

Satellite ocean color data products for marine biogeochemical research applications

Jeremy Werdell

NASA Goddard Space Flight Center
Science Systems & Applications, Inc.

18 January 2010 @ NIO

professional background

NASA Goddard Space Flight Center - Jun 99 to present
oceanographer @ Ocean Biology Processing Group
ocean color from all instruments & SST from MODIS & VIIRS
located in Maryland near Washington D.C.

academic background

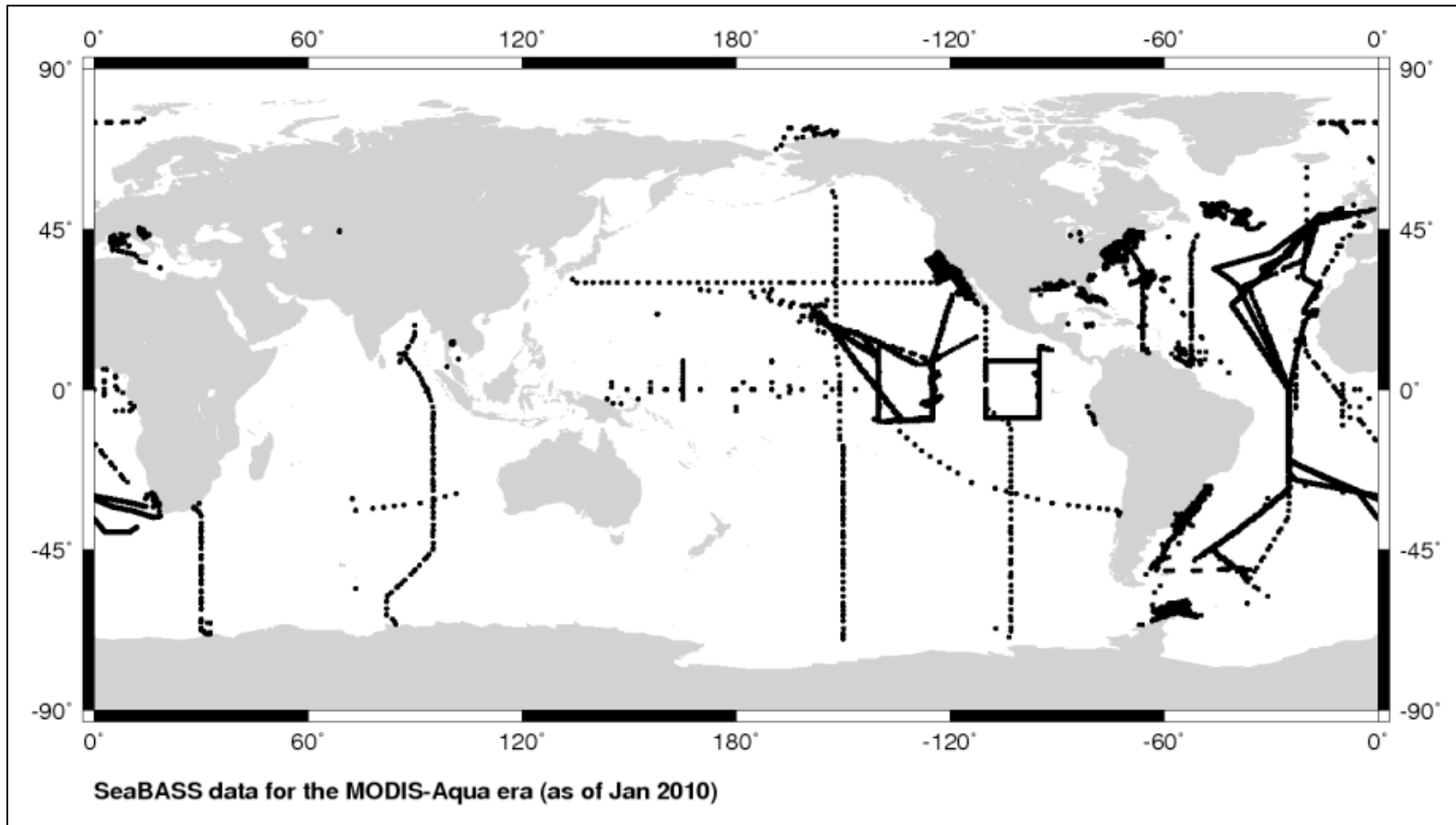
biology & environmental science @ University of Virginia - 1996
oceanography @ the University of Connecticut - 1998
oceanography @ the University of Maine - Sep 09 to present

1. why use satellites for oceanographic applications?
2. why study ocean color?
3. ocean color @ NASA
4. the NASA Ocean Biology Processing Group (OBPG)
5. international collaborations

1. why use satellites for oceanographic applications?
2. why study ocean color?
3. ocean color @ NASA
4. the NASA Ocean Biology Processing Group (OBPG)
5. international collaborations

why use satellites?

NASA funds *in situ* sampling programs in support of its cal/val programs



bio-optical data collected during the MODIS-Aqua era (June 2002 to present)

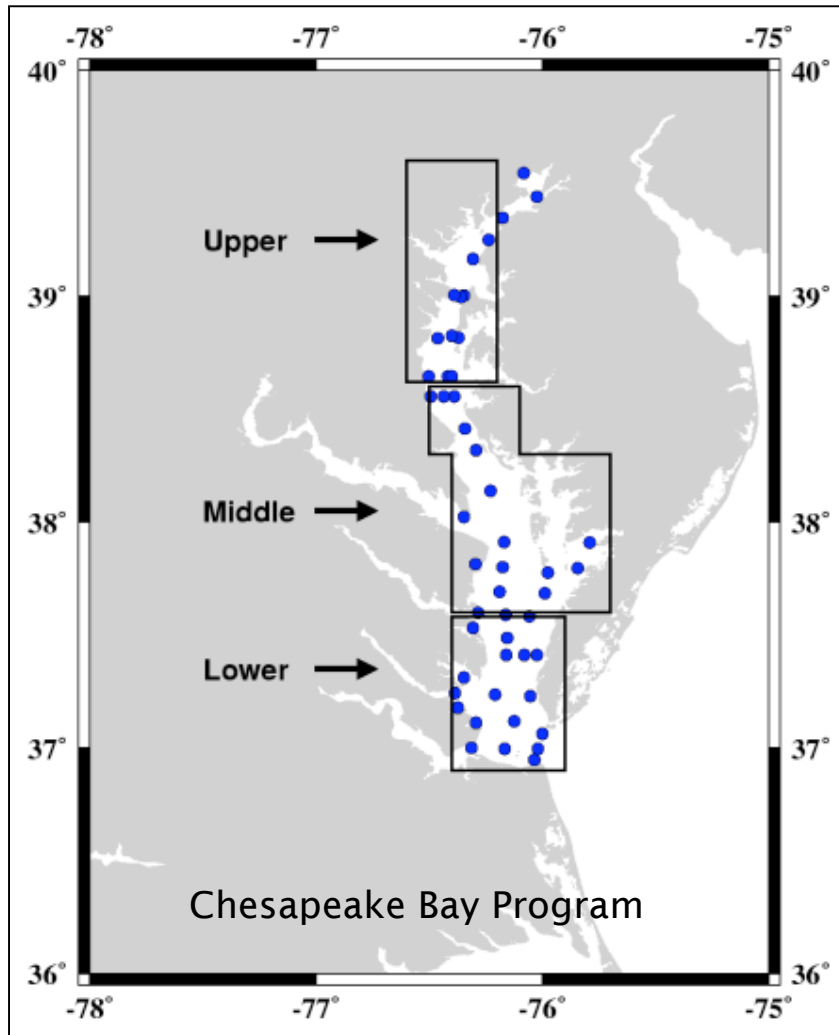
why use satellites?

SeaWiFS, MODIS-Aqua, & others provide a daily, synoptic view of the Earth

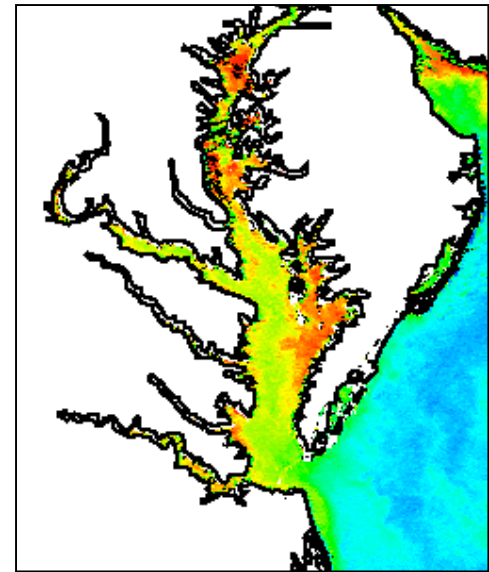
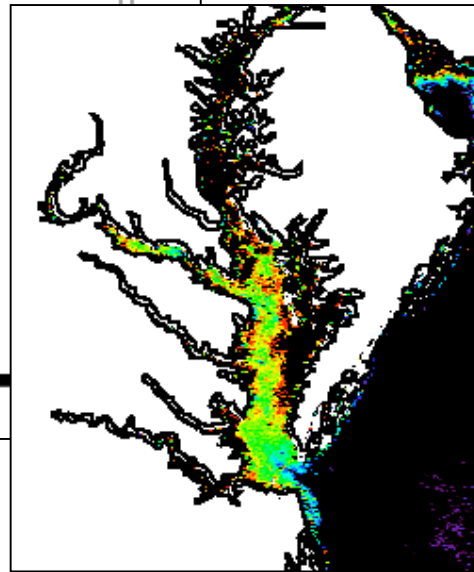
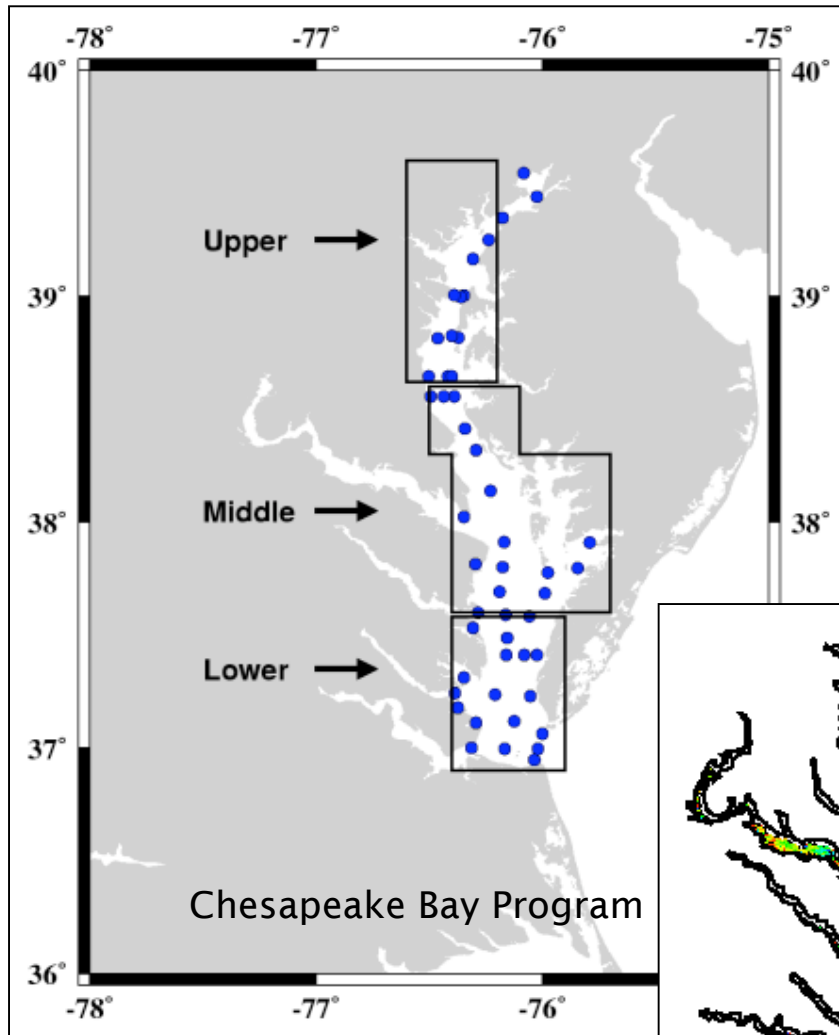


MODIS-Aqua observations for one day (1 February 2008)

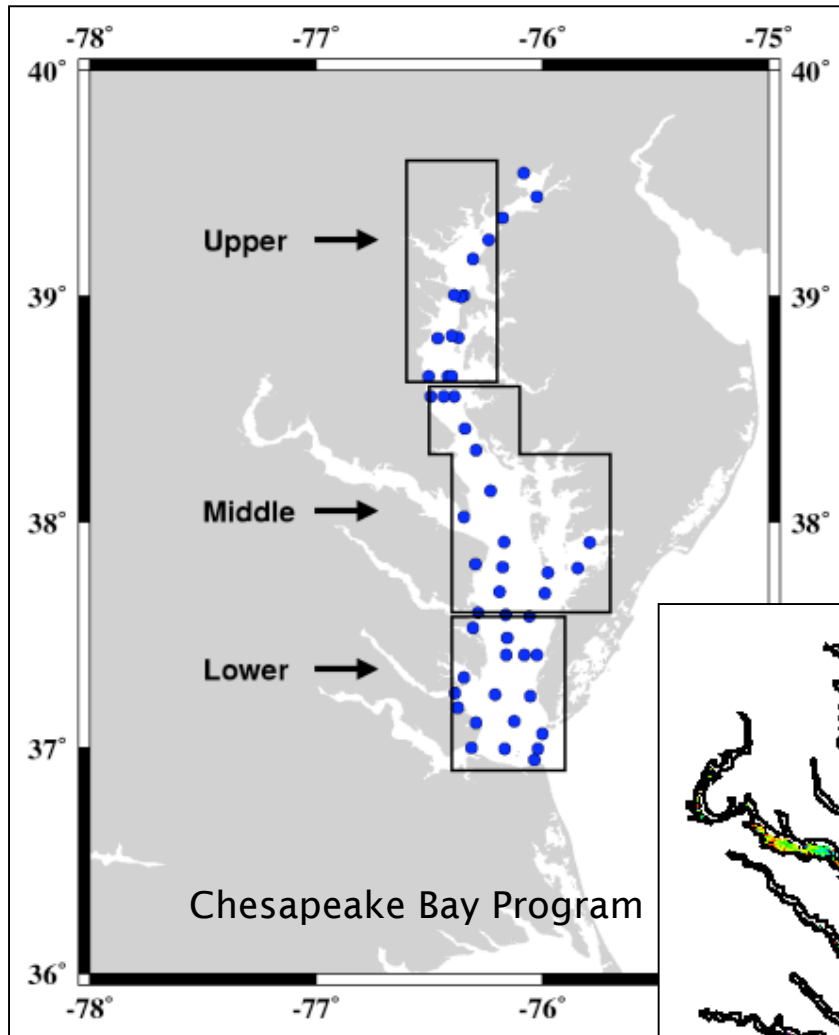
why use satellites?



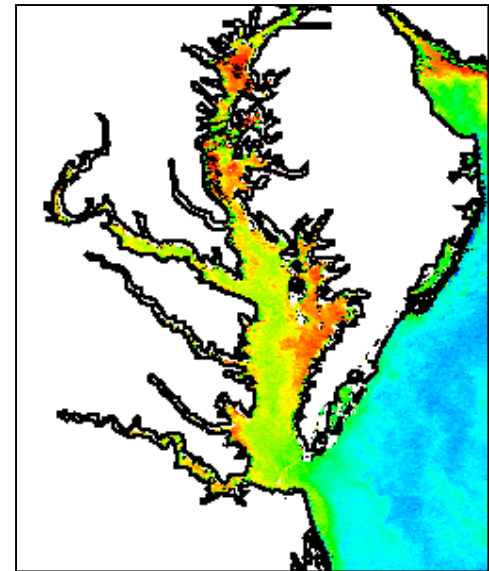
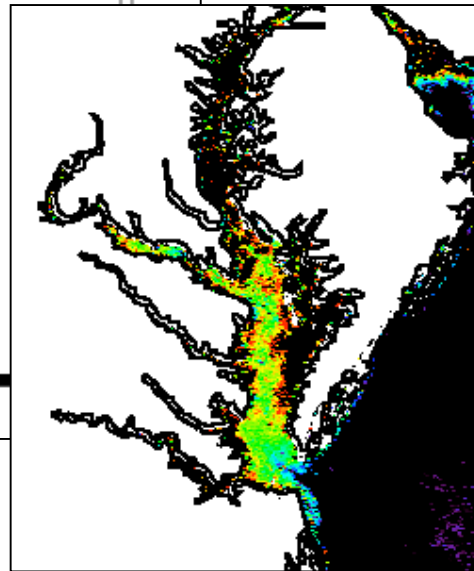
why use satellites?



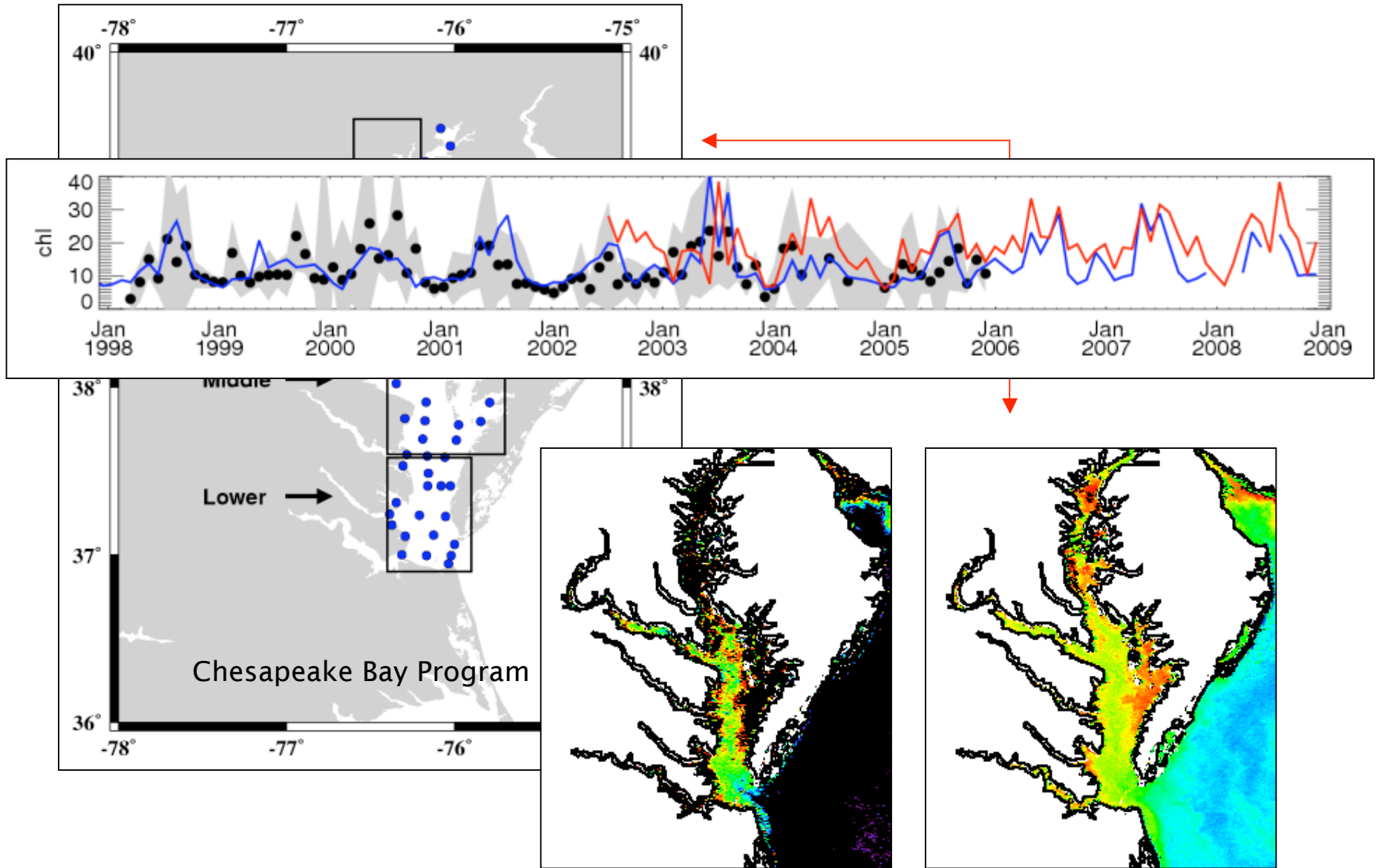
why use satellites?



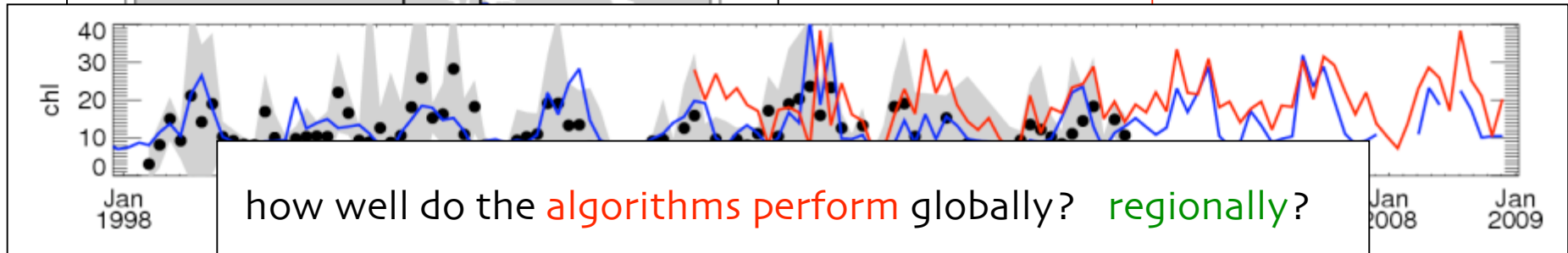
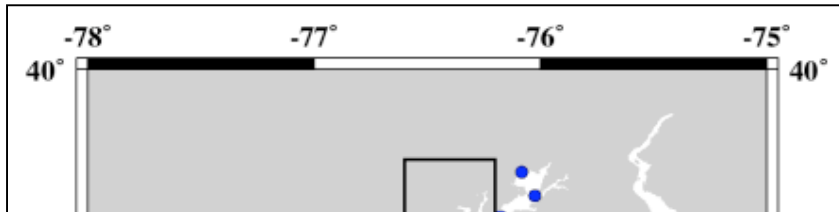
← complementary data streams ↓



why use satellites?



why use satellites?

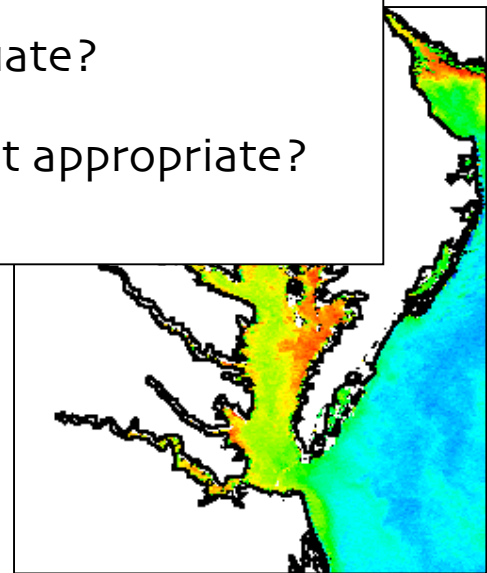
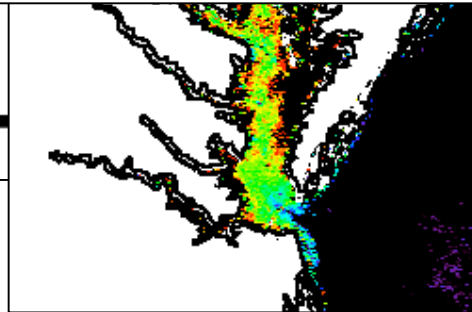
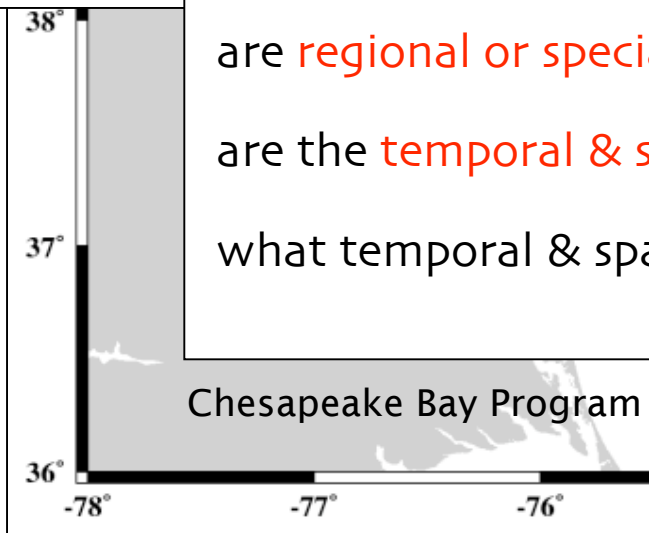


how well do the algorithms perform globally? regionally?

are regional or specially tuned algorithms required?

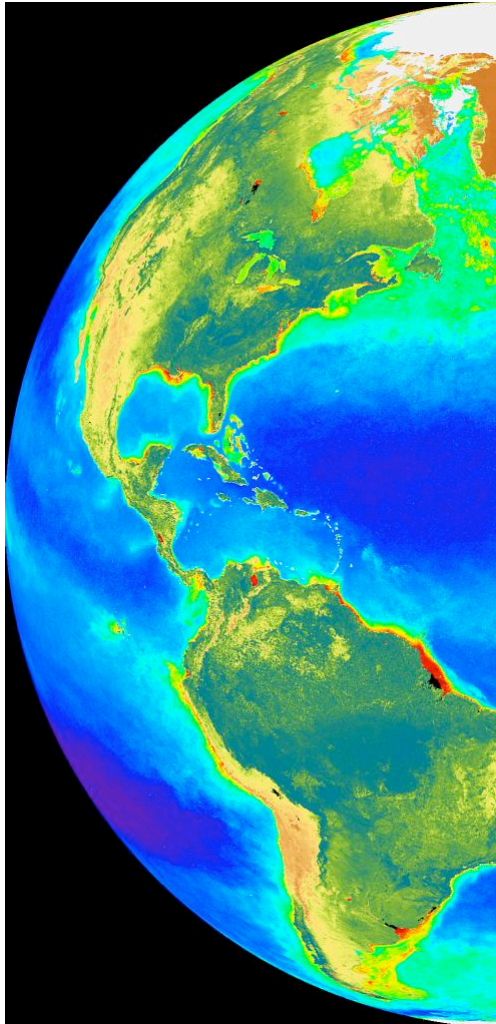
are the temporal & spatial resolutions adequate?

what temporal & spatial resolutions are most appropriate?



1. why use satellites for oceanographic applications?
2. why study ocean color?
3. ocean color @ NASA
4. the NASA Ocean Biology Processing Group (OBPG)
5. international collaborations

why ocean color?



we want to understand how the Earth is changing & the how these changes impact life on Earth

how is the global Earth system **changing**?

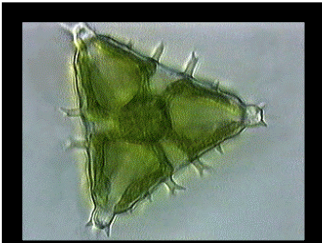
what are the primary **forcings** of the Earth system?

how does the Earth system **respond** to natural and human induced changes?

what are the **consequences** of changes in the Earth system for human civilization?

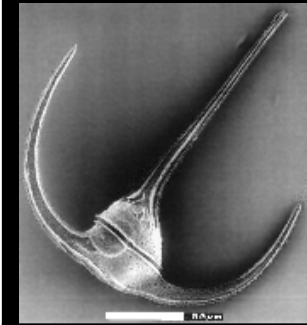
how well can we **predict** the changes to the Earth system that will take place in the future?

why ocean color?



ocean color:

ocean monitoring in the visible range of the electromagnetic spectrum



primary (historical) goal:

to extract concentrations of marine phytoplankton



phytoplankton:

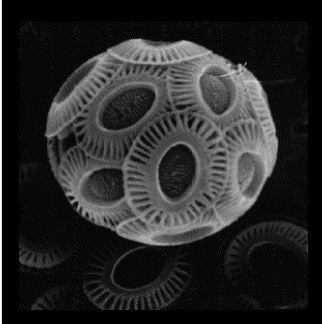
fix carbon dioxide into organic material

play a profound role in the global carbon cycle and climate

responsible for ~half of Earth net primary production

form the basis of the marine food chain

support various industries, primarily fisheries



secondary (modern) goals:

separate phytoplankton species (e.g. coccolithophore, harmful algae)

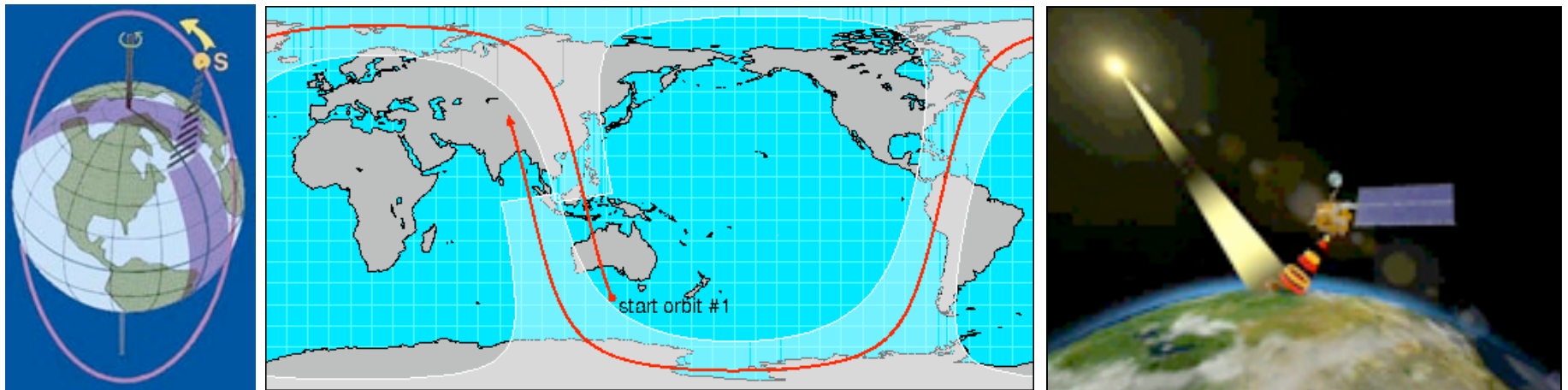
monitor coastal environments

why ocean color?

near-polar, sun-synchronous orbits

near-polar orbits enable low-altitude imaging & global daily coverage

sun-synchronous orbits cross the equator at the same local time



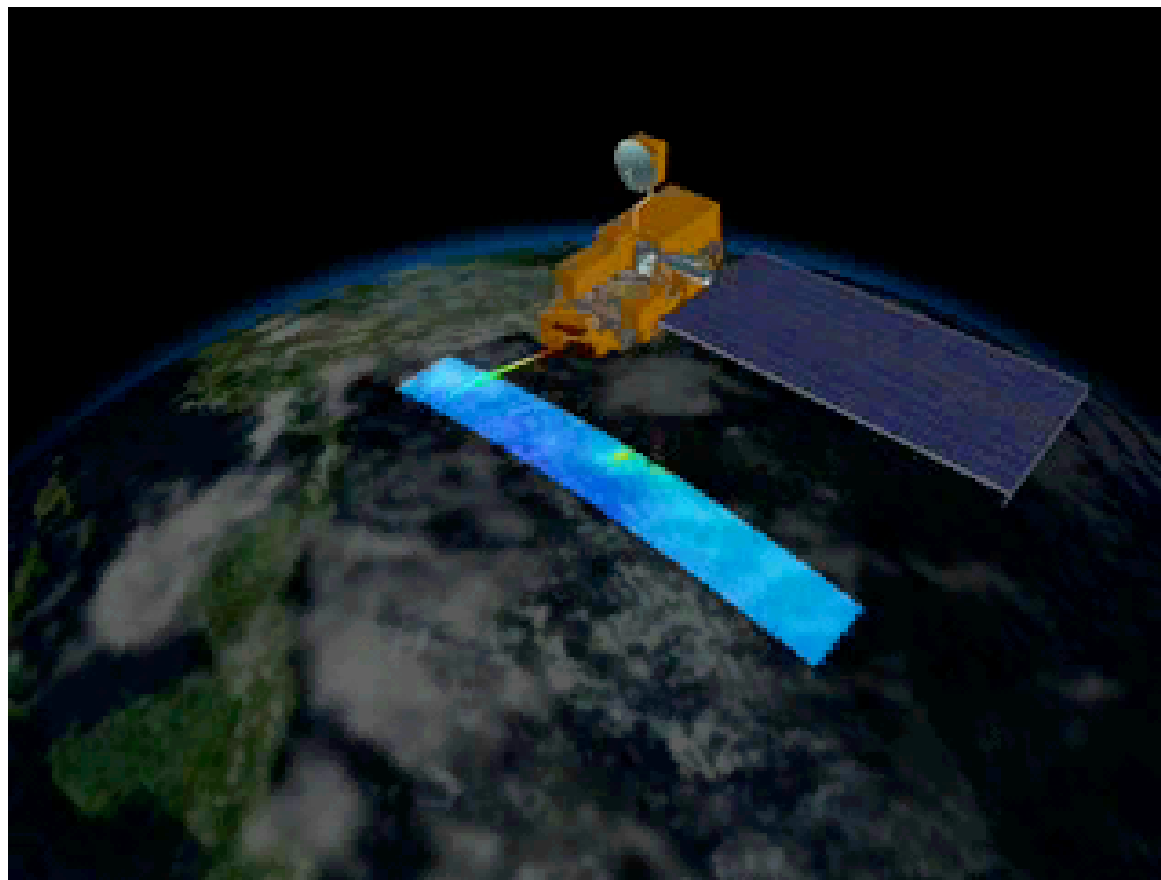
ocean color instruments are passive sensors

they measure electromagnetic radiation reflected or emitted by the Earth surface

MODIS has **20 reflective solar bands** from 410 nm – 2.1 μm

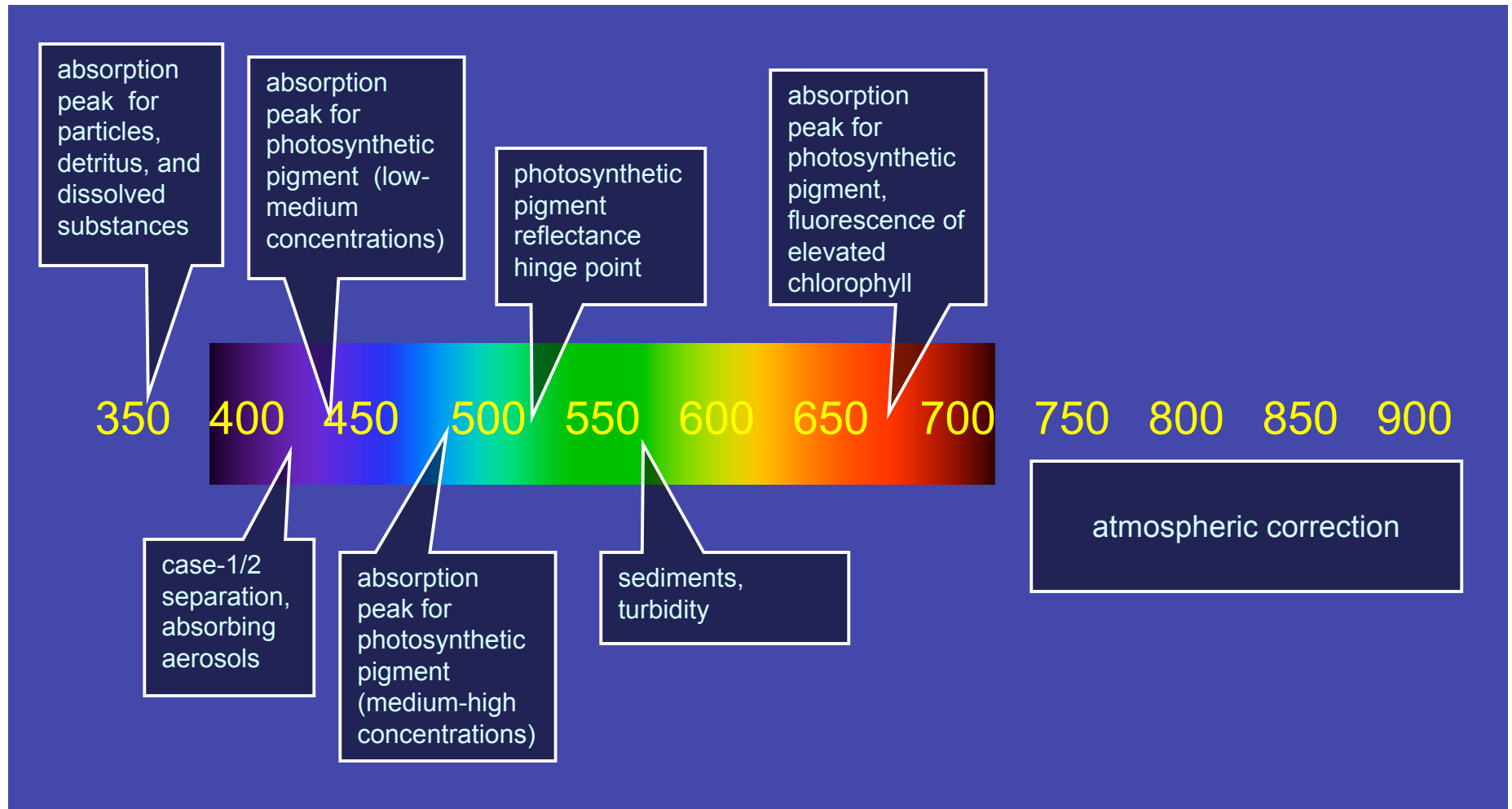
MODIS has 16 thermal emissive bands from 3.7 – 14.4 μm

why ocean color?



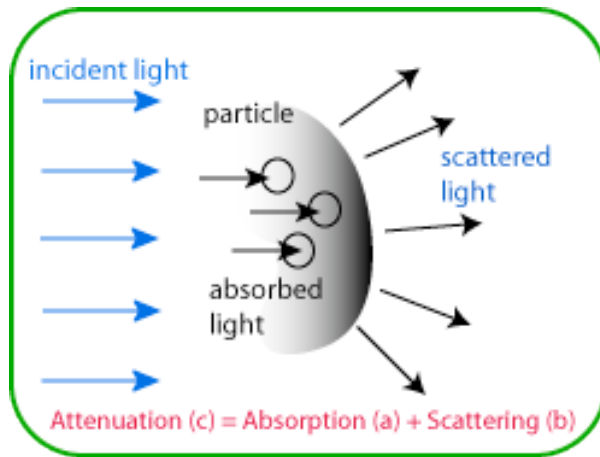
why ocean color?

spectral characteristics of ocean waters



why ocean color?

data products: relative concentrations of water column constituents



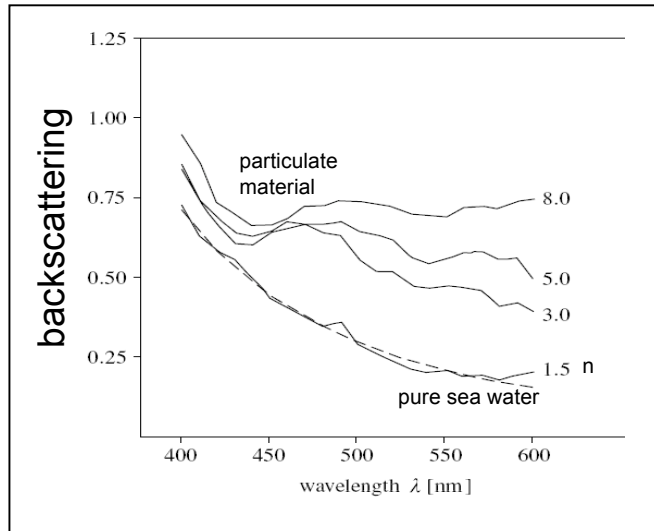
photons have two fates when they travel through a medium:

- (1) absorbed, a
- (2) scattered, b (backwards, b_b)

$$R(\lambda) \approx \frac{b_b(\lambda)}{a(\lambda)}$$

why ocean color?

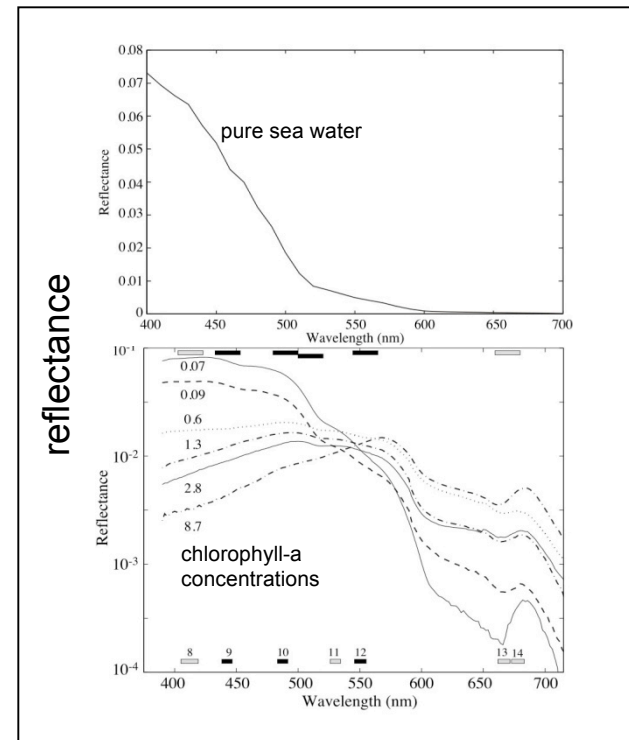
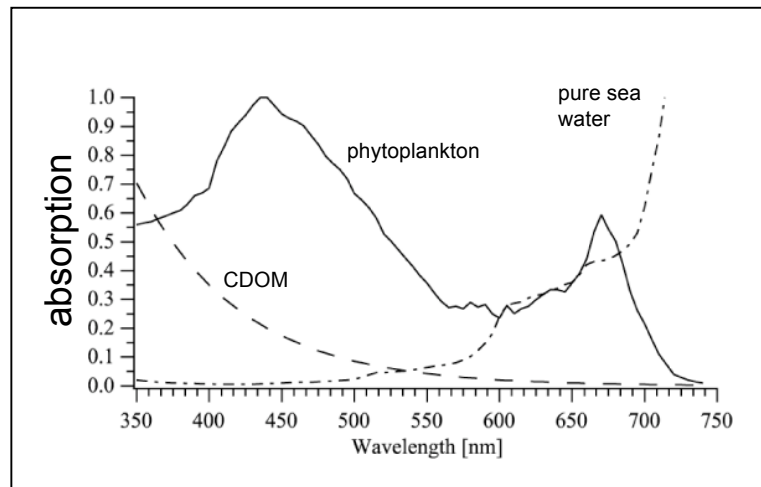
data products: relative concentrations of water column constituents



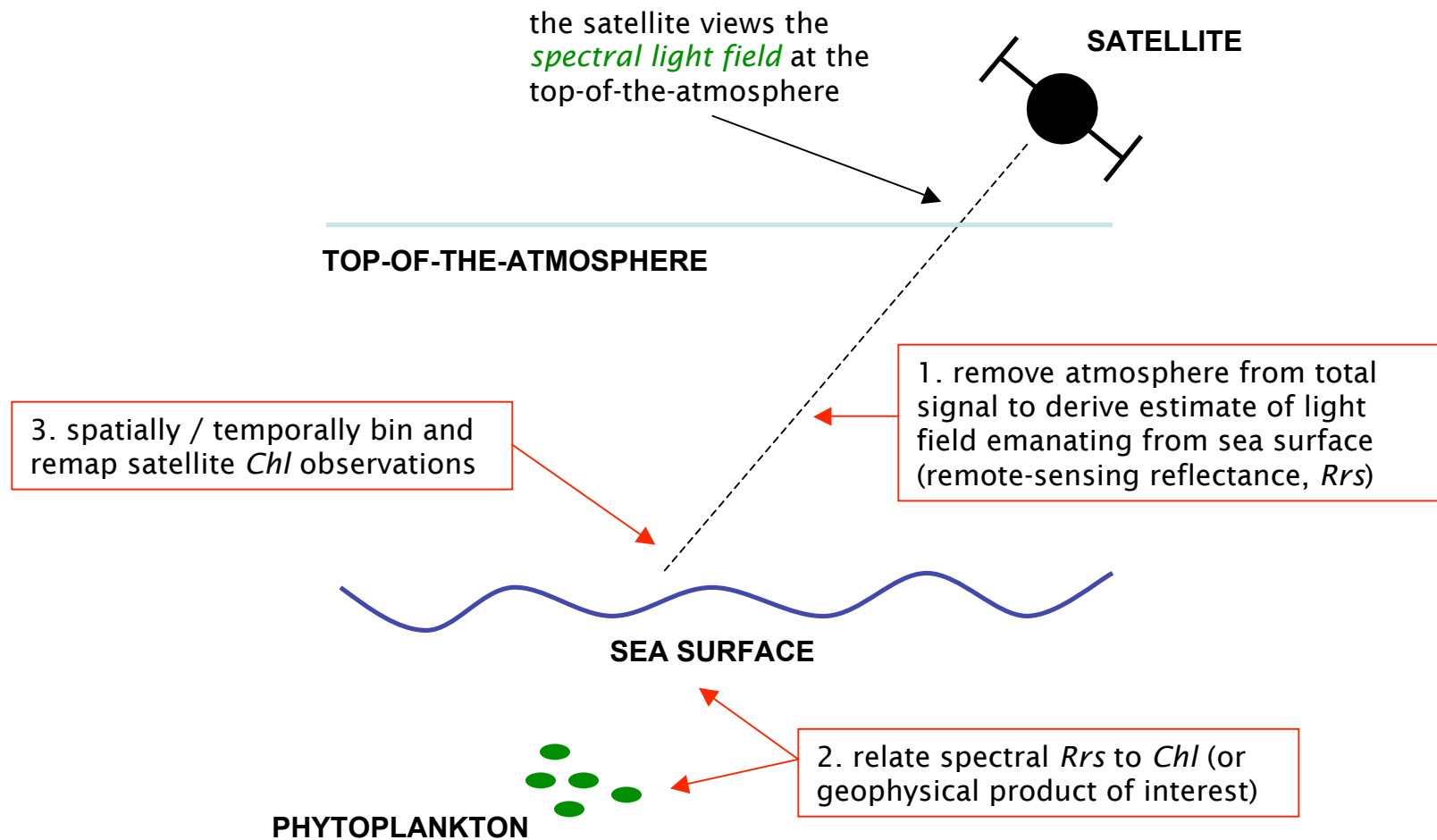
photons have two fates when they travel through a medium:

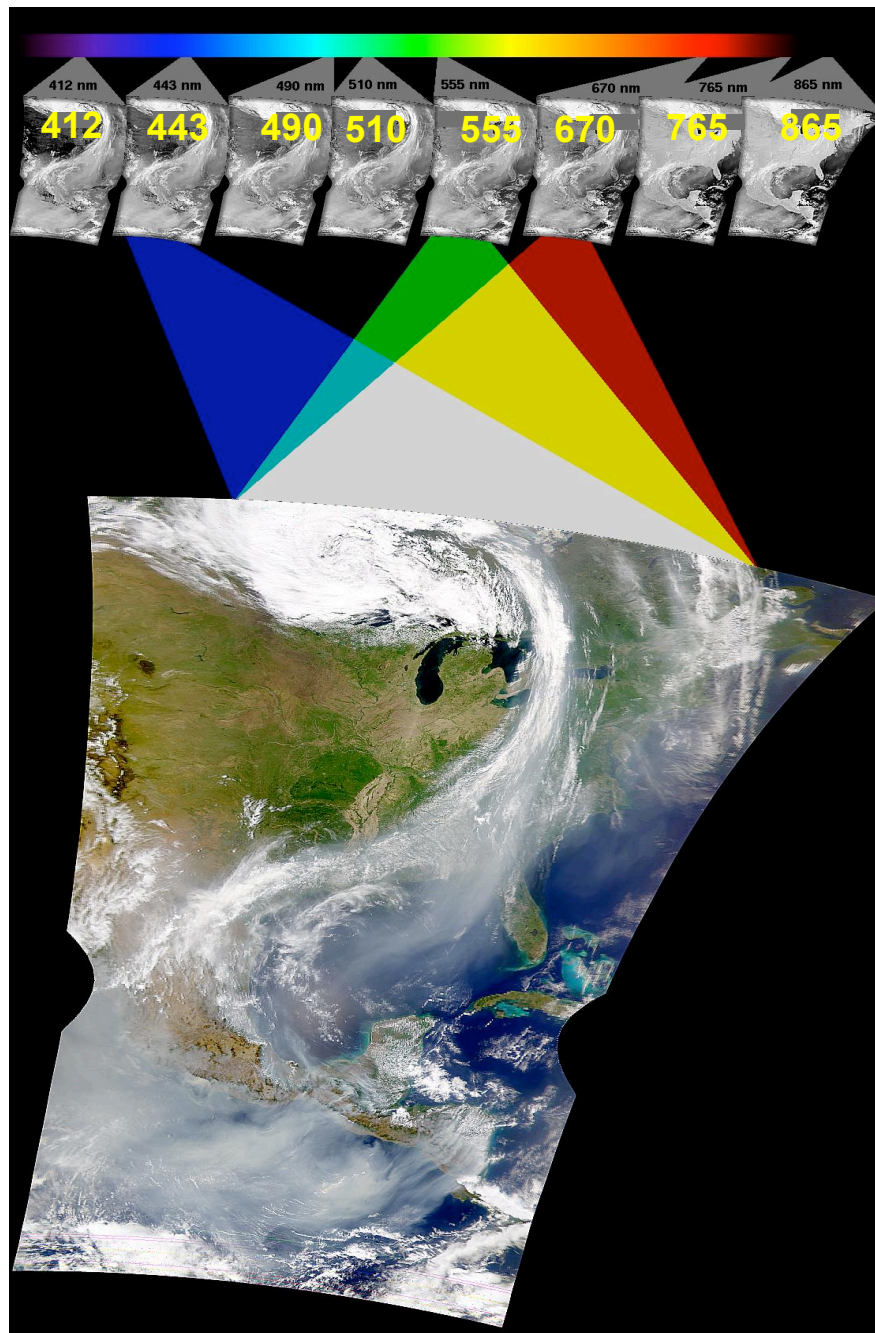
- (1) absorbed, a
- (2) scattered, b (backwards, b_b)

$$R(\lambda) \approx \frac{b_b(\lambda)}{a(\lambda)}$$



why ocean color?





ocean color data products

primary optical variable

remote-sensing reflectance (R_{rs} ; units sr^{-1});

the subsurface upwelled radiance that propagates through the sea-air interface, normalized by the downwelled irradiance

primary bio-optical variable

chlorophyll-a concentration (Chl; units $mg\ m^{-3}$);

main photosynthetic pigment of phytoplankton, used as index of phytoplankton biomass;

other data products

concentrations of water column constituents, e.g., particulate inorganic & organic carbon, & descriptors of the light field (e.g., PAR, euphotic depth, fluorescence line height & quantum yield)

types of algorithms: operational empirical algorithms

operational empirical (statistical) algorithms typically have a form that resembles

$$\log_{10}(C_a) = c_0 + \sum_{i=1}^N c_i \log_{10} \left(\frac{R_{rs}(\lambda_b)}{R_{rs}(\lambda_g)} \right)$$

including all OC* & KD* algorithms developed by the OBPB, plus POC, TSM, etc. algorithms developed elsewhere

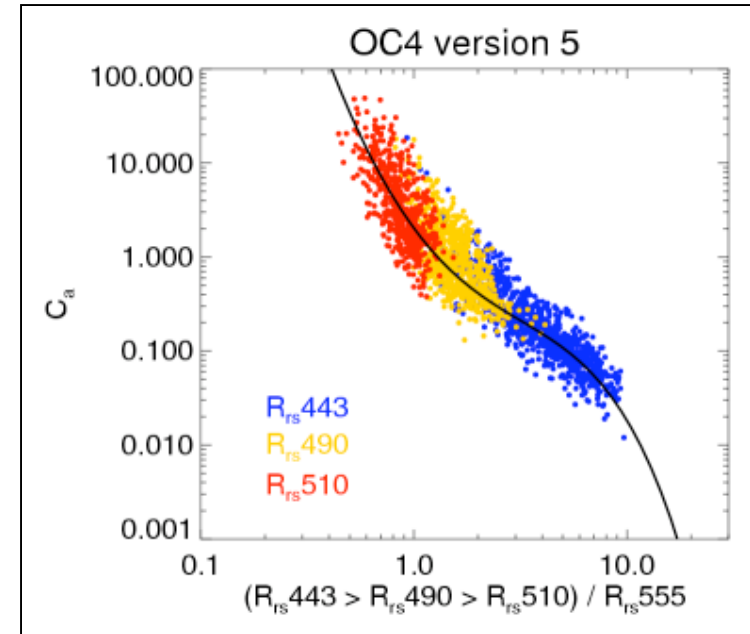


Table 1

Coefficients for the OC version 5 algorithms (O'Reilly, personal communication).

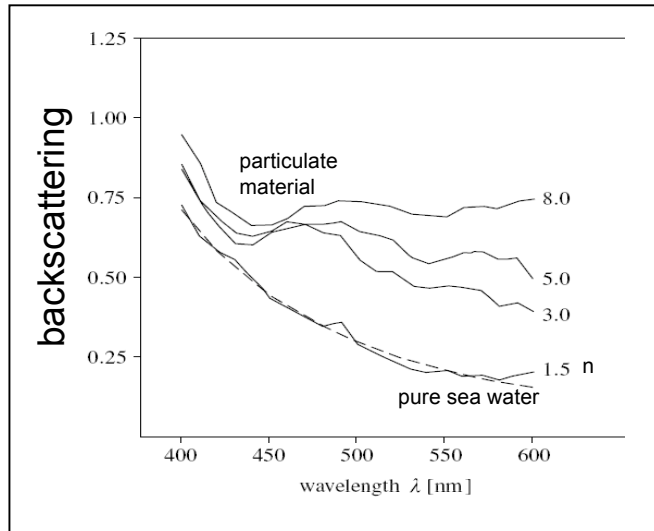
	λ_b	λ_g	c_0	c_1	c_2	c_3	c_4
OC4	443,490,510	555	0.3080	-3.0882	3.0440	-1.2013	-0.7992
OC3S ^a	443,490	555	0.2409	-2.4768	1.5296	0.1061	-1.1077
OC3M ^b	443,488	551	0.2254	-2.6354	1.8071	0.0063	-1.2931

^a For SeaWiFS.

^b For MODIS-Aqua.

types of algorithms: "semi-analytical" algorithms

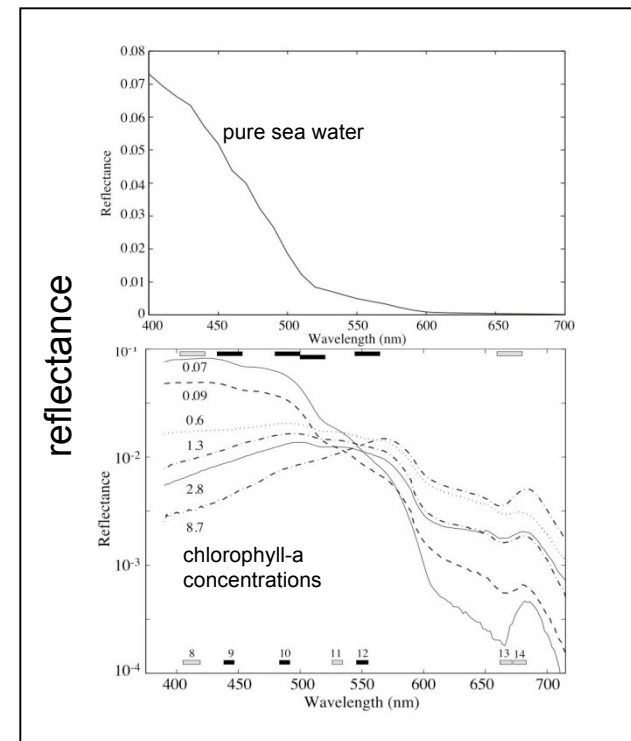
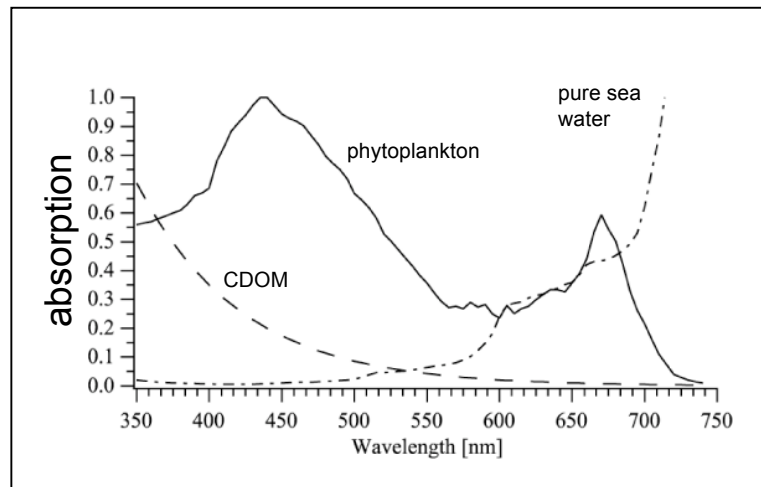
Collin will provide a comprehensive overview in the next talk



photons have two fates when they travel through a medium:

- (1) absorbed, a
- (2) scattered, b (backwards, b_b)

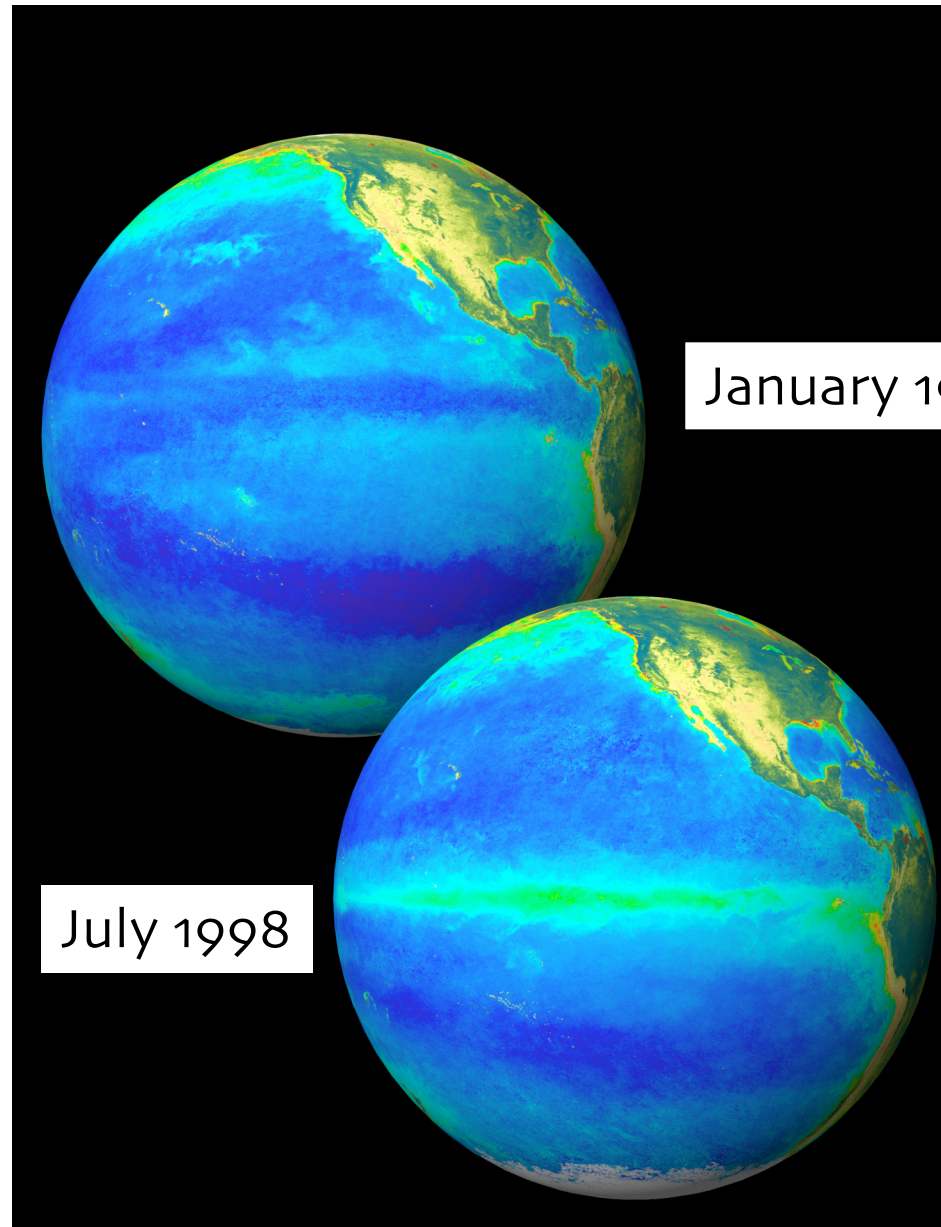
$$R(\lambda) \approx \frac{b_b(\lambda)}{a(\lambda)}$$



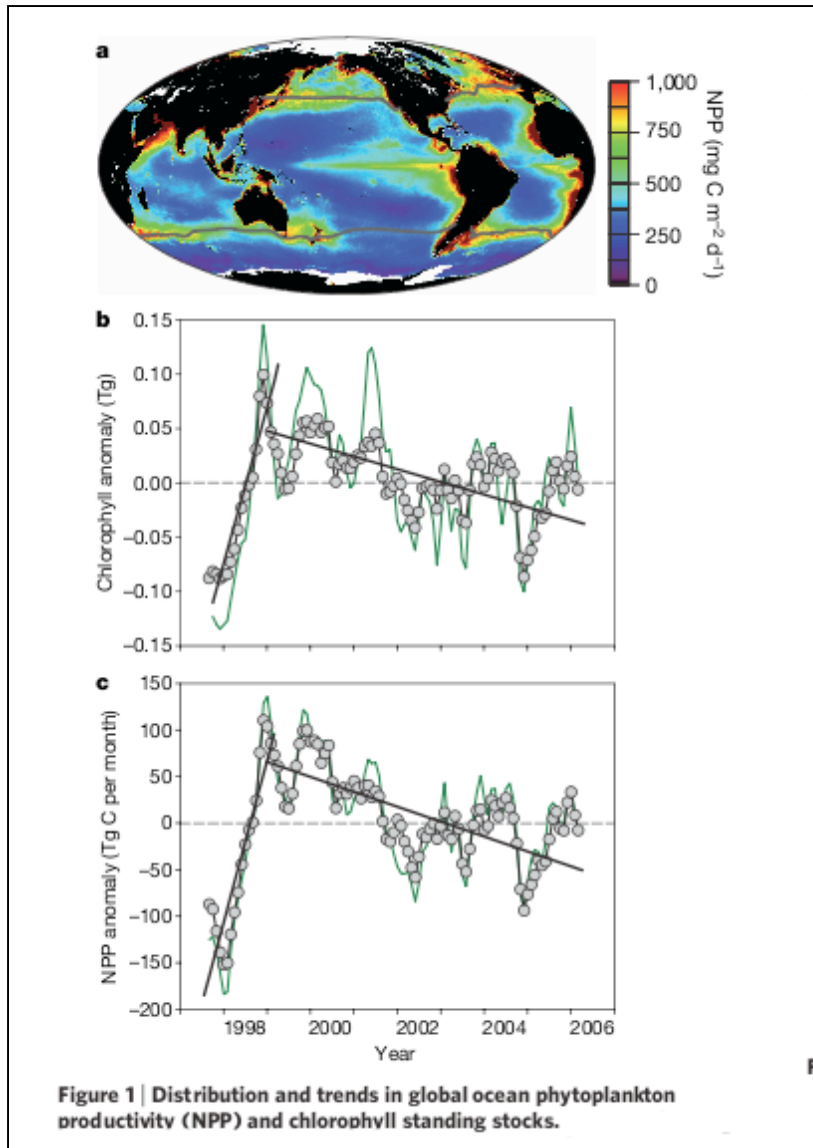
examples of ocean color applications

SeaWiFS captured
the El Nino / La
Nina transition

see Behrenfeld et al.
"Biospheric primary
production during an
ENSO transition,"
Science 30 (2001)

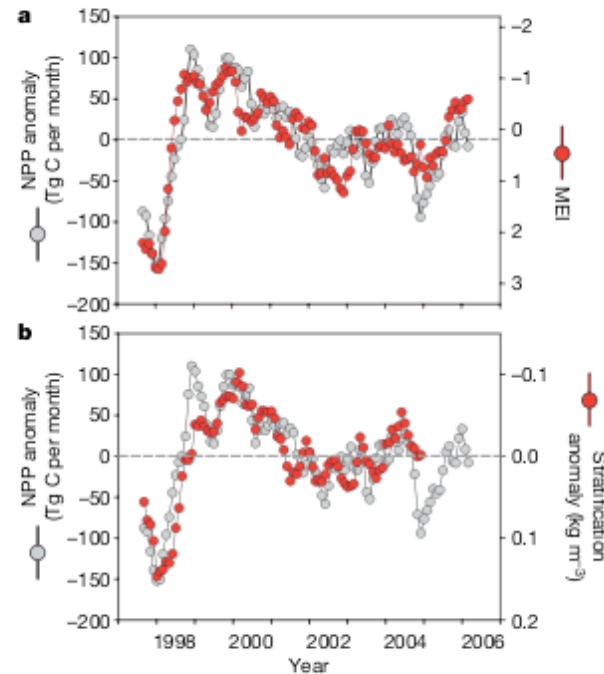


examples of ocean color applications



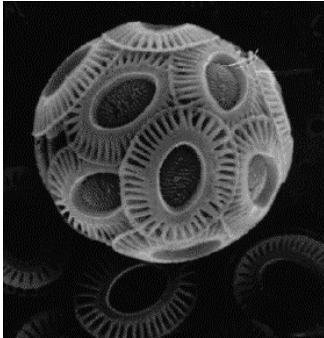
climate & productivity are related

see Behrenfeld et al. "Climate-driven trends in contemporary ocean productivity," Nature 444, (2006)



examples of ocean color applications

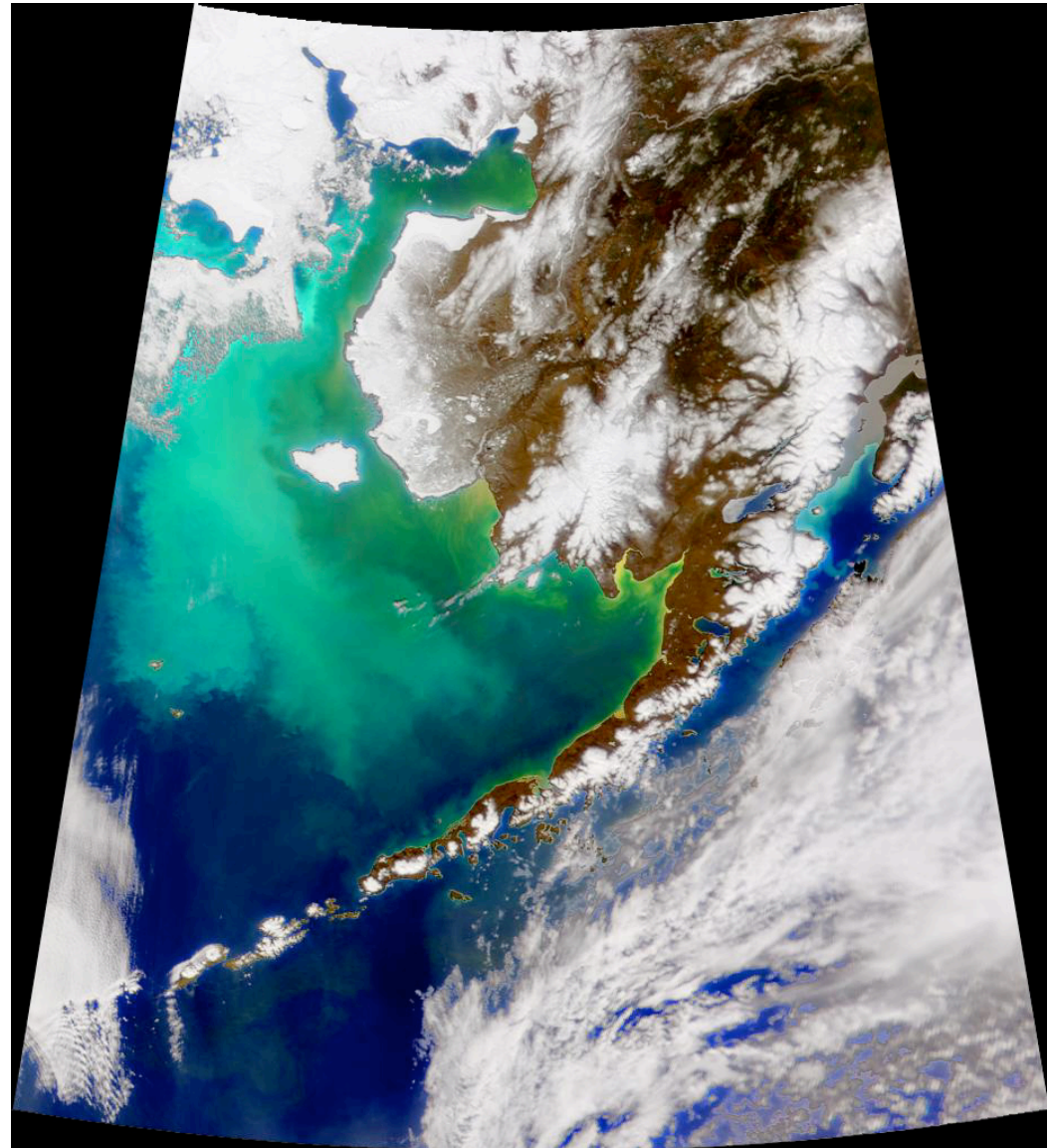
Bering Sea blooms



coccolithophore


reflective carbonate plates
shed in water, giving it
opaque, milky quality

reduced water clarity
affects ecology (birds, fish)



examples of ocean color applications

harmful algal blooms



Gulf of Mexico Harmful Algal Bloom Bulletin
27 October 2005
National Ocean Service
National Environmental Satellite, Data, and Information Service
Last bulletin: October 24, 2005

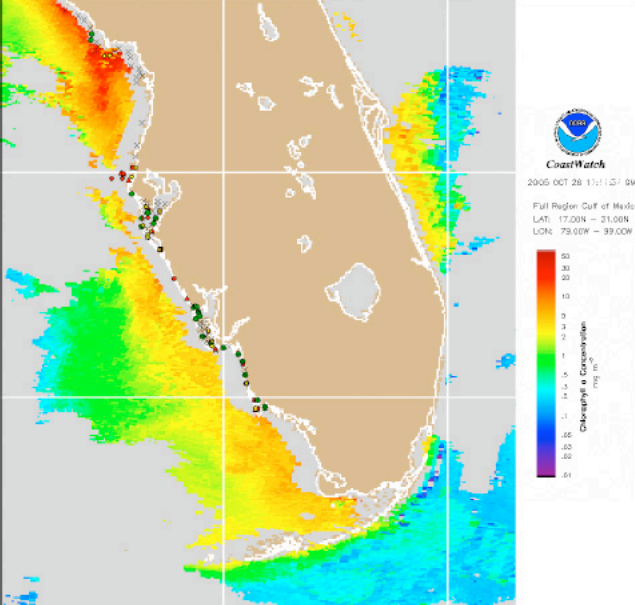
Conditions: Harmful algal blooms have been identified in Pinellas County, Dixie to Levy County and in very small patches from Manatee to Collier County in Florida. A secondary bloom has been identified in patches along Alabama and the Florida Panhandle. No impacts are expected along the coast from Pinellas to Collier County or from Dixie to Levy County today through Sunday. Patchy very low to low impacts are possible from Wakulla to Okaloosa County, FL and Baldwin to Mobile County, AL today through Sunday. Dead fish have been reported in Bay and Okaloosa Counties over the past few days. Dead fish smell, while unpleasant, does not produce the same respiratory irritation as red tide.

Analysis: The harmful algal bloom continues to dissipate along the SW Florida coastline; however very small remnant populations of *K. brevis* may still be present in patches from Pinellas to Collier County. Low *K. brevis* concentrations remain offshore of Bunces Pass in southern Pinellas County. Previous low *K. brevis* concentrations in Sarasota County have decreased to background levels (FWRI 10/20-26). Chlorophyll levels are elevated all along the Florida coast due to resuspension produced by Hurricane Wilma; thus bloom extent analysis is limited. Results of a wind transport model indicate possible bloom movement 20-30km southward since October 24. No recent samples have been reported from Levy to Dixie Counties. Sampling is recommended. Persistent northeasterlies will minimize coastal impacts through Sunday. Continual dissipation of the bloom is expected. Reports of discolored water are likely.

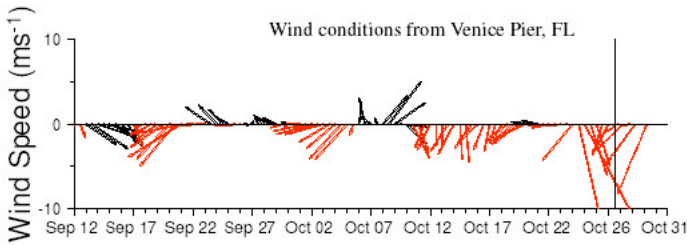
Fisher, Bronder

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. These data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Distribution for military, or commercial purposes is NOT permitted.
3. There are restrictions on Internet/Web/public posting of these data.
4. Image products may be published in newspapers. Any other publishing arrangements must receive OrbImage approval via the CoastWatch Program.



Chlorophyll concentration from satellite with HAB areas shown by red polygon(s). Cell concentration sampling data from October 19, 2005 shown as red squares (high), red triangles (medium), red diamonds (low b), red circles (low a), orange circles (very low b), yellow circles (very low a), green circles (present), and black "X" (not present).



Wind conditions from Venice Pier, FL

Wind speed and direction are averaged over 12 hours from measurements made on buoys. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

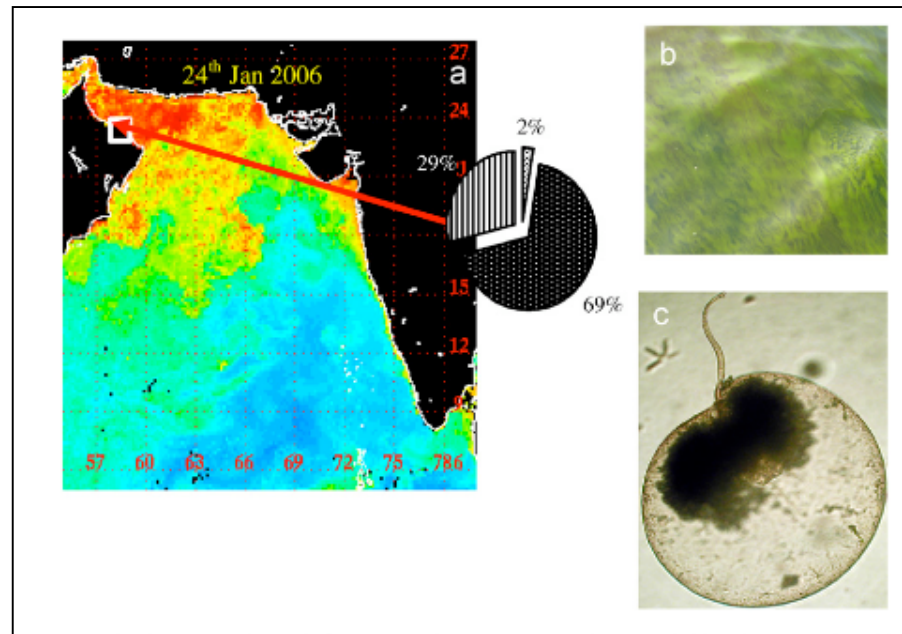
SW Florida: Moderate (10-15kts, 5-8m/s) northeasterly winds today will continue through Sunday; strengthening up to 20kts (10m/s) Saturday and Sunday.

examples of ocean color applications

two (of many) studies of the Arabian Sea that used satellite ocean color

Goes et al., "Warming of the Eurasian landmass is making the Arabian Sea more productive," *Science* 22 (2005)

Gomes et al., "Blooms of *Noctiluca miliaris* in the Arabian Sea - an *in situ* and satellite study," *Deep Sea Research I* 55 (2008)



examples of ocean color applications

impacts of natural disasters

Hurricane Floyd

23 September 1999

massive flooding

rivers carried sediment & sewage
discharge into coastal areas

resulted in anoxic conditions in bays



Sept. 23, 1999

examples of ocean color applications

SeaWiFS coral reef activities

collaborative effort between NASA, NOAA & WCMC to create the most accurate global map of potential coral reef habitats

accurate to 1 km; improved coral reef maps - nearly 2K reef groups corrected in ReefBase

nearly 44K images processed

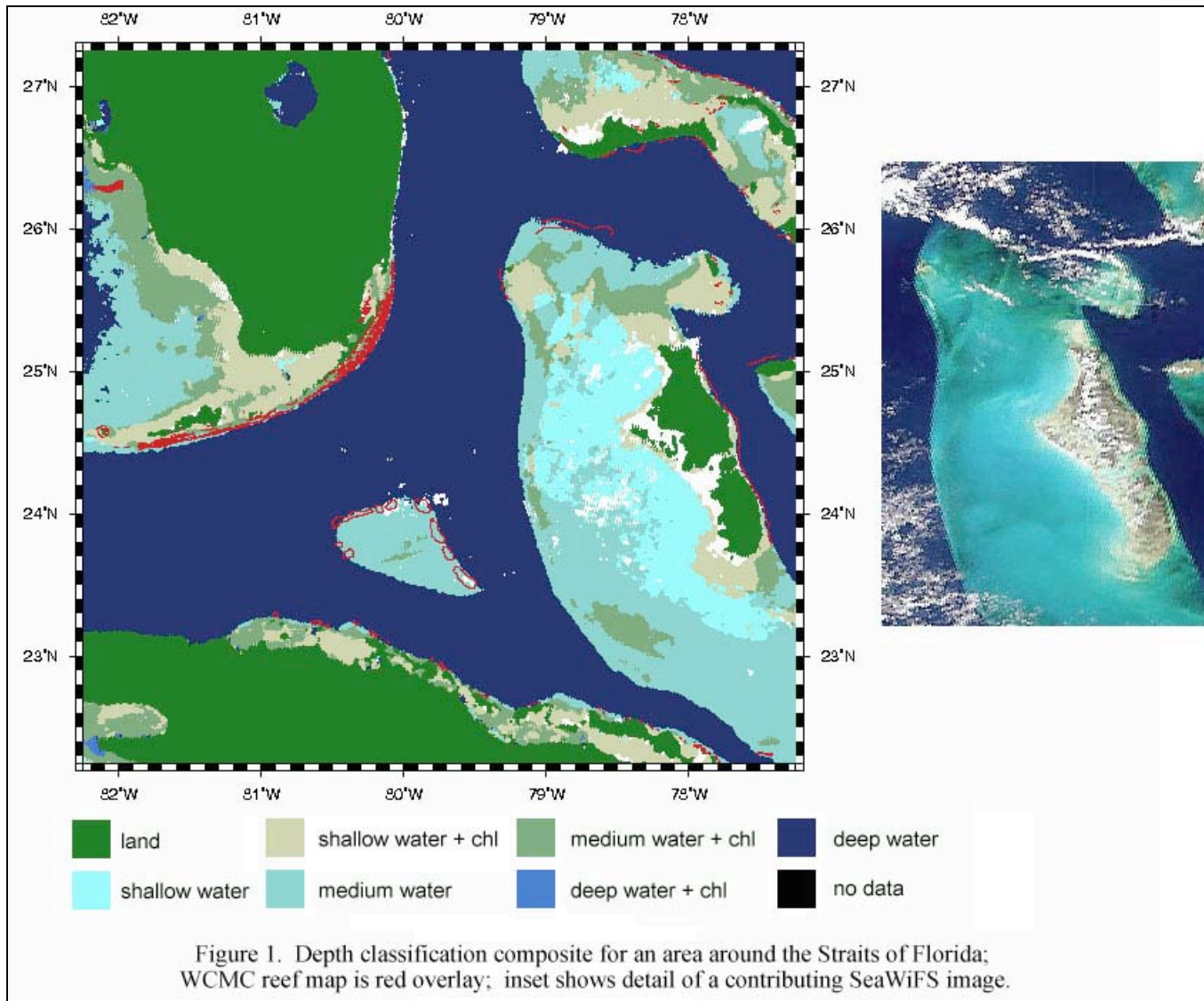
online web-based tool



<http://seawifs.gsfc.nasa.gov/reefs>

examples of ocean color applications

SeaWiFS depth classification



examples of ocean color applications

IOCCG Report 7 (2008)

“Why Ocean Colour? The Societal Benefits of Ocean-Colour Technology”

<http://www.ioccg.org>

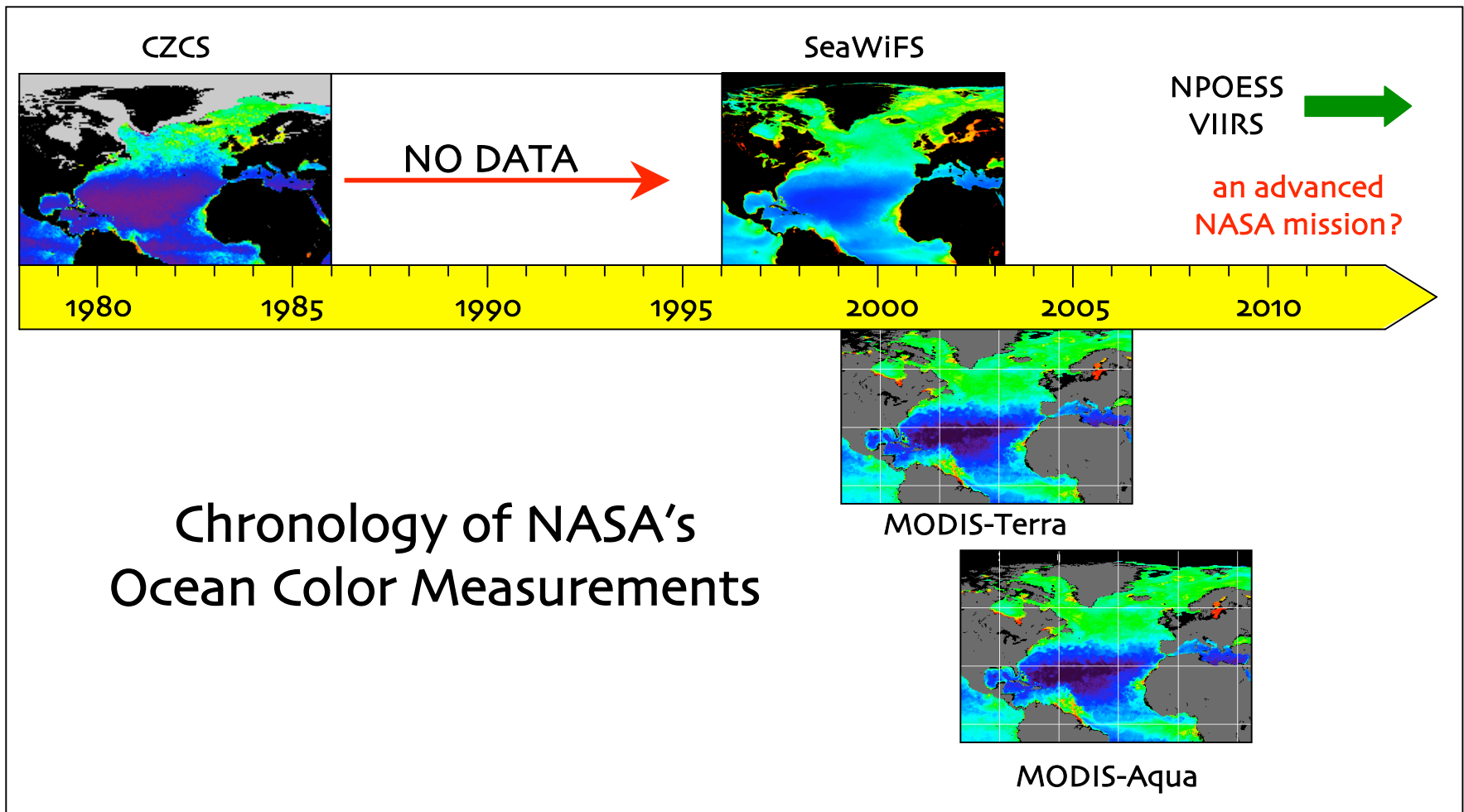
1. why use satellites for oceanographic applications?
2. why study ocean color?
3. ocean color @ NASA
4. the NASA Ocean Biology Processing Group (OBPG)
5. international collaborations

ocean color @ NASA

NASA's goals are to:

make available high quality ocean color (& sst) data to the broadest user community in the most timely & efficient manner possible

facilitate the continuity & consistency of a long-term ocean color data record for climate research through international collaborations on satellite missions and field campaigns



Chronology of NASA's Ocean Color Measurements

other
satellite data

sea surface temperature: AVHRR, MODIS, VIIRS, ...

winds: SSMI, Nscat, Quikscat, SeaWinds, ...

sea surface topography: TOPEX, Jason, Grace, OSTM, ...

salinity: Aquarius

1. ACE (Aerosols-Clouds-Ecosystems)

mission & payload

low Earth orbit

sun-synchronous, early-afternoon orbit, with altitude of 500-650 km

instruments and technology

HSR Lidar for assessing the heights of aerosol & cloud properties.

dual frequency Doppler cloud radar for cloud properties & precipitation

multi-angle, swath polarimeter for imaging aerosol & clouds

ocean ecosystem multi-channel spectrometer (OES)

IR multi-channel imager for cloud temperatures & heights

high frequency swath radiometer for cloud ice measurements

low frequency swath radiometer for precipitation measurements

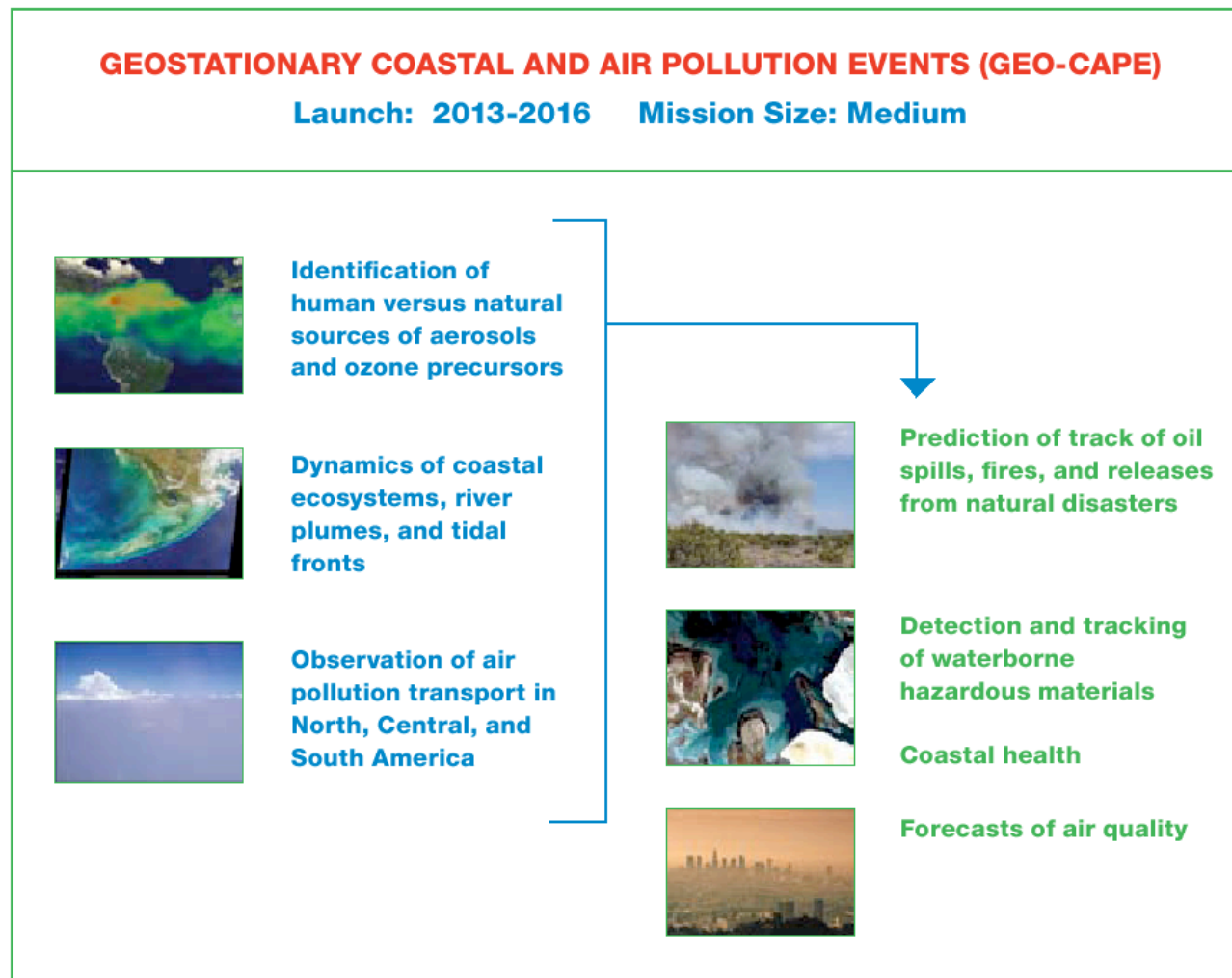
microwave temperature/humidity sounder

the ACE mission – with its advanced instruments will likely not launch until 2020

black – specified by NAS Decadal Survey & red – Science Definition Team recommendations

2. GEO-CAPE (Geostationary Coastal & Air Pollution Events)

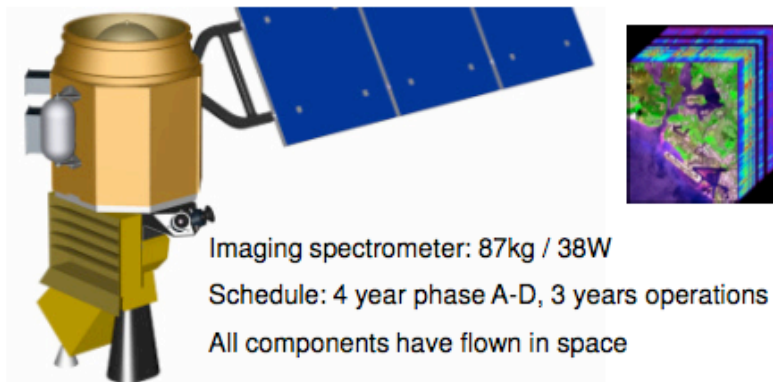
UV-visible-near IR wide area spectrometer covering 45°S to 50°N hourly steerable, high spatial resolution, event-imaging spectrometer
O₃, NO₂, CH₂O, SO₂, aerosols & IR correlation radiometer for CO mapping



3. HypsIRI (Hyperspectral Infrared Imager)



HypsIRI Imaging Spectroscopy Science Measurements



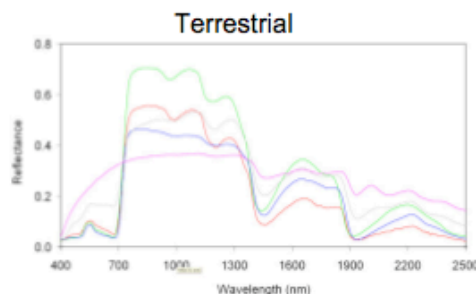
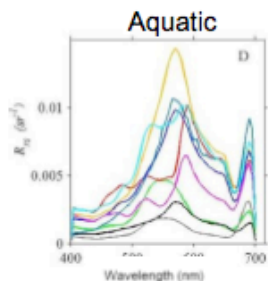
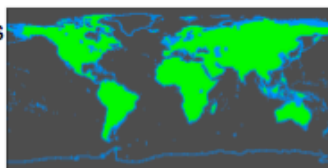
Imaging spectrometer: 87kg / 38W
 Schedule: 4 year phase A-D, 3 years operations
 All components have flown in space

Science Questions:

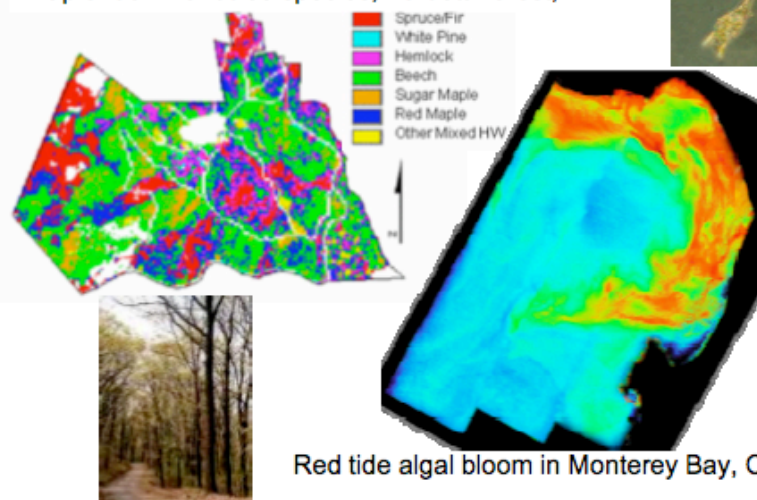
- *What is the composition, function, and health of land and water ecosystems?*
- *How are these ecosystems being altered by human activities and natural causes?*
- *How do these changes affect fundamental ecosystem processes upon which life on Earth depends?*

Measurement:

- 380 to 2500 nm in 10nm bands
- Accurate 60 m resolution
- 19 days revisit
- Global land and shallow water



Map of dominant tree species, Bartlett Forest, NH

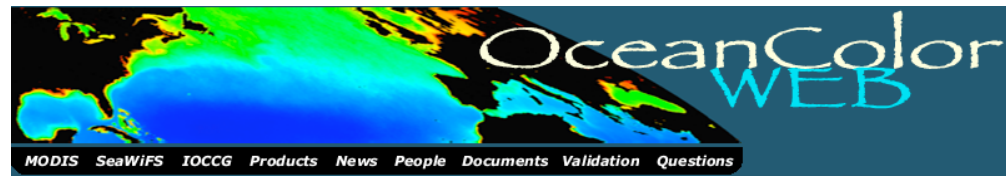


Red tide algal bloom in Monterey Bay, CA

1. why use satellites for oceanographic applications?
2. why study ocean color?
3. ocean color @ NASA
4. the NASA Ocean Biology Processing Group (OBPG)
5. international collaborations

the NASA Ocean Biology Processing Group

- Ocean Color (OC)
- SST for MODIS, GHRSSST
- Salinity from Aquarius
- End-to-End Shop for Ocean Color
 - Sensor calibration/characterization
 - Processing software & algorithms
 - Product validation (SeaBASS)
 - Algorithm development (NOMAD)
 - User processing and display (SeaDAS)
 - Data archive and distribution
 - User support (Ocean Color Forum)
- Distributed processing system
 - 400x global reprocessing for MODIS
 - 4000x for SeaWiFS
- Data archive and distribution
 - ~1 PB online storage (RAID)
 - distribution: 34 million files OC (2004-)
 - 9 million files SST



oceancolor.gsfc.nasa.gov

Consolidated data access, information services, and community feedback.

Missions Supported

MODIS/Aqua: 2002-present
MODIS/Terra: 1999-present
SeaWiFS/Orbview-2: 1997-present
OCTS/ADEOS: 1996-1997
MOS/IRS-P3: 1996-2004
CZCS/NIMBUS-7: 1978-1986
VIIRS/NPP: 2011 launch
Glory Data System : 2009 launch
Aquarius / SAC-D : May 2010 launch
New Mission Development (ACE)

the NASA Ocean Biology Processing Group

measurement-based organization

consolidated expertise in ocean color measurements

- multi-mission, end-to-end

- sensor calibration/characterization, prelaunch & on-orbit

- product validation (SeaBASS validation data set)

- algorithm development & evaluation (NOMAD)

- data processing and distribution (ODPS, OceanColorWeb)

- user processing and display (SeaDAS)

- user support (Ocean Color Forum)

global processing & distribution

- SeaWiFS

- MODIS (Aqua & Terra)

- CZCS

- OCTS (Japan)

the NASA Ocean Biology Processing Group

standard ocean products

observed radiance (uncalibrated)

ocean color

remote-sensing reflectances, $R_{rs}(\lambda)$

chlorophyll, Chl

diffuse attenuation, $K_d(490)$

aerosol type & concentration

FLH, FQY, iPAR, PAR, POC, PIC, Morel CDOM index

ocean temperature (MODIS only)

data types (online archive)

Level-0 or Level-1A: uncalibrated radiances

Level-2: retrieved geophysical parameters

Level-3: global gridded composites - daily, 8-day, monthly, merged

the NASA Ocean Biology Processing Group



[MODIS](#) [SeaWiFS](#) [IOCCG](#) [Products](#) [News](#) [People](#) [Documents](#) [Validation](#) [Questions](#)

Data Access

Data Production and Distribution Status

 [SeaWiFS in safe-haven: data outage](#)

NOTE: FTP connections must be made in PASSIVE mode

Level 1 and 2 Browser

Visually search the ocean color data archive. Directly download or order data from a single file to an entire mission.

Level 3 Browser

Browse the entire global ocean color data set for many parameters and time periods and download PNG images or digital data in HDF format.

Global Time Series

Time series plots of selected SeaWiFS, MODIS and OCTS Standard Mapped Images for a set of selected regions or the entire globe.

Data by FTP

The FTP access to our most popular data products, including the complete Level 3 data archive.

Ocean Productivity

Ocean Net Primary Productivity data products derived from MODIS and/or SeaWiFS data available from Oregon State University.

Giovanni

An easy-to-use, Web-based interface for the visualization and analysis of Earth Science data provided by the GES DISC DAAC.

Ocean Color Web Feature

Recent topics and imagery of interest to the OceanColor community.

The Chatham Rise



The **Chatham Rise**, extending eastward from the Banks Peninsula on New Zealand's South Island, separates two areas of deeper water to the north and south. Tides and other currents flowing over this submarine topography cause **increased mixing** in the water column. That and the location of the rise along the **subtropical front** often results in large blooms of phytoplankton in the area -- particularly during the austral spring and summer. The above image collected by Terra-MODIS on January 5, 2008 shows such blooms coloring the waters above the rise. The view is toward the west.

Image Gallery

NOTE: All SeaWiFS images presented here are for research and educational use only. All commercial use of SeaWiFS data must be coordinated with [GeoEye](#)

Ocean Color Distribution Statistics

Support Services

SeaDAS

A comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.

SeaBASS

An archive of *in situ* oceanographic and atmospheric data for use in algorithm development and satellite data product validation.

Registration for support services:

- [Data access and Subscriptions](#)
- [Forgotten password](#)
- [Email change](#)
- [SeaWiFS Access Authorization](#)

Near Real-Time (NRT) Services:

- [NRT Data Subscriptions](#)
Subscriptions allow users to specify regions for NRT data to be continually staged on our FTP server for download.

Information Services:

- [Ocean Color Forum](#)
- [Ocean Color Mailing List](#)

Other Services:

- [Satellite Overflight Predictions](#)
- [SeaWiFS LAC scheduling](#)
- [Data subscription status](#)
- [L1/L2 browser order status](#)
- [Ocean Data Processing System](#)
Information related to the ocean color data production system.

<http://oceancolor.gsfc.nasa.gov/>

the NASA Ocean Biology Processing Group

data distribution

free & open data distribution policy

all data available on-line

Web-based browsing & direct FTP access

automated ordering system

subscription services

geographic & parameter sub-setting

the NASA Ocean Biology Processing Group

SeaWiFS

GAC LAC MLAC

OCTS (ADEOS) MODIS (Terra) MODIS (Aqua) CZCS (Nimbus-7)

Day Night

Radius (km) about map click or about typed-in location:

- 72
- 400
- 800
- 1200
- 1500

Select swaths containing (at least):

- any part
- 25 %
- 50 %
- 75 %
- all

of the area of interest.

Select only scenes having in situ matchups.

Monday, 30 October 1978 through Friday, 18 January 2008

Chlorophyll

Display results at a time.

Select one or more regions:

- AdriaticSea
- AegeanSea
- Antarctica
- ArabianSea
- AralSea
- Arctic
- Australia
- AustraliaCoast
- Azores
- Bahamas
- BalticSea

or specify boundary coordinates or a single location:

N:

W: :E

S:

1978	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1984	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2006	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

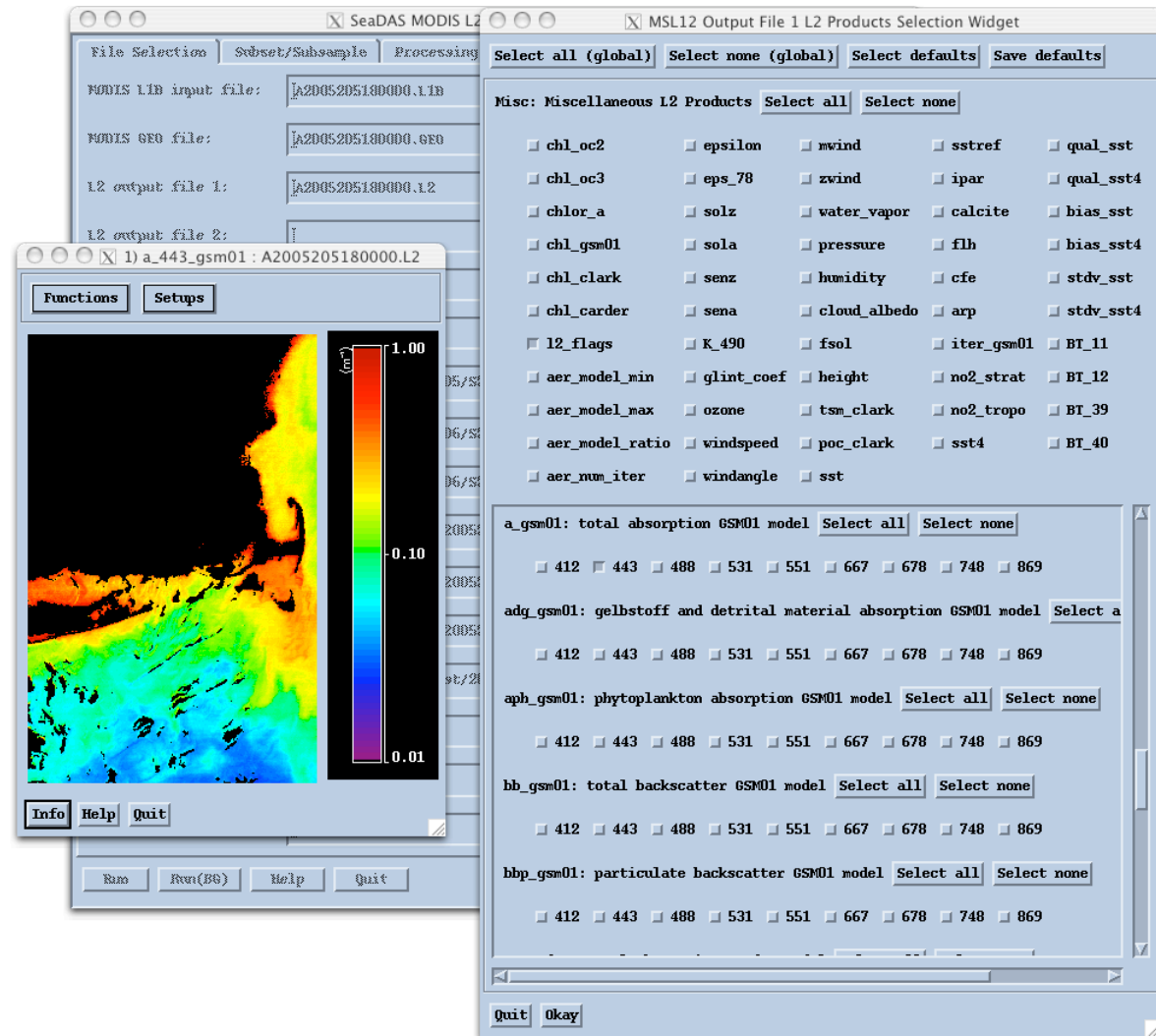
November 2007							December 2007							January 2008							
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	
				1	2	3							1	***							
				***	***	***							2	3	4	5	6	7	8		
4	5	6	7	8	9	10	***	***	***	***	***	***	***	***	6	7	8	9	10	11	12
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
11	12	13	14	15	16	17	***	***	***	***	***	***	***	***	13	14	15	16	17	18	19
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
18	19	20	21	22	23	24	***	***	***	***	***	***	***	***	20	21	22	23	24	25	26
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
25	26	27	28	29	30	***	***	***	***	***	***	***	***	***	27	28	29	30	31		
***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
							30	31													
							***	***													

<http://oceancolor.gsfc.nasa.gov/>

the NASA Ocean Biology Processing Group

SeaDAS

- free
- multi-mission
- display tools
- analysis tools
- processing
- open source



reprocessing algorithms in latest SeaDAS

The screenshot displays the SeaDAS software interface on a Mac OS X desktop. The main window shows a satellite image of a coastal area with a color scale overlay. A menu is open, listing various processing options under 'Process MODIS'. A histogram plot shows the distribution of chlorophyll-a data. A terminal window shows the command-line interface for SeaDAS, including the command 'seadas' and the output of the 'display' command. Other windows include a 'Roam' window and a 'Zoom' window.

Terminal — idl — 76x20

```
palapa:modis_data mike$ seadas
IDL Version 7.0, Mac OS X (darwin ppc #32). (c) 2007, ITT Visual Information
Solutions
Installation number: 17915.
Licensed for use by: NASA/GSFC SeaWiFS Project

SeaDAS Version 5.3.0 (pid = 58254)
SeaDAS> load, 'A2004080182010.png', ftype='png'
SeaDAS> display
SeaDAS> load, 'A2004080182010.L2', prod_name='chlor_a', ftype='modis'
grp_name=Geophysical Data
Getting 'chlor_a' data from HDF file...
SeaDAS> display, fbuf=2
SeaDAS> loadpal, '$SEADAS/config/color_luts/standard/02-standard_chl.lut'
SeaDAS> loadgp, color=2, red=75, green=75, blue=55
SeaDAS> landmask, color=2
SeaDAS> grid, grdcol=7, lblcol=7, latdel=0.5, londel=0.5
SeaDAS> cbar
SeaDAS>
```

15 years in distribution, free, open-source, linux/os-x/solaris/windows(vm), international training
~1400 downloads in 2009 alone

the NASA Ocean Biology Processing Group

examples of non-standard ocean products

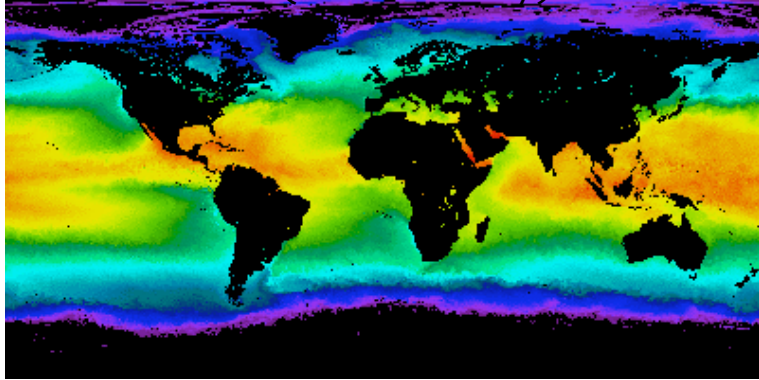
alternate C_a and K_d algorithms

inherent optical properties (various bio-optical models)
absorption (total, phytoplankton, dissolved material)
backscatter (total, particulate)

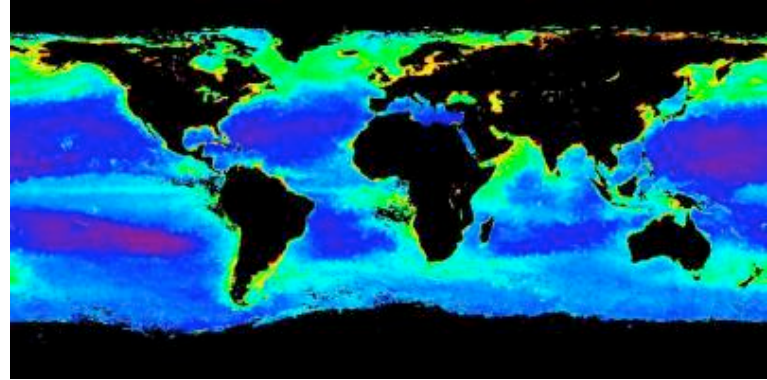
euphotic depth (Z_{eu} , Z_{sd})

spectrally integrated diffuse attenuation, $K_d(\text{PAR})$

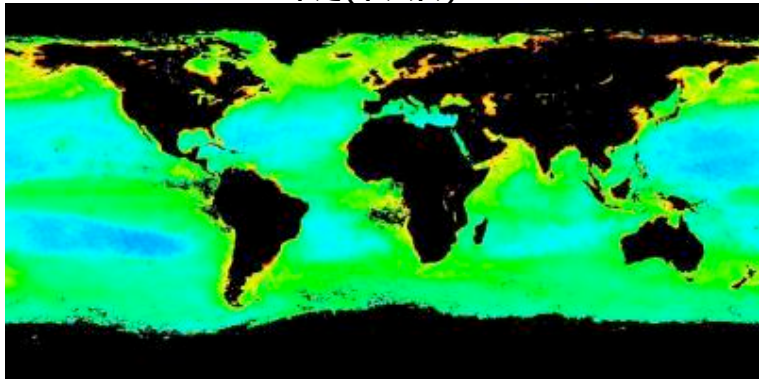
SST (11-12mm day)



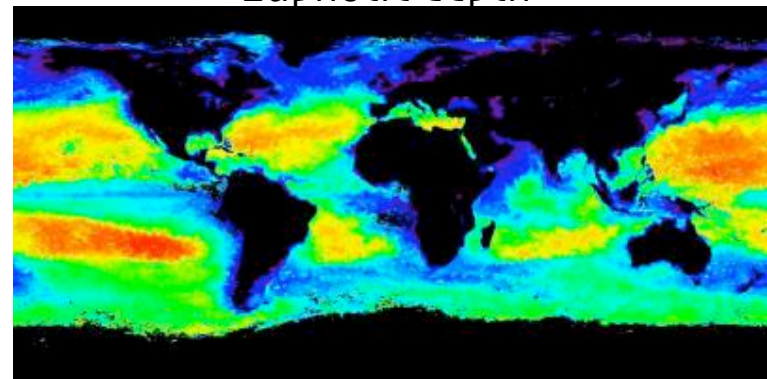
Chlorophyll



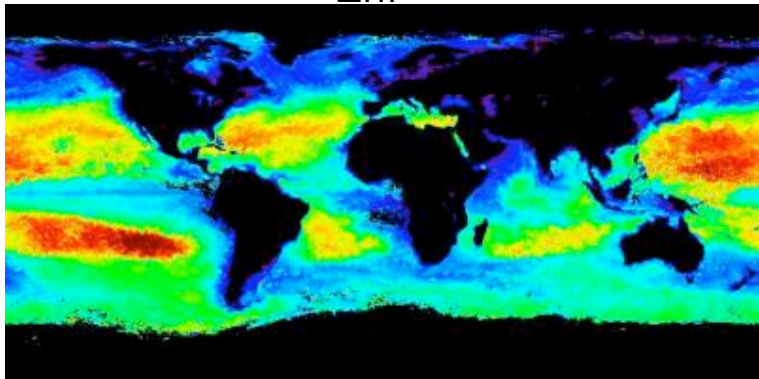
Kd(PAR)



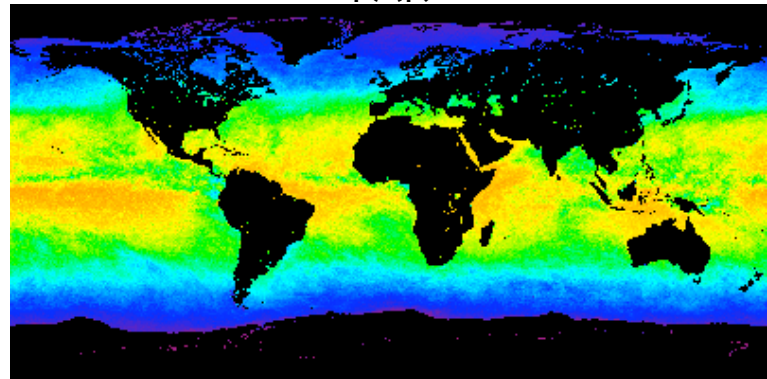
Euphotic depth



Zhl

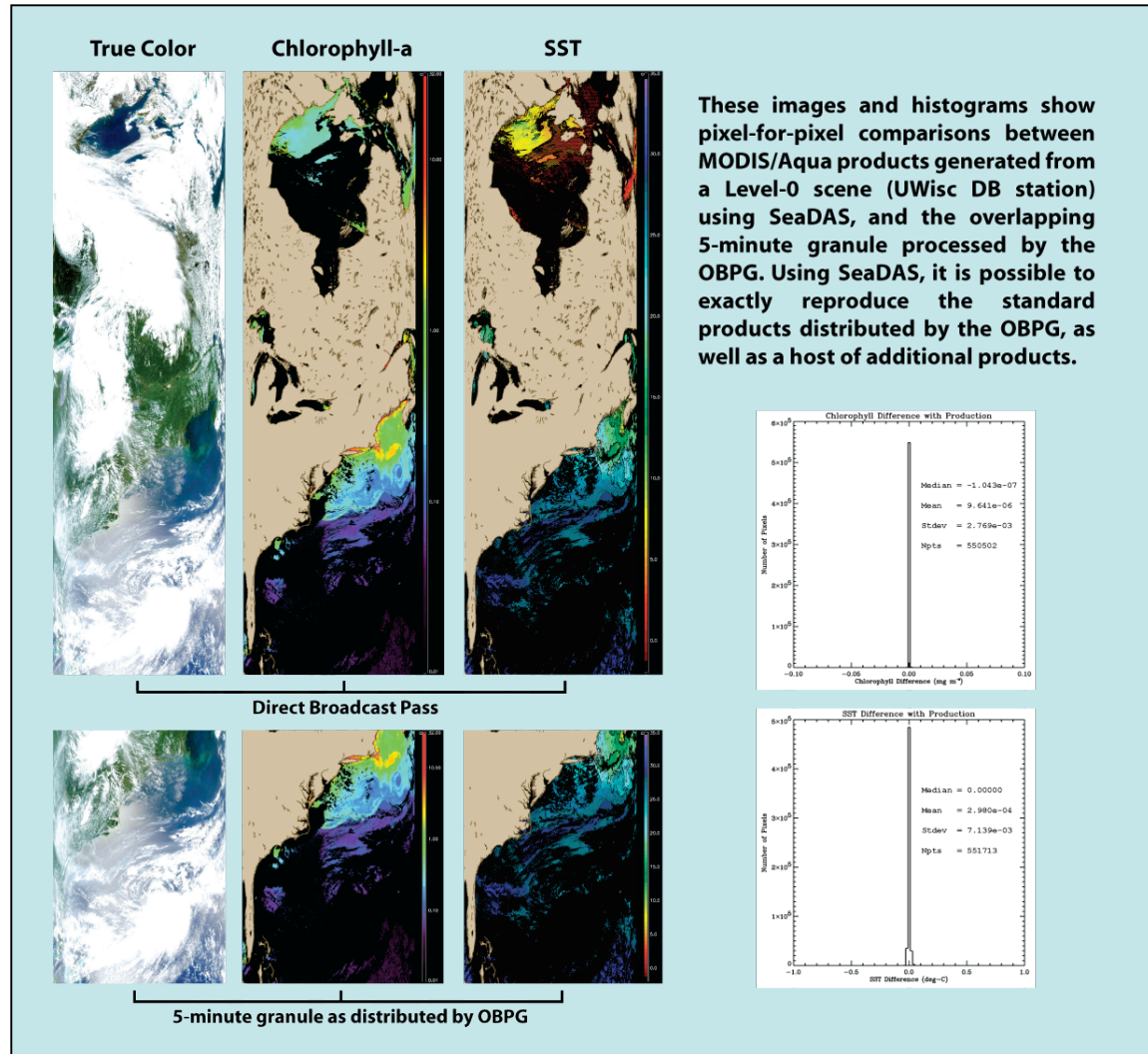


PAR




the NASA Ocean Biology Processing Group

MODIS direct broadcast support



the NASA Ocean Biology Processing Group



Ocean Color Forum - Welcome, gene

Forum Ocean Color Home Help Search Options Logout

Forum

Mark Old Mark Read New Posts Unread Posts ToDo Feeds Info

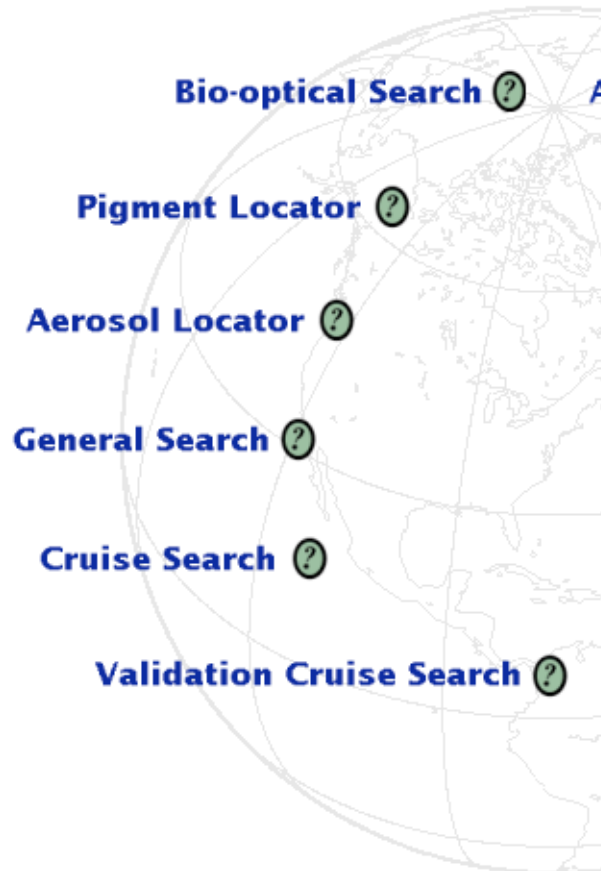
	Posts	Last Post
Announcements		
<input checked="" type="checkbox"/> Ocean Color Announcements	76 (2 new)	2008-01-14 18:59
<input type="checkbox"/> SeaDAS Announcements	53	2008-01-04 16:53
Frequently Asked Questions		
<input checked="" type="checkbox"/> General Forum Information	7	2007-12-10 20:00
<input checked="" type="checkbox"/> SeaDAS FAQ	36	2007-12-18 19:01
<input checked="" type="checkbox"/> Data Products & Algorithms FAQ	29 (2 new)	2008-01-18 13:55
<input checked="" type="checkbox"/> Data Access FAQ	16	2007-11-28 02:02
Products and Algorithms		
<input type="checkbox"/> Satellite Data Products & Algorithms	1732 (14 new)	2008-01-18 13:01
<input type="checkbox"/> Satellite Data Access	1029 (4 new)	2008-01-16 16:38
<input checked="" type="checkbox"/> Field Data	21	2007-07-23 12:19
SeaDAS		
<input type="checkbox"/> SeaDAS General Questions	5362 (26 new)	2008-01-18 00:47
<input checked="" type="checkbox"/> MODIS Direct Broadcast Support	99	2007-12-05 20:14
<input type="checkbox"/> Non-SeaDAS Packages (e.g. MATLAB, ENVI, GIS, etc)	107 (1 new)	2008-01-14 07:42
Ocean Color Features Discussion		
<input checked="" type="checkbox"/> Madagascar Plumes	11	2007-04-26 14:02

Forum Go

http://oceancolor.gsfc.nasa.gov/forum/oceancolor/forum_show.pl

the NASA Ocean Biology Processing Group

SeaBASS



NASA NOMAD - Galeon

File Edit View Tab Settings Go Bookmarks Tools Help

Back Stop 110 http://seabass.gsfc.nasa.gov/cgi-bin/nomad.cgi

Search engine

LIMIT BY DATE

Start: Dec 1 1991 End: Apr 6 2005

LIMIT BY LOCATION
(positive values are north of the equator and east of the Prime Meridian)

North (+/- 90.0) : 90.0 South (+/- 90.0) : -90.0
West (+/- 180.0) : -180.0 East (+/- 180.0) : 180.0

LIMIT BY ETOPO2 WATER DEPTH
(depth is increasing positive)

Minimum : 0.0 Maximum : 6300.0

LIMIT BY CRUISE or EXPERIMENT
(cruises names are for specific field campaigns, as cataloged in SeaBASS)
(experiments names are those listed in Table 2 of the above citation)

Cruise keyword(s):
Experiment: ALL

SELECT OUTPUT PARAMETERS
(metadata and chlorophyll a concentrations always output)

Lw Es Kd oisst etopo2

LIMIT RESULTS BY CHL AVAILABILITY

everything only valid fluorometry only valid HPLC require both valid fluorometry and HPLC

SEARCH CLEAR

Done.

the NASA Ocean Biology Processing Group

the SeaWiFS Bio-optical Archive & Storage System (SeaBASS)

archive for bio-optical data & related oceanographic / atmospheric measurements

data contributed by research groups from ~50 institutions in 15 countries

50,000 data files from over 2,000 field campaigns, as of January 2010, including:

- 40,000 radiometric (AOP) stations
- 70,000 pigment (CHL) stations
- 25,000 spectroscopy (IOP) stations
- 17,000 aerosol optical thickness (AOT) stations

all data are publicly accessible online: <http://seabass.gsfc.nasa.gov>

consolidated processing of high performance liquid chromatography (HPLC) samples at the University of Maryland

comprehensive series of community-vetted protocol documents

P.J. Werdell and S.W. Bailey, "The SeaWiFS Bio-optical Archive and Storage System (SeaBASS): Current architecture and implementation," NASA/TM-2002-211617, NASA Goddard Space Flight Center, 45 pp. (2002).

the NASA Ocean Biology Processing Group

data submission policy

- permanent archive for NASA Ocean Biology & Biogeochemistry (OB&B) data
- data **submitted to archive within 1-year of date of collection** (DOC)
- periodic release to NOAA National Oceanographic Data Center
- planned periodic release to WHOI BCO-DMO

data access policy

- follows NASA Earth Science Data & Information Policy
- **all data publicly available** for research and education use
- original contributors to be offered **authorship for 3-years** of DOC
- contributors, NASA, & SeaBASS **always to be acknowledged**

benefits of a centralized archive

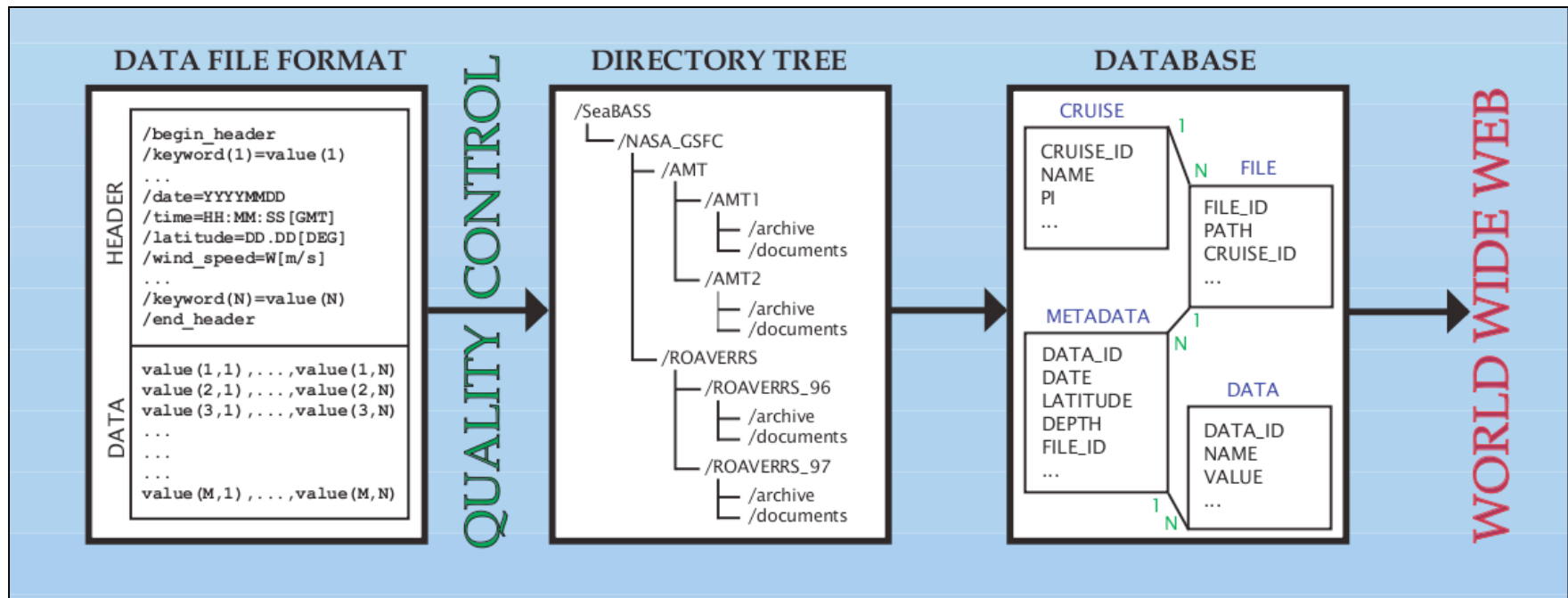
consolidated ...

- data acquisition by community members
- file formats
- quality control & quality assurance
- permanent (redundant) archival

facilitates ...

- systematic post-processing
- rigorous quality control & quality assurance
- development of algorithm development & validation data sets
- centralized cal/val activities

the NASA Ocean Biology Processing Group



physical storage at
NASA Goddard
Space Flight Center

relational database
management
system (MySQL)

SeaBASS

$AOP(\lambda, z)$, $IOP(\lambda, z)$, & $C_a/CTD/bottle(z)$

format provided by PI

minimal exclusion

$L_U(\lambda, z) \rightarrow L_W(\lambda)$

VDS (Validation Data Set)

$AOP(\lambda, o^+)$, $IOP(\lambda, o^+)$, & $C_a/CTD/bottle(o^+)$

no restrictions on coincidence

exclusion criteria applied (x2) / data reduction

calibration quality with protocol adherence

NOMAD (algorithm development)

$AOP(\lambda, o^+) + IOP(\lambda, o^+) + C_a/CTD/bottle(o^+)$

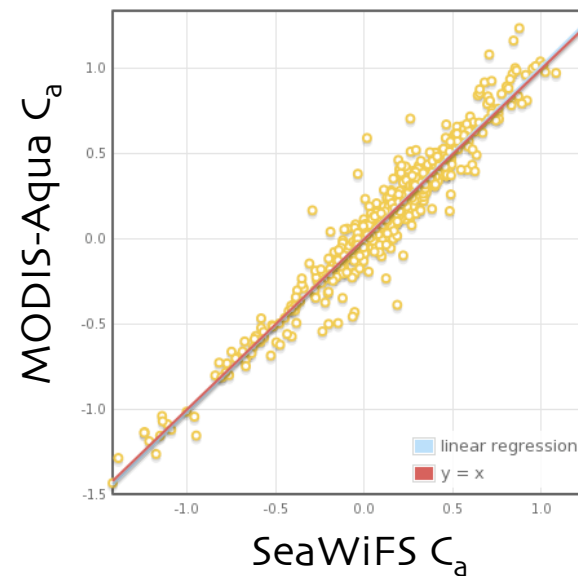
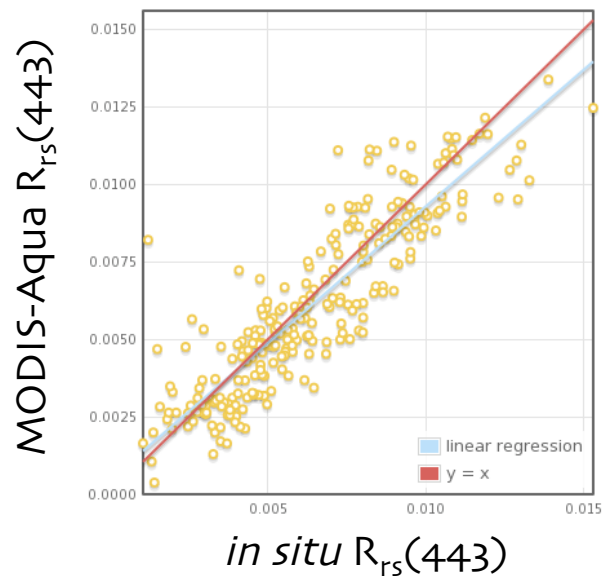
coincidence requirement

the NASA Ocean Biology Processing Group

Level-2 validation (“match-up”) results publicly posted online at:
http://seabass.gsfc.nasa.gov/seabasscgi/validation_search.cgi

highlights

- analyze match-ups for satellite-to-*in situ* & satellite-to-satellite
- search by date, location, water depth, or specific cruise
- customize exclusion criteria
- all operational data products



S.W. Bailey and P.J. Werdell, “A multi-sensor approach for the on-orbit validation of ocean color satellite data products,”
Remote Sensing of Environment 102, 12-23 (2006)

1. why use satellites for oceanographic applications?
2. why study ocean color?
3. ocean color @ NASA
4. the NASA Ocean Biology Processing Group (OBPG)
5. international collaborations

international collaborations

cost-free, **open data policy** for all NASA ocean color missions

open source software (SeaDAS - the SeaWiFS Data Analysis System)

SIMBIOS Program

sensor intercomparison studies, data merging algorithms, instrument pools & data processing round robins, & coordinated field data collection

visiting scientists and engineers

Antoine & Morel (f/Q algorithm evaluation), Tanaka (OCTS & GLI, cal/val & processing), Hagolle (POLDER implementation in SeaDAS), Kim (OSMI implementation in SeaDAS), Neumann (IRS-P₃/MOS processing stream)

MOS/IRS-P₃ Receiving Station at Wallops

OCTS/ADEOS reprocessing & distribution

MODIS SST data for GHRSSST

MERIS/ESA - participation in Quality Working Group and (proposed) CoastColour

MERIS Level-2 data displayed in SeaDAS

The screenshot displays the SeaDAS software interface on a Mac OS X system. The main window, titled "1) Mapped - algal_1 : MER_FR_2PNEPA20030714_102918_00000982018_00094_07162_0053.N1", shows a global map with a color scale for chlorophyll-a concentration ranging from 0.01 to 64.57 mg m⁻³. A red box highlights a region in the North Atlantic. To the left, the "Band List Selection" window shows loaded bands: 1. reflc_6 : MER_FR_2PNEPA20030, 2. algal_1 : MER_FR_2PNEPA200307, and 3. Mapped - algal_1 : MER_FR_2PN. Below this, "Current Product Information" lists dimensions (600 x 800), raw min/max (0.000 / 1000), and scale type (LIN). The "Display Controls" window shows LUT no. 1 and Window 2. The "Cursor Position" window displays Pixel/Line (465 / 279), Lat/Lon (53.32 / 5.55), Data Value (59.11), and Geo. Value (59.11). The "Zoom" window shows a magnified view of the highlighted region. On the right, the "Product Selection For MERIS File" window shows the MERIS filename and a list of products with checkboxes, including latitude, zonal_wind, reflc_5, water_vapour, rect_refl_red, longitude, merid_wind, reflc_6, algal_1, surf_press, dem_alt, atm_press, reflc_7, algal_2, aero_epsilon, dem_rough, ozone, reflc_8, yellow_subs, aero_opt_thick, lat_corr, rel_hum, reflc_9, total_susp, cloud_albedo, lon_corr, reflc_1, reflc_10, photosyn_rad, cloud_opt_thick, sun_zenith, reflc_2, reflc_12, boa_veg, cloud_top_press, sun_azimuth, reflc_3, reflc_13, boa_veg, cloud_type, view_zenith, reflc_4, reflc_14, rect_refl_nir, l2_flags, and view_azimuth. At the bottom right, a terminal window shows the command "seadas" and its output, including version information and processing progress for various products.

```
palapa:meris mike$ seadas
IDL Version 7.0, Mac OS X (darwin ppc m32). (c) 2007, ITT Visual Information Solutions
Installation number: 17915.
Licensed for use by: NASA/GSFC SeaWiFS Project

SeaDAS Version 5.3.0 (pid = 96310)
SeaDAS>
GENERIC_FILE_TYPE detected a non-HDF file.
GENERIC_FILE_TYPE detected a MERIS file.
SeaDAS>
Getting MERIS - "reflec_6" data from HDF file...
Getting MERIS - "algal_1" data from HDF file...
SeaDAS>
SeaDAS Projection -      128 out of      800 lines processed
SeaDAS Projection -      256 out of      800 lines processed
SeaDAS Projection -      384 out of      800 lines processed
SeaDAS Projection -      512 out of      800 lines processed
SeaDAS Projection -      640 out of      800 lines processed
SeaDAS Projection -      768 out of      800 lines processed
SeaDAS Projection -      800 out of      800 lines processed
SeaDAS>
```

international collaborations

Letter of Intent & Proposed Responsibilities between NASA & ISRO (also NOAA & ISRO) signed 18 November 2009 regarding the OCM-2 & scatterometer instruments onboard the ISRO Oceansat-2 satellite

highlights:

ISRO to provide online access to global OCM-2 data (4-km) at Level-1B for research use to all international users at no cost

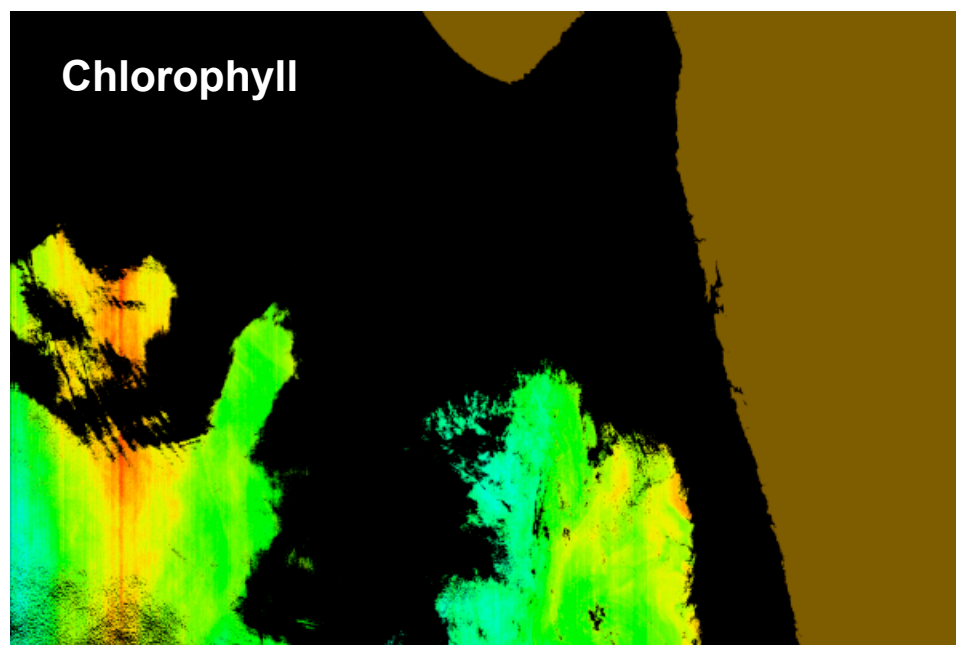
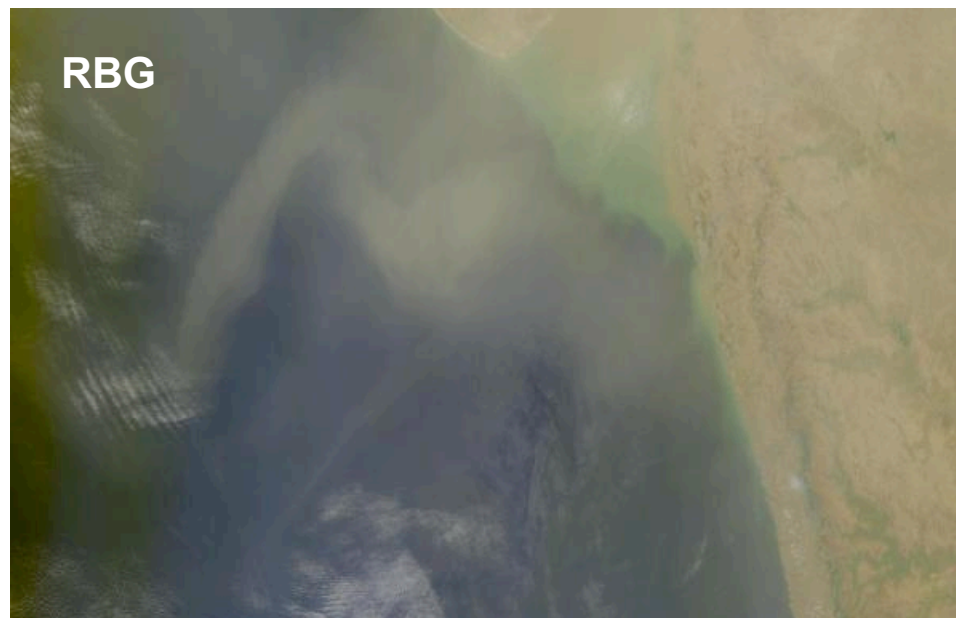
NASA to provide processing capability (Level-1B through Level-3) for use by ISRO & the international community

- distributed via SeaDAS
- preliminary capability based on OCM already implemented
- need ISRO to finalize Level-1B format

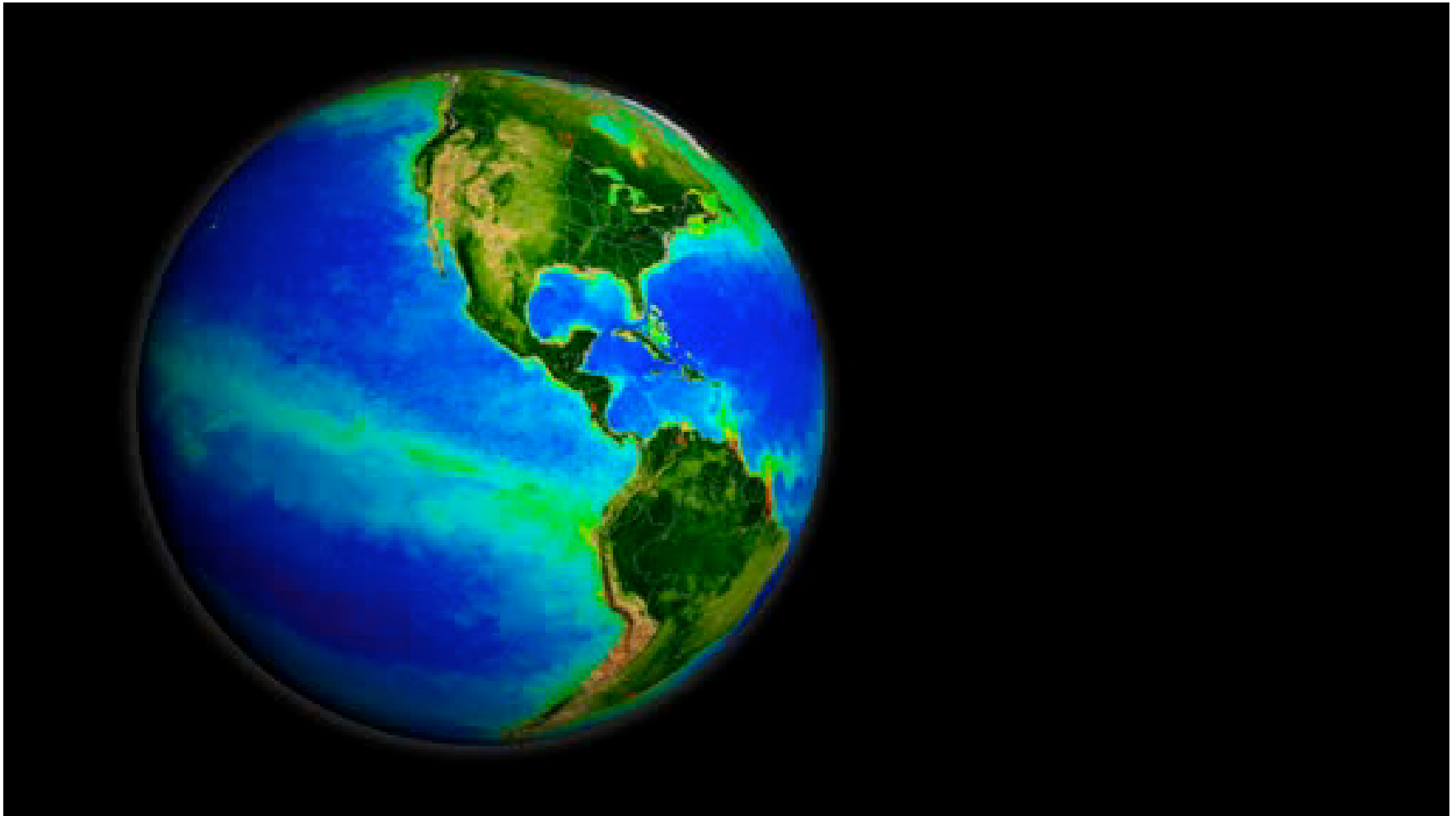
NASA & NOAA to participate in Joint Cal/Val Team

preliminary OCM-2 Level-1B
format, simulated from OCM-1

sample OCM processing via
NASA OBPG software & common
SeaWiFS/MODIS algorithms.



thank you



ocean color @ NASA

missions to measurements:

a consistent series of systematic ocean color measurements from **multi-instrument, multi-platform, and multi-year** observations based on accurate and **uniform calibration and validation** over the lifetime of the measurement

global accuracy goals for climate data records:

$R_{rs}(443)$: $\pm 5\%$ absolute uncertainty in clear water

Chl: $\pm 35\%$ over a range of 0.05 - 50 mg m⁻³