Predicting Phytoplankton Functional Types with Remote Sensing Data

Tim Moore
University of New Hampshire

Chris Brown
NESDIS STAR

8/27/15
Ocean color approaches for discerning phytoplankton communities from remote sensing

- **Functional type** (biogeochemical function)
  - Spectral approach – PHYSAT, PhytoDOAS
- **Phytoplankton size** (governs many traits)
  - Spectral approaches (absorption, backscattering properties)
  - Chlorophyll approaches

Table 1. Summary of the algorithms, contact person, PFT represented.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Contact Person</th>
<th>PFTs</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewin et al. (2010)</td>
<td>R.J.W. Brewin</td>
<td>Micro, Nano, Pico</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>Devred et al. (2006)</td>
<td>E. Devred</td>
<td>Micro, Nano+Pico</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>OC-PFT</td>
<td>T. Hirata</td>
<td>Micro, Nano, Pico, Diatom, Haptophytes, Prokaryotes, Chlorophytes, Pico-Eukaryotes, Prochlorococcus</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>Uitz et al. (2006)</td>
<td>J. Uitz</td>
<td>Micro, Nano, Pico</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>PHYSAT</td>
<td>S. Alvain</td>
<td>Diatom, Nanoeukaryote, Prochlorococcus, Synechococcus-like, Phaeocystis</td>
<td>Optics-based</td>
</tr>
<tr>
<td>PhytoDOAS</td>
<td>A. Bracher</td>
<td>Diatom, Coccolithophore, Cyanobacteria</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Ciotti and Bricaud (2002)</td>
<td>A. Bricaud</td>
<td>Micro, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Fujiwara et al. (2011)</td>
<td>T. Hirawake</td>
<td>Micro, Nano, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Kostadinov et al. (2009)</td>
<td>T. Kostadinov</td>
<td>Micro, Nano, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Mouw et al. (2010)</td>
<td>C. Mouw</td>
<td>Micro, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Roy et al. (2012)</td>
<td>S. Roy</td>
<td>Micro, Nano, Pico</td>
<td>Optics-based</td>
</tr>
</tbody>
</table>

http://pft.ees.hokudai.ac.jp/satellite/index.shtml
Niche Concept

- Widely accepted that PFT groups have distinct biogeography.
- Margalef Mandala is a useful construct to understand phytoplankton distributions across a varied environmental landscape.
- Niche models widely used in ecology to describe species distributions.
- Statistical in nature, and depends on assumptions regarding species presence/absence.

from Balch, 2004
SeaWiFS coccolithophore bloom patterns

Moore et al, 2011 RSE
A Coccolithophore ‘bloom’ niche model

- Using OC data, bloom pixels used as mask to select co-located environmental data
- Niche was characterized by statistical distribution of environmental data (SST, MLD, PAR, Winds).
HPLC-based functional groups

AMT in situ data (HPLC, nutrient, CTD) 1998-2010

Functional Groups (CHEMTAX)

Satellite Data
- SST (NOAA AVHRR)
- Wind (NOAA CFSR)
- PAR (SeaWiFS)
- PSD (SeaWiFS)
- MLD (HYCOM)
- Nutrients

Ocean Color Particle Size (SeaWiFS)

Match-up data set sorted by PFT

Evaluation

PFT Probabilities

Habitat/niche model (environmental + ocean color)

Development
PFT Training Data Set

Atlantic Ocean HPLC Data

- AMT SeaBASS CLIVEC Pangea
- N ~ 2500

CHEMTAX (based on ‘known’ pigment ratios)

% Phytoplankton of Chla

- Diatoms
- Dinoflagellates
- Prochlorococcus
- Prymensiophytes
- Chlorophytes
- Chrysophytes
- Crytpophytes
- Synechococcus
- Prasinophytes

PFT groups
- 4 PFT groups created
- Dominant PFT identified as fraction of biomass > 0.45
- Coccolithophores added from existing model

Coccolithophores added from existing model
Atlantic matchup data set

- ~800 matchup points between HPLC in situ and satellite variables.
- 340 points had a ‘dominant’ PFT present (~50%).
- Nanoflagellates dominated PFTs (~70%).
- Synechococcus dominant least abundant (5%).
\[ Z^2 = (V_{rs} - y_j)^T \Sigma_j^{-1} (V_{rs} - y_j) \]

- \( V_{rs} \) – Environmental vector
- \( y_j \) – \( j \)th PFT mean vector
- \( \Sigma_j \) – \( j \)th PFT covariance matrix

Chi-square PDF
### Performance matrix – 5 PFT types

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Training* % correct</th>
<th>Eval** % correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43.9</td>
<td>40.6</td>
</tr>
<tr>
<td>2</td>
<td>58.8</td>
<td>50.7</td>
</tr>
<tr>
<td>3</td>
<td>70.7</td>
<td>55.6</td>
</tr>
<tr>
<td>4</td>
<td>72.3</td>
<td>55.7</td>
</tr>
<tr>
<td>5</td>
<td>79.3</td>
<td>63.9</td>
</tr>
<tr>
<td>6</td>
<td>88.7</td>
<td>72.6</td>
</tr>
</tbody>
</table>

- Best performance with all variables combining OC & env data.
- Systematic additions of variables improved performance.

Scenario 1: PSD only  
Scenario 2: Sc1 + SST  
Scenario 3: Sc2 + PAR  
Scenario 4: Sc3 + MLD  
Scenario 5: Sc4 + wind  
Scenario 6: Sc5 + nutrients

*Training Data used from ‘dominant’ points in pool of data (N=370)

**Data not used but ‘not dominant’ from remaining pool of data (N=421)
Summary

• A model was developed to predict dominant PFT groups at the oceans *surface* using particle size information from ocean color imagery combined with environmental data.

• The model was based on a ‘habitat/niche’ concept formed by observed relationships between identified PFT groups (from in situ HPLC) and co-located satellite variables (e.g., PAR, MLD, wind, SST and nutrients).

• Model is driven by assumptions on 1) initial Chemtax-derived phytoplankton group accuracy, 2) partitioning of these groups into PFTs, and 3) niche concept applying to broad phytoplankton groups.

• 5 PFTs were characterized in this model: Nanoflagellates, Diatoms, Coccolithophores, Prochlorococcus and Syneococcus.
Summary (continued)

• The model currently works predicts correct PFT 86-90% based on training set, and about 70% accuracy with a separate data set that is not totally appropriate for the model since there are no ‘Dominant’ points in that data set.

• Despite the large matchup data set, only 1/3 of the points were ‘dominant’, and more data would be beneficial for both further training, and evaluation.

• The output maps look reasonable, but its difficult to assess without other metrics to validate.
Future Work

• Explore alternative PFT groupings.
• Utilize upcoming PSD imagery for Aqua and VIIRS (Kostadinov).
• Assess model with an appropriate validation data set.
• Utilize monthly nitrate product for Atlantic (J. Goes).
Backup Slides
Synecococcus

Prochlorococcus

Dominant PFT

Nanoflagellates

Diatoms

South Latitude North

South Latitude North