water reflectance model

• Added a new first guess: test several points of the cost function instead of a single fixed point
  \( \rightarrow \) impact on stability, eg in Curonian lagoon

• Added band 1020 for atmospheric correction (OLCI)
  (these updates are not yet publicly released)
Impact of Polymer modifications on Curonian lagoon (S3B OL 1 EFR____20200604T090813)

Improved stability
Impact of Polymer modifications on Gironde estuary (S3A OL 1 EFR 20170123T102913)

Reduced the underestimation of (very turbid) water reflectance
Bathymetry effects (bottom visibility)

• Bottom visibility impacts the observation of water colour
• Depends on the bathymetry, on the tide height, and on the water optical properties
• Can be estimated using multi-temporal and multi-spectral measurements, for clear waters (Wei et al, 2020). Can it be applied to transitional waters as well?
• Objectives:
  1. Detect and mask out pixels affected by bottom visibility, first in the inter-tidal zone, then in the sub-tidal zone
  2. If possible, provide bathymetry and seabed albedo
Bathymetry effects

- Generic method for estimating bathymetry effects from Sentinel-2 timeseries. Requires sufficient tidal amplitude and external water level information
- **Bathymetry effect detection** (correlation of reflectance with water level)
- Bathymetry and seabed albedo inversion, assuming spatial homogeneity of water IOPs
- Inversion of spectral seabed albedo and NDVI

<table>
<thead>
<tr>
<th>Site</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curonian lagoon</td>
<td>✗</td>
</tr>
<tr>
<td>Elbe estuary</td>
<td>✓</td>
</tr>
<tr>
<td>Razelm-Sinoe lagoon</td>
<td>✗</td>
</tr>
<tr>
<td>Tagus estuary</td>
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</tr>
<tr>
<td>Tamar estuary</td>
<td>✓</td>
</tr>
<tr>
<td>Venice lagoon</td>
<td>✓</td>
</tr>
</tbody>
</table>

**MSI timeseries processed with ACOLITE**

Calculate correlation between reflectance and $\exp(-k.z)$  
(max. $R^2$ over multiple $k$, and multiple bands)  
**Note:** this regression is insensitive to an offset on $z$.  

1) Seabed visibility detection (threshold)  
2) Deep pixel identification

Water level (per-scene)

Seabed visibility mask

Seabed albedo and depth inversion (known seabed spectral albedo model: sand)

Bathymetry and albedo scale

Seabed spectral albedo estimation from known depth

Seabed spectral albedo and NDVI

Site Applicability
Bathymetry effects: Venise Lagoon

Consistent decoupling between bathymetry and seabed albedo
Bathymetry effects: Venise Lagoon (validation)

Our bathymetry from S2 timeseries

Venice lagoon bathymetry from Zaggia et al 2017
Recommendations: AC for transitional waters

• Good to have consistent methods and open source tools for validation exercises. Support EUMETSAT initiative in this regard.

• Importance of in-situ data in complex waters

• Additionally consider consistency verifications (spatial or temporal features) which do not require in-situ data, in addition to traditional validation:
  • Impact of sun glint
  • Impact of observation geometry
  • Water/atmosphere decoupling
Thank you

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