Observations of chromophoric dissolved and detrital organic matter using remote sensing in Antarctic waters: Validation, dynamics and regulation

Eva Ortega-Retuerta
Dave A. Siegel, Norm B. Nelson
Carlos M. Duarte
Isabel Reche

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The development of ocean color satellite oceanography

Development of remote sensing:

Determination of biogeochemical parameters from the space

Sensors situated in polar-orbiting satellites

Different wavelengths are used for different applications
Ocean Color Remote Sensing

Two principal sensors: SeaWIFS and MODIS:

Passive sensors that measure reflected radiation at 7 discrete wavelength bands (visible and infrared)
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What do we want to measure?

Inherent Optical Properties:
Absorption and backscattering of water, pigments, CDOM and detrital particles

![Example absorption spectra](image)

$\text{Example absorption spectra}$

$\text{Wavelength (nm)}$

$\text{Absorption (arbitrary units)}$

$400$ $450$ $500$ $550$ $600$ $650$ $700$

$0$ $0.05$ $0.1$ $0.15$ $0.2$ $0.25$ $0.3$ $0.35$ $0.4$ $0.45$

$\text{b}_{\text{bw}}(\lambda)$

$\text{b}_{\text{bp}}(\lambda)$ – open ocean range

![Graph showing absorption spectra](image)

$\text{Wavelength (nm)}$

$400$ $450$ $500$ $550$ $600$ $650$ $700$

$0$ $0.5$ $1$ $1.5$ $2$ $2.5$ $3 \times 10^{-3}$
The development of ocean color satellite oceanography

- Allows information about broad areas of the ocean
- Allows to obtain data at a daily basis or near-real time

My data after 30 days on a boat

Seawifs data after 1 day cycle
Remote sensing of ocean color

Aim: To get information of inherent optical properties (IOPs) from total reflected radiance

Two steps:

1) Atmospheric correction to retrieve water-leaving radiance ($L_W$)

2) Algorithms to retrieve biogeochemical variables from $L_W$

$L_W$: function of water and inherent optical properties (IOPs)
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Application of atmospheric correction algorithms

<table>
<thead>
<tr>
<th>Band</th>
<th>Center ( \lambda ) (nm) SeaWiFS</th>
<th>Center ( \lambda ) (nm) MODIS</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>412</td>
<td>412</td>
<td>CDOM and detritus</td>
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<tr>
<td>2</td>
<td>443</td>
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<td>CDOM- pigment</td>
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<td>3</td>
<td>490</td>
<td>488</td>
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<tr>
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<tr>
<td>8</td>
<td>865</td>
<td>869</td>
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</tbody>
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Remote sensing of ocean color

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$L_W$: function of water and inherent optical properties (IOPs)
Algorithms to retrieve IOP’s from $L_W$
Absorption and backscattering of water, pigments, CDOM and detrital particles

$$L_W = f(a_T + b_T)$$

$$a_T(\lambda) = a_w(\lambda) + a_{ph}(\lambda) + a_{cdm}(\lambda) + a_{det}(\lambda)$$

$$b_T(\lambda) = b_{bw}(\lambda) + b_{bp}(\lambda)$$
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To retrieve IOP’s (primarily chl a) from $L_W$:

Empiric algorithms:

✓ $L_W = f({\text{chl}})$
✓ Assume covariation between chl and other IOPs
✓ Not always valid
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Semianalytic algorithms: Retrieve inherent optical properties independently

GSM algorithm (Garver-Siegel-Maritorena)

\[
L_{WN}(\lambda) = \left( \frac{tF_0(\lambda)}{n_{sw}^2} \sum_{m=1}^{2} g_m \right) \left[ \frac{b_{bw}(\lambda) + BBP(\lambda_0/\lambda)^\eta}{b_{bw}(\lambda) + BBP(\lambda_0/\lambda)^\eta + a_\lambda(\lambda) + Chl_\lambda(\lambda) + CDM exp[-S(\lambda - \lambda_0)]} \right]^m
\]
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The Antarctic Peninsula

- Highly productive area limited to ice-free periods
- In high latitude regions, frequent satellite measurements are difficult to obtain
- Previous studies have reported an underestimation of satellite data of chlorophyll a when using global algorithms
Our Goals:

✓ To validate the GSM algorithm for satellite determinations of CDOM in the Antarctic Peninsula, and test CDOM as a potential source of chl a underestimations

✓ To describe spatial and temporal dynamics of CDOM in the area and their potential drivers using satellite data
Protocol

Field database:

- SeaBASS: Greg Mitchell 2000-2002
- ICEPOS: 2004-2005

Satellite database:
GSM CDM products
- 1997-2001: SeaWIFS
- 2002-2005: merged(SeaWIFS+MODIS)

http://www.icess.ucsb.edu/OCisD/
Validation

20 match-ups

when considering only field CDOM:

✓ Slope > 1
✓ $r^2 = 0.70$

when considering field CDOM + detrital absorption:

✓ Slope = 1
✓ $r^2 = 0.75$

The GSM algorithm seems accurate to obtain CDM data in the Antarctic Peninsula
CDM Distribution

CDM spatial distribution

✓ high CDM near land and areas of recent ice melting

CDM seasonal dynamics

✓ Highest CDM at the end of austral spring
✓ Dynamics from homogeneous to patchy pictures
Good correspondence between CDM and chlorophyll a spatial distributions
Seasonal dynamics of chlorophyll a and CDM are also related
CDM has an ultimate algal source?

Phytoplankton → Non-chromophoric DOM → BACTERIA → CDOM

CDM and chlorophyll are driven by the same factors?

✓ Antarctic Ecosystem: Seasonally driven by the dynamics of the ice cap

ICE → Nutrients → Organisms → CDOM

Direct source
Long-term dynamics

CDM Anomaly = \( \frac{CDM_a - CDM_a}{CDM_a} \times 100 \)

8 year time series
AAO Index:
Difference of atmospheric pressures at sea level between 40 and 65 S

Positive AAO around Antarctic Peninsula:

✓ Increase Sea Surface Temperature
✓ Decrease ice extent
✓ Increase chl a

Positively related to CDM anomaly
CDM around Antarctic Peninsula:

**Seasonal drivers:**
- ✓ Phytoplankton
- ✓ Ice advance and retreat

**Climatic forcings:**
- ✓ Antarctic Oscillation Index
Thanks!!!

Organizers of DOM Spectroscopy Workshop
Crew of R/V Hesperides and UTM
Institute For Computational Earth System Science (UCSB)
You all for your attention!!!