Seasonal to Interannual Variability in Phytoplankton Biomass and Diversity on the New England Shelf:
In Situ Time Series for Validation and Exploration of Remote Sensing Algorithms

(The proposal submitted to NASA ROSES (NNH09ZDA001N-TERRAQUA; recently awarded)

Heidi Sosik (P.I): Woods Hole Oceanographic Institution
Hui Feng (Co-I): University of New Hampshire

the MODIS Science Team Meeting, Adelphi, MD (May 18-20, 2011)
• New England shelf
• Time series approach
• Leverage existing observing assets
  – Martha’s Vineyard Coastal Observatory (MVCO – cabled facility)
  – AERONET-OC (i.e. SeaPRISM) for sea surface radiometry (Lwn, aot)
  – In situ flow cytometry to characterize phytoplankton communities

AERONET-OC: nLw(λ), AOT(λ)

Automated submersible flow cytometry
The study site presents important Opportunities and Challenges

- Predictable seasonal switch in phytoplankton dominance
  - large diatoms in winter
  - small cells in summer

- Phytoplankton community changes impact bulk optical properties
  - Seasonality strong
  - Interannual variability also evident

- MODIS products influenced by atmospheric correction and other potential issues
  - Well-known for northeast US waters
  - Unique dataset to evaluate new approaches
Objectives

- Extend/analyze the existing phytoplankton community time series at MVCO with focus on resolving seasonal to interannual patterns and modes of variability;

- **Extend/analyze the existing AERONET-OC times series at MVCO for coastal ocean color validation for expanded understanding of uncertainty sources for satellite ocean color retrievals (on going; more today);**

- Explore (and possibly adapt) published approaches to retrieve phytoplankton functional groups and/or size classes from AERONET-OC / MODIS water-leaving radiances on the basis of comparison with the in situ time series;

- Develop approaches and criteria for extending the spatial / temporal footprint of phytoplankton community characteristics in using MODIS products (existing and exploratory) to beyond the locations of detailed in situ measurements (e.g., MVCO).
Validation of MODIS ocean color and aerosol retrievals in the northeastern US coast using AERONET-OC:

On-going activities
Objectives

• Establish a high-quality observational time series dedicated to satellite ocean color product validation at a NW Atlantic coastal site (MVCO)

• Quantify major uncertainty sources in ocean color retrievals, and understand temporal and spatial variability of these uncertainties

• Examine coastal validation (and/or calibration) approaches

• Explore improvement of satellite ocean color atmospheric correction in coastal waters
AERONET measurement sites along the US NE coastal region

AERONET-OC: nLw(λ)
**MVCNO AERONET-OC Observations**

- 2004-present (the 1st deployment in the US coast)
- Spectral Channels:

<table>
<thead>
<tr>
<th>AERONET-OC (i.e. SeaPRISM)</th>
<th>MODIS-aqua</th>
</tr>
</thead>
<tbody>
<tr>
<td>412nm</td>
<td>412nm</td>
</tr>
<tr>
<td>439nm</td>
<td>442nm</td>
</tr>
<tr>
<td>500nm</td>
<td>490nm</td>
</tr>
<tr>
<td>555nm</td>
<td>555nm</td>
</tr>
<tr>
<td>674nm</td>
<td>668nm</td>
</tr>
<tr>
<td>870nm</td>
<td>870nm</td>
</tr>
</tbody>
</table>

- Operations by UNH/WHOI
MVCO Matchup Validation: MODIS-Aqua (Version 5) vs. AERONET-OC (Feng et al., 2008)

- \(\text{nLw}(412)\) underestimated
- Angstrom underestimated
- \(\tau_a(870)\) overestimated

\[ N = 65 \]

2004-2005 AERONET-OC observations
#1: MODIS- nLw @488, 531, and 551nm performs well.

#2: MODIS-AOT(870) is overestimated systematically
   MODIS-Angstrum Exp is underestimated significantly,

#3: MODIS nLw(412) and nLw(443) is under-estimated significantly with 15-20% negative values

Motivations

A) Is there a linkage between #2 and #3 ?.

B) Is there any improvement in MODIS Version 6 (Reprocessing 2009) ?
Major changes in Atmospheric Correction Approach
SeaDAS Version 5 vs. SeaDAS Version 6

Version 5: 12 candidate aerosol models (Gordon and Wang, 1994) were used for AC lookup tables: As shown, these models not adequately represent observed aerosol properties.

Version 6 (reprocessing 2009):
- 80 new aerosol models are now used in terms of observations of aerosol size distributions and single scattering albedos from various AERONET coastal and island sites (Ahmad et al., 2010).
- In-water IOP models in NIRs are modified (Bailey et al., 2010).
- New Vicarious calibration coefficients.
Validation of ocean color nLw

MODIS-V5/MODIS-V6

vs.

AERONET-OC

(2004-2009 AERONET-OC observations)
Scatterplot of Matchups in nLw spectra

MODIS-Aqua Version 5

MODIS-Aqua Version 6
(Reprocessing 2009)
nLw-412m
MODISv5/v6 vs. AERONET-OC

15-day bin averaged
nLw-551nm MODISv5/v6 vs. AERONET-OC

15-day bin averaged
nLw-667nm

MODIS v5/v6 vs. AERONET-OC
Validation of aerosol properties

MODIS-V5 and MODIS-V6 vs. AERONET-OC

(2004-2009 AERONET-OC observations)
Scatterplot of Matchups

MODIS-V5

MODIS-V6
Angstrum Exp (531,869)

MODIS v5/v6 vs. AERONET-OC

$Y = 0.63X + 0.021; r^2 = 0.33$

$N = 816; Ngx = 8; Ngy = 4$
AOT(869)

MODIS v5/v6 vs. AERONET-OC

Graph showing the relationship between Version 5: AOT (869) and Version 6: AOT (869). The graph includes a linear regression line with the equation $Y = 0.7X + 0.005$ and $r^2 = 0.81$. The number of data points, $N = 816$.
Summary

• The AERONET-OC deployed at MVCO has provided a valuable long time series for coastal ocean color validation efforts.

• The Validation of the MODIS-Aqua ocean color products of Version 5 and Version 6 (reprocessing 2009) in MVCO shows that the MODIS V6 products gives a significant improvement over the Version 5 ones. Specifically:
  • MODIS-retrieved aerosol properties, i.e. Angstrum exponent (531,869) and AOT at 869nm, agree with AERONET measurements better in V6 than in V5
  • MODIS-retrieved nLw(412) is significantly improved in terms of
    ▪ that the number of negative values decreases
    ▪ that the mean mode of nLw(412) increases
    ▪ that nLw(412) matches to measurements better
Future Work

• Keep it in a stable/normal operational mode,

• Extend the validation effort to inter-satellite ocean color products from MODIS, SeaWiFS, VIIRS…

• Explore the optimal atmospheric correction and the site vicarious calibration potential to minimize bias and uncertainties,

• Explore approaches to retrieve phytoplankton functional groups and/or size classes from AERONET-OC/Satellite nLw on the basis of comparison with the in situ time series
Acknowledgements

• the UNH/NOAA Center for Coastal Ocean Observation and Analysis (COOA).

• NASA’s Science Directorate
  – Ocean Biology Biogeochemistry program
  – New Investigator program
  – AquaTerro team project (newly funded)

• WHOI-MVCO tower operation team

• Data
  – NASA DAAC for MODIS-Aqua data
Thank you