Ocean Color Climate Records
NASA REASoN CAN

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Ocean Color Climate Records

Global Mean Air Temperature:
0.74°C increase 1906-2005 (IPCC 2007)

From Hansen et al. 2006, PNAS
SST:

0.2°C increase 1980-2003 (OISST)

Does ocean chlorophyll respond?

Does ocean chlorophyll play a role?

(from Rayner et al 192, JGR)
Global Trend Analyses

Gregg et al. (2005, GRL): 4% increase 1998-2003 (P<0.05)
10% increase on coasts (<200m bottom depth)
No change open ocean

Behrenfeld et al. (2006, Nature): 0.01 Tg integrated chl decrease per year 40°S to 40°N, 1999-mid-2006 (P<0.0001)
No change poleward of 40°

Both used SeaWiFS and matched changes to changes in other climate variables
Longer-Term Global Analyses

Gregg and Conkright (2002, GRL): 6% decline 1980’s (CZCS) to 2000’s (SeaWiFS)
Open ocean only

Antoine et al. (2005, JGR): 22% increase
Case 1 waters, open ocean only; Maximum 1.5 mg m\(^{-3}\)

Both used consistent algorithms for CZCS and SeaWiFS
Using a single sensor (SeaWiFS) trends can be reconciled between different approaches/investigators; trends are consistent with climate changes.

Changes determined from different sensors are not in agreement, despite consistent processing methodologies across sensors, but reconciliation is possible (confirmation is more difficult).

MODIS-Aqua provides a test of the consistent processing/consistent data assumption: coincident with SeaWiFS.
Global Annual Trends using SeaWiFS, and SeaWiFS/Aqua

Aqua starts here

- SeaWiFS: -1.04% (NS)
- SeaWiFS/Aqua: -9.12% (P < 0.05)
Linear trends using 7-year average/composite images were calculated, and when significant (P < 0.05), shown here.
Maybe there is something different between SeaWiFS and MODIS that is not corrected by consistent processing.

Or maybe consistent processing is not enough.
Goal:

Provide consistent, seamless time series of Level-3 ocean color data from 1979, with a 9-year gap (1987-1996)

Produce Climate/Earth Science Data Records (CDR/ESDR) of ocean color

Make CDR’s available to the public
CDR: A time series of sufficient length, consistency, and continuity to determine climate variability and change
National Research Council, 2004

Technical Definition of Consistent/Seamless:
all temporal sensor artifacts removed
no obvious interannual discontinuities unattributable to natural variability
all known mission-dependent biases removed or quantified
similar data quality and structure
Ocean Color Satellite Missions: 1978-2010 and Beyond

CZCS

1980 1990 2000 2010

OCTS/POLDER

VIIRS-NPP

VIIRS-2

SeaWiFS

MODIS-Aqua

MODIS-Terra

“Missions to Measurements”
New and Post-Processing Enhancements

- Fine-tune radiance-chlorophyll relationships post-processing
  Correct for residual biases

- In situ data blending

- Integrate Models
  - Aerosols
  - Data assimilation

- All of the above
The NASA Ocean Biogeochemical Model (NOBM) consists of the following components:

- **Radiative Model (OASIM)**
  - Inputs: Dust (Fe), Sea Ice
  - Outputs: \( E_d(\lambda) \), \( E_s(\lambda) \)
  - Processes: IOP, Layer Depths, Temperature, Layer Depths
  - Outputs: Chlorophyll, Phytoplankton Groups, Primary Production, Nutrients, DOC, DIC, pCO2, Spectral Irradiance/Radiance

- **Biogeochemical Processes Model**
  - Inputs: Winds, ozone, relative humidity, pressure, precip. water, clouds (cover, \( \tau_c \)), aerosols (\( \tau_a \), \( \omega_a \), asym)
  - Inputs: Winds, SST
  - Outputs: \( E_d(\lambda) \), \( E_s(\lambda) \)
  - Processes: Advection-diffusion

- **Circulation Model (Poseidon)**
  - Inputs: Winds, SST
  - Outputs: \( E_d(\lambda) \), \( E_s(\lambda) \)

**Global model grid:**
- Domain: 84°S to 72°N
- 1.25° lon., 2/3° lat.
- 14 layers
Model vs. SeaWiFS:
Bias = +5.5%
Uncertainty = 10.1%
Global Annual Mean Chlorophyll

chl (mg/m³)


3 sensor bias-adjusted assimilation
SeaWiFS assimilation
3 sensor assimilation
OCTS+ SeaWiFS SeaWiFS SeaWiFS+ Aqua Aqua
Advantages of Data Assimilation

- Achieves desired consistency, with low bias
- Responds properly to climatic influences
- Full daily coverage – no sampling error
- Effective use of data to keep model on track
- Only spatial variability required from sensors

Disadvantages of Data Assimilation

- Low resolution (for now)
- No coasts (for now)
- Excessive reliance on model biases
- Cannot validate model trends with sensor data
## Compared to In situ Data

<table>
<thead>
<tr>
<th>Model</th>
<th>Bias</th>
<th>Uncertainty</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>SeaWiFS</td>
<td>-1.3%</td>
<td>32.7%</td>
<td>2086</td>
</tr>
<tr>
<td>Free-run Model</td>
<td>-1.4%</td>
<td>61.8%</td>
<td>4465</td>
</tr>
<tr>
<td>Assimilation Model</td>
<td>0.1%</td>
<td>33.4%</td>
<td>4465</td>
</tr>
</tbody>
</table>
Can the CZCS provide a Climate Data Record?

CDR: A time series of sufficient length, consistency, and continuity to determine climate variability and change
National Research Council, 2004

(from Gregg and Conkright, 2002 GRL)
CZCS Deficiencies

1) Low SNR
   Solution: Take mean over 25km

2) 5 bands, only 4 of which quantitatively useful
   -- limits aerosol detection capability
   Solution: Innovative approaches for aerosols

3) Navigation
   Solution: Bias corrected, orbit vectors obtained, reconstructing viewing angles

4) El Chichon
   Solution: Tighter restriction on reflectance

5) Anomalous behavior post-1981
   Solution: Don’t use Band 2

6) Sampling
CZCS Sampling

CZCS Pigment; June 1979

SeaWiFS Chlorophyll; June 1999
Ship observations per decade: light symbol=10, medium=100, dark=400

from Rayner et al 1993, JGR
**Ocean Color Climate Records**

Distinct from Operations Data Sets managed by OGBP

Stored at GES-DAAC, access using Giovanni

L3 format, 25-km, monthly, consistent with other climate data sets

Includes discontinuous time series
   1978-1986; 1996-2005
   chlorophyll only for now
mission names not mentioned except under detailed information

Facilitates new and post-processing advances to ensure CDR consistency

Does not interfere with operations requirements and community
Climate Records Issues

1) How calibrate historical and future sensors, maintaining consistency?

2) Is BRDF a good idea?

3) Can we define more rigorous metrics than in situ comparisons, that constrain global mean estimates?

4) Is it acceptable to have two data streams:
   operational (best available methods; mission-dependent, high resolution)
   climate (maximum commonality/consistency of methods, low resolution)?

5) How much consistency can we achieve without resorting to post-processing methods (blending of in situ data, assimilation)?