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DOC and Climate

- S. Arrhenius 1896: CO₂ from fossil fuel burning leads to greenhouse effect
- Siegenthaler and Sarmiento 1993: DOC comprises vast majority of marine organic carbon ~equivalent to atmospheric CO₂ pool
- Hedges 2002: Oxidation of just 1% of DOC would generate a flux of CO₂ into the atmosphere equal to all fossil fuel burned in a year
- Belanger et al. 2006: Photoproduction of CO₂ through oxidation of CDOM increased ~15% in the Arctic recent years due to the decrease in sea ice
\[ a_g(\lambda) = a_g(\lambda_0) \exp(-S_g(\lambda - \lambda_0)) \]

Spectral slopes reflect age, molecular weight, origin, photooxidation, etc.
NOMAD and the synthetic IOCCG datasets have been extremely useful to algorithm development, but for our purposes, a carbon-centric, ocean color database is required which extends into the UV, includes larger numbers of field stations (~40X more), and matches CDOM & DOC to satellite imagery as well as in situ radiometry.
Global Ocean Carbon Algorithm Database
GOCAD
GOCAD

SeaBASS
Hansell/Carlson

5-10 m surface average, 1 km gridded, hyperspectral, Bailey & Werdell 2006 (5x5, 8 hrs, etc.)

RSR-weighted

OBPG L2

GEBCO 08 0.05

rigorously quality controlled!
<table>
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<tr>
<th>Experiment</th>
<th>Principal Investigators</th>
<th>Cruises</th>
<th>CDOM</th>
<th>CDOM &amp; IS*</th>
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* IS is in situ Rs(\lambda), **SAT is satellite Rs(\lambda)
Field Stations with CDOM and/or DOC
What/where are Case 1 waters, anyway?
Algorithm Development
**Empirical Approaches**
- Band ratio, one-phase exponential decay model (EXP)
- Multiple Linear Regression (MLR)
- Machine Learning
  - Random Forest Tree-Bagger (RFTB)

**Semi-analytical Approaches** (*Hybridized here for CDOM, not CDM, but no UV, and no DOC*)
- Quasianalytical Algorithm (QAA)
- Generalized Inherent Optical Property (GIOP)
  - *CDM is related to $a_g$ (CDOM) and $b_{bp}$ (NAP)

All algorithms were tuned/optimized/trained on *in situ* reflectances and validated on satellite data from independent field stations.
n:654 $r^2:0.66$ MAPD:30.2 MSE:0.02 Bias:-0.01

$\lambda:412$

n:654 $r^2:0.65$ MAPD:31.3 MSE:0.01 Bias:-0.01

$\lambda:443$

n:654 $r^2:0.63$ MAPD:33.6 MSE:0 Bias:0

$\lambda:488$

QAA hybrid
n:431 $r^2$:0.59 MAPD:161.5 MSE:20.61 Bias:1.48  n:542 $r^2$:0.55 MAPD:436.2 MSE:0.38 Bias:0.29  n:8703 $r^2$:0.56 MAPD:657.2 MSE:0.06 Bias:0.21
What is most predictive of DOC?
Algorithm Validation
Algorithm Application
Figure 9. Climatological DOC distribution from a regression analysis based upon wintertime SST values. Concentrations of DOC are in units of $\mu$mol L$^{-1}$. The regression models used are presented in Table 2, and further details may be found in the text.

Global distribution and dynamics of colored dissolved and detrital organic materials

D. A. Siegel, S. Maritorena, and N. B. Nelson
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D. A. Hansell
Division of Marine and Atmospheric Chemistry, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida, USA

M. Lorenzi-Kayser
Institute for Computational Earth System Science, University of California, Santa Barbara, Santa Barbara, California, USA
ANOMALY = YEARBLOCK – AQUA-ERA-AVERAGE
ANOMALY = YEARBLOCK – AQUA-ERA-AVERAGE

$\alpha_{(275)}$ % Anomaly, Autumn 2009

$\beta_{(275)}$ % Anomaly, Autumn 2009
ANOMALY = YEARBLOCK - AQUA-ERA-AVERAGE
Remote sensing of CDOM, spectral slope, and DOC are important to understanding marine carbon budgets and the underwater light field.

GOCAD is a global, carbon-centric, algorithm development database including hyperspectral data extending into the UV with ~50k field stations.

Several algorithms performed reasonably well retrieving $a_g(\lambda)$, $S_g(\lambda)$, and DOC, but MLR proved the most versatile and easy to implement on satellite imagery.

- Combining ocean color imagery with SSS from Aquarius vastly improved retrievals of DOC.

ANOMALY = YEARBLOCK – AQUA-ERA-AVERAGE
CDOM

- Strongly absorbs in the blue and UV
  - Limits light for photosynthesis
  - Shades cells from UV damage
  - Leads to surface heating/stratification
- Together with chlorophyll, CDOM dominates the blue-green ratio of sea-surface reflectance
  - Increases uncertainty in band-ratio algorithms for Chl
  - $S_g$ important to semi-analytical retrievals, particularly those that separate CDOM from non-algal particulate absorption
CDOM Remote Sensing

2001 Kahr u et. alia (regional)
2002 D’Sa et al. (regional)
2003 Johannsen et al. (regional)
2008 Mannino et al. (regional)
2009 Morel & Gentili (CDOM index)
2011 Zhu et al. (regional)
2011 Tiwari et al. (NOMAD)
2011 Shanmugan et al. (NOMAD)
2011 Matthews (review)
2012 Odermatt (review)
2012 Brando et al. (regional)
2012 Tilstone et al. (regional)
2013 Doug et al. (regional,NOMAD)
2013 Tahrani et al. (regional)
2013 Swan et al. (CLIVAR, n=127)
2013 Matsuoka et al. (regional)
...