Atmospheric Correction of DESIS HSI Over Dark, Aquatic Targets and Applications for Chesapeake Bay Water Quality

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Objective: Estimate concentrations of water-borne constituents with algorithms for inverting OC

OC derives from Inherent Optical Properties (IOPs; absorption and scattering of light in the medium)

Constituent properties (phytoplankton biomass, sediment, dissolved materials, e.g. in/organic carbon) determine the IOPs

High spectral resolution provides more information about the IOPs and constituents (e.g. phytoplankton type, age-origin of dissolved carbon)

High spatial resolution shows fine-scale features and extends more effectively near/inshore
The OC Challenge

Water is dark. <10% of the VIS/NIR/SWIR signal reaching orbit over water is from water. >90% is atmosphere and sea-surface reflectance. Ocean color (OC) remote sensing requires high radiometric accuracy and SNR compared with land targets.

OC changes rapidly over space and time.

Absorbing aerosols can have a profound impact on OC retrievals, are difficult to retrieve over water, and vary spectrally over space and time.

Typical atmospheric correction schemes for satellite imagery over land are not generally sufficient to get accurate estimates of water leaving radiance/reflectance.

Radiometric validation for DESIS is typically performed over land targets (i.e. RadCalNet, e.g. Alonso et al. (2019), in which AOT was not retrieved as per L2A).

Image: NASA OceanColor Web Gallery
Atmospheric Correction (AC) for Ocean Color (OC)

Over water, atmospheric path reflectance is typically retrieved from predetermined wavebands in the NIR/SWIR assuming zero water-leaving radiance (i.e. high absorption by H$_2$O and constituents).

Dark Spectrum Fitting* (DSF) dynamically identifies the darkest pixels in each band in a scene to generate a "dark spectrum" from which aerosol optical thickness, path transmittance, and spherical albedo are estimated from 6SV-generated continental and maritime aerosol models/LUTs.

By selecting the lowest non-zero AOT(550), this approach avoids overcorrection common in complex waters when using typical approaches.


Region of Study: Chesapeake Bay

- Largest estuary in North America
- Highly developed with abundant aquaculture and recreation
- Water quality is significantly impacted (Harmful Algal Blooms, high turbidity, shellfish bed closures, eutrophication, etc.) and improved methods for synoptic monitoring to meet Total Maximum Daily Loads are needed
- Chesapeake Bay working group connects remote sensing scientists to resource managers
- NASA AIST project is developing artificial intelligence approaches to retrieve water quality products in the Bay from imagery such as DESIS
Preliminary Findings; Reality Check

Starting in July 2021, we are developing a module to process L1B/L1C DESIS HSI imagery to atmospherically corrected (DSF) L2R surface reflectances in Acolite

https://github.com/acolite/acolite; Quinten Vanhellemont, RBINS
Validation Sites (tentative)

- Chesapeake_Bay (New node!)
- 1 Venise
- 2 Galata Platform
- 3 Gloria
- 4 Helsinki Lighthouse
- 5 Gustav Dalen Tower
- 6 Palgrunden
- 7 Thornton E-power
- 8 LISCO
- 9 Lake Erie
- 10 WaveCIS Site CSI 6
- 11 USC SEAPRISM 2


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And references therein...

### Table 3

Spatiotemporal collocation choices implemented in different validation studies.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number of elements in satellite extract, quantity reported</th>
<th>Temporal window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zibordi et al. (2009a)</td>
<td>3 × 3, mean</td>
<td>±2 h</td>
</tr>
<tr>
<td>Zibordi et al. (2018)</td>
<td>3 × 3, mean</td>
<td>±2 h (70% ±1 h) for AERONET-OC, ±4 h for BioMap (50% ±2 h)</td>
</tr>
<tr>
<td>Bailey and Weddell (2006)</td>
<td>5 × 5, filtered mean Bailey and Weddell (2006), Filtering: Value is within +/- 1.5 <em>standard deviation plus mean, with standard deviation evaluated on the x</em>x pixels window.</td>
<td>±3 h for homogenous water masses</td>
</tr>
<tr>
<td>Volpe et al. (2019)</td>
<td>3 × 3; median; 1 km resolution on the equiangular grid covering</td>
<td>Same day for L3</td>
</tr>
<tr>
<td>Qiu et al. (2017)</td>
<td>3 × 3; mean of the pixel that pass: differences between the value of each valid pixel and their mean in the box were limited to twice the standard deviation to eliminate outliers</td>
<td>±12 h or ±3 h (ship) and ±2 h (AERONET-OC); sensitivity study for ±0.5, ±2, ±3, ±4, ±6 and ±12 h</td>
</tr>
<tr>
<td>Cai et al. (2010)</td>
<td>3 × 3; Similar as Bailey and Weddell (2006) but with median of filtered and valid values, instead of mean. Filtering: Value is within +/- 1.5 <em>standard deviation plus median, with standard deviation evaluated on the x</em>x pixels window.</td>
<td>Same as Bailey and Weddell (2006)</td>
</tr>
<tr>
<td>Müller et al. (2015)</td>
<td>3 × 3, median and standard deviation</td>
<td>±3 h</td>
</tr>
<tr>
<td>Barnes et al. (2019)</td>
<td>Mentions: 3 × 3, 5 × 5, 11 × 11; Used: 3 × 3, mean</td>
<td>Mentions: ±2, ±3, ±3.5, ±8 h; Used: ±2 h</td>
</tr>
<tr>
<td>Vanhellemont (2019)</td>
<td>3 × 3 (manually shifted), mean</td>
<td>±2 h</td>
</tr>
<tr>
<td>Ilori et al. (2019)</td>
<td>7 × 7, removing 3 × 3 to avoid the structure and shadow</td>
<td>±0.5 h</td>
</tr>
<tr>
<td>Van der Zande et al. (2016)</td>
<td>1 × 1</td>
<td>±1 h</td>
</tr>
<tr>
<td>Warren et al. (2019)</td>
<td>ONLY central pixel was used for the regression; 3 × 3 at 60 m (180 × 180 m) was used for Deming regression</td>
<td>±3 h for Coastal, ±24 h for inland</td>
</tr>
<tr>
<td>Caballero et al. (2018)</td>
<td>5 × 5, mean</td>
<td>&lt;±0.5 h; &lt;±1 h</td>
</tr>
<tr>
<td>Pahlavan et al. (2018)</td>
<td>Not mentioned for AERONET-OC</td>
<td>Not mentioned</td>
</tr>
</tbody>
</table>
Validation Preliminary Findings

Lwn [uW/cm²/2/nm/sr)

DEISIS-002-2019-02-08

Wavelength [nm]

45.50° N
45.40° N
45.30° N
45.20° N

DESIS L2R δTime=0 hr Pixels=9 GlintCorr: YES

*Venise AAOT, Lvl 1.5 Aeronet-OC, 9x9 pixels, CV(rhos(555)) < 0.20, +/- 2 hrs for interpolated or nearest within +/- 3 hrs
Validation Preliminary Findings

L wn

[μW/cm²/nm/sr]

DEISIS-HSI-002-2021-08-03

Wavelength [nm]

* Lvl 1.5 Aeronet-OC, 9x9 pixels, CV(rhos(555)) < 0.20, +/- 2 hrs for interpolated or nearest within +/- 3 hrs
Summary

- Ocean Color (OC) remote sensing requires high radiometric accuracy & SNR and a specialized approach to atmospheric correction.

- Dark Spectrum Fitting (DSF) optimizes the atmospheric model retrieval by identifying the darkest pixels of the scene in each band and reducing the tendency to overcorrect in complex/turbid waters.

- A module has been developed for this study to atmospherically correct DESIS HSI for aquatic targets using Acolite (DSF).

- Preliminary, qualitative results indicate that DESIS L2R (DSF) compares reasonably well with MODIS in the Chesapeake Bay.

- Very preliminary, qualitative vicarious validation utilizing the AERONET-OC shows mixed results comparing L2R to in situ radiometry.

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Questions?

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