VIIRS Ocean Color Data and Global Modeling: Extending the Time Series of Ocean Biology from Space

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Use of Ocean Color in global numerical models

- Maximize use of satellite data via data assimilation into global models
  1. Improve the representation of past and present variability and change
  2. Detection of trends in ocean biogeochemistry
  3. Forecast seasonal to decadal variability

- Use Ocean Color Chlorophyll Data; assimilate into the NASA Ocean Biogeochemical Model (NOBM)

<table>
<thead>
<tr>
<th>Year</th>
<th>Satellite</th>
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<tbody>
<tr>
<td>1997</td>
<td>SeaWiFS</td>
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<tr>
<td>2002</td>
<td>MODIS-Aqua</td>
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<tr>
<td>2010</td>
<td></td>
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<tr>
<td>2011</td>
<td>S-NPP VIIRS</td>
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</tbody>
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1997 SeaWiFS, 2002 MODIS-Aqua, 2011 S-NPP VIIRS
Radiative Model (OASIM)

Winds, ozone, relative humidity, pressure, precip, clouds, aerosols

Winds, SST

Sea Ice
Dust (Fe)
$\text{CO}_2$

NOBM

Temperature, Layer Depths
Advection-diffusion

Radiative Model (OASIM)

Layer Depths

Outputs:
- Chlorophyll, Phytoplankton Groups
- Primary Production
- Nutrients
- DOC, DIC, pCO$_2$, alkalinity, CDOC
- Spectral Irradiance/Radiance

Circulation Model (Poseidon)

E$_d$(λ) = downwelling irradiance
E$_s$(λ) = surface irradiance
IOP = Inherent Optical Properties
1. Improve the representation of past and present variability and change

It is widely known that data assimilation improves model results. It is less widely known that data assimilation also improves data representations. Global mean chlorophyll representations are distorted by gaps in sampling. Ocean color missions typically observe only about 15% of the ocean per day due to:

- inter-orbit gaps
- insufficient light for detection at high latitudes
- sun glint
- clouds
- aerosols

Ice fields are shown in white. Missing data is shown in black.
Note the plumes of high chlorophyll in the Southern Ocean that are artifacts of sampling. Missing data along some continental shelves, which is due to the underlying model domain.
Chlorophyll mg m$^{-3}$
Antarctic Median Satellite Chlorophyll

Antarctic Median Assimilated Chlorophyll

Chlorophyll mg m$^{-3}$
Differences in sampling between MODIS-Aqua (top) and VIIRS (bottom)
2. Detection of trends in ocean biogeochemistry

Global Annual Median Chlorophyll

SeaWiFS: R2010.0
MODIS: R2013.1
OCX

Assimilated: $r = -0.219$  NS

SeaWiFS/MODIS: $r = -0.654$
P<0.02

Gregg and Rousseaux 2014; JGR Oceans
Significant Trends 1998-2012

Chlorophyll mg m⁻³
Gregg and Rousseaux 2014; JGR Oceans
Increasing occurrence of coccolithophores in the North Atlantic

Rivero-Calle, 2015; Science
Global Annual Median Chlorophyll

- **SeaWiFS**
- **MODIS-Aqua**
- **VIIRS**
- **Assimilation SeaWiFS-Aqua-VIIRS**

Chlorophyll mg m$^{-3}$

Global Annual Median Chlorophyll

SeaWiFS-Aqua-VIIRS

Assimilation SeaWiFS-Aqua-VIIRS

r = 0.48  P<0.05

r = -0.17  NS
3. Forecast seasonal to decadal variability

Significant correlation of model versus satellite:
SeaWiFS (R=0.77), MODIS (R=0.64), VIIRS (R=0.74)
GMAO Seasonal Forecast Data (e.g. wind stress, SST, shortwave radiation)

Mid-May 2016 Plume of Model ENSO Predictions

Source: NOAA Climate Prediction Center
Forecasting Chlorophyll in the 2015-2016 El Niño using VIIRS

A. 1997 El Niño
Total Chlorophyll December 1997 (El Niño)

B. 1998 La Niña
Total Chlorophyll August 1998 (La Niña)

C. 2015 El Niño
Total Chlorophyll June 2015 (El Niño)

D. August 2016
Total Chlorophyll August 2016 (forecast)

Application for ENSO but also HABs, heat content, etc
Summary

- A rigorous integration of satellite data and models via data assimilation shows
  - Reduction of inconsistencies between chlorophyll observed by different satellites/sensors
  - Reduction of sampling biases among the sensors
  - Provide a global coverage and information on products that cannot (currently) be derived from ocean color
- Enables trend detection over decades with multiple satellites
- Next step: Use of VIIRS in improving and evaluating forecast chlorophyll in ENSO events is promising