The MODIS Chlorophyll *a* Product: Strategy and Recommendations

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MODIS Science Team Meeting
Baltimore, MD
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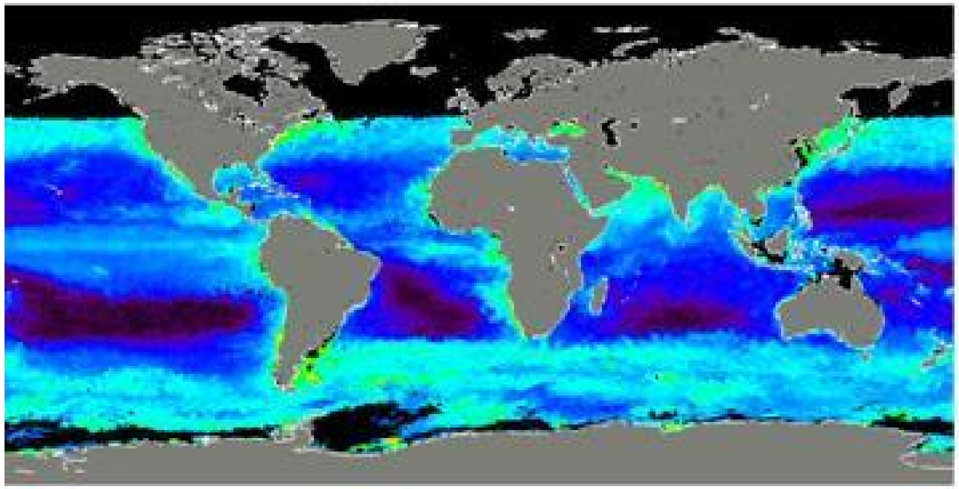
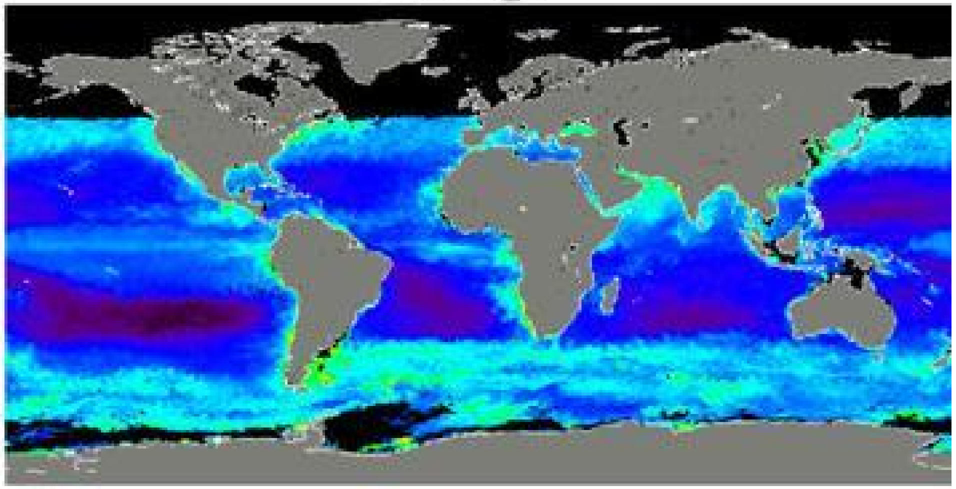
BACKGROUND

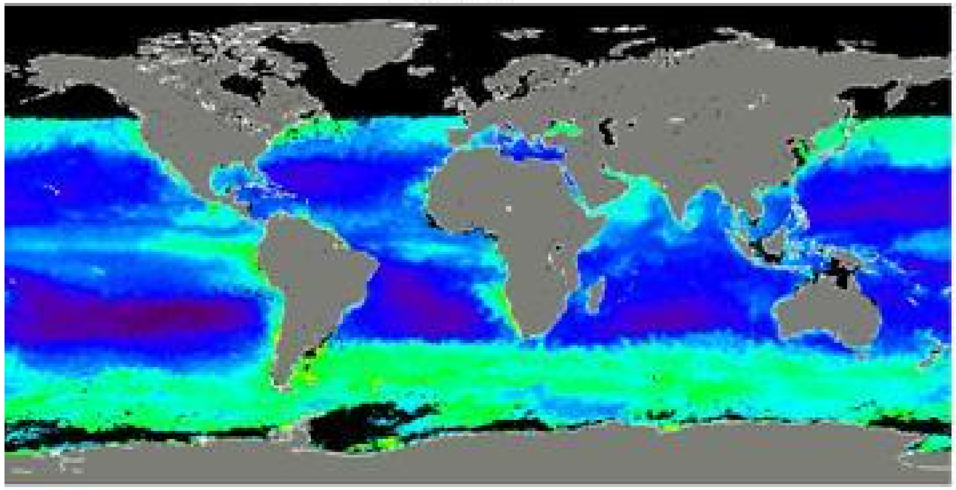
chlor_MODIS



chlor_a2

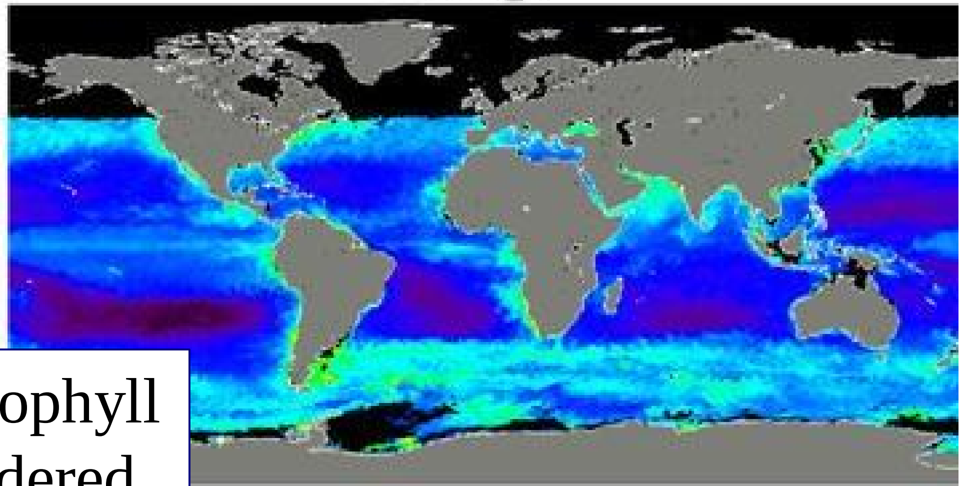


chlor_a3

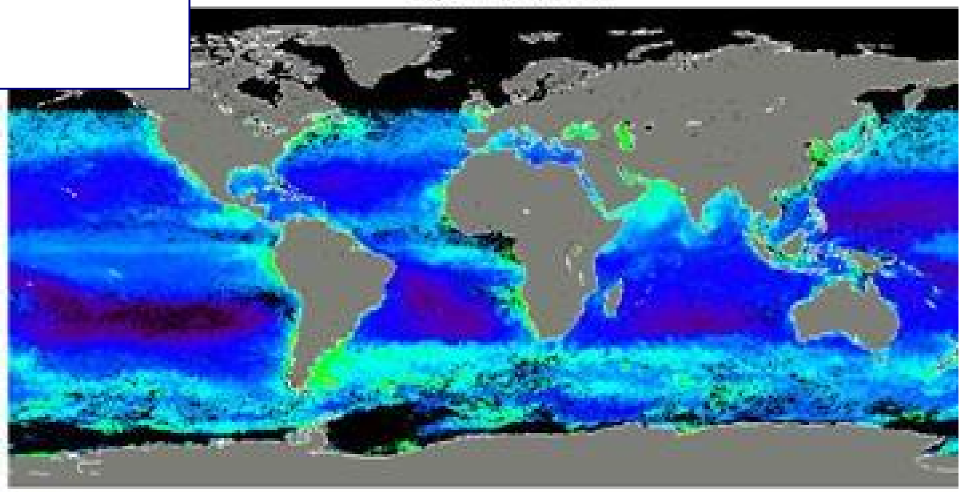


In the past, MODIS produced 3 chlorophyll products. Chlor_MODIS used an empirical "case 1" algorithm; Chlor_a3 was based on a semi-analytic algorithm that also solved for CDOM absorption, absorbed radiation by phytoplankton, and other optical properties; and Chlor_a2 was introduced as an analog to the SeaWiFS chlorophyll product.

chlor_a2



SeaWiFS OC4

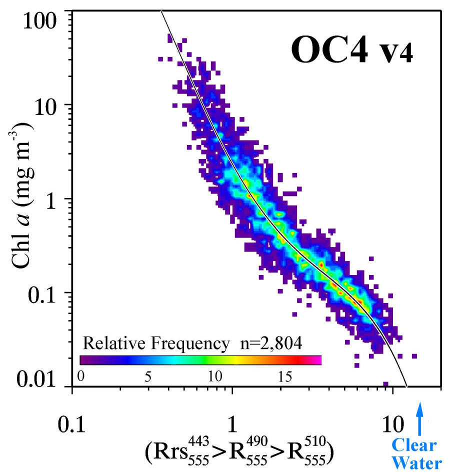


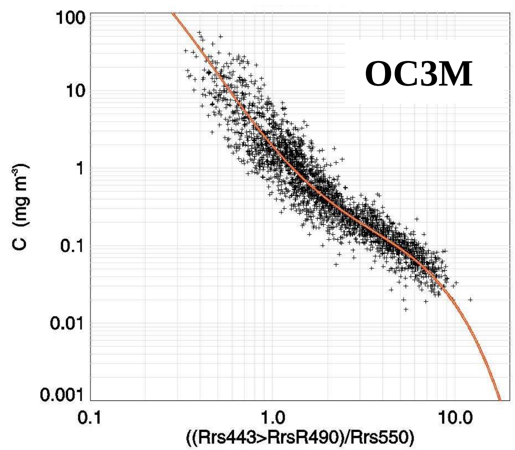
The “SeaWiFS analog” chlorophyll product (chlor_a2) was considered valid if it agreed with the SeaWiFS chlorophyll.

BACKGROUND

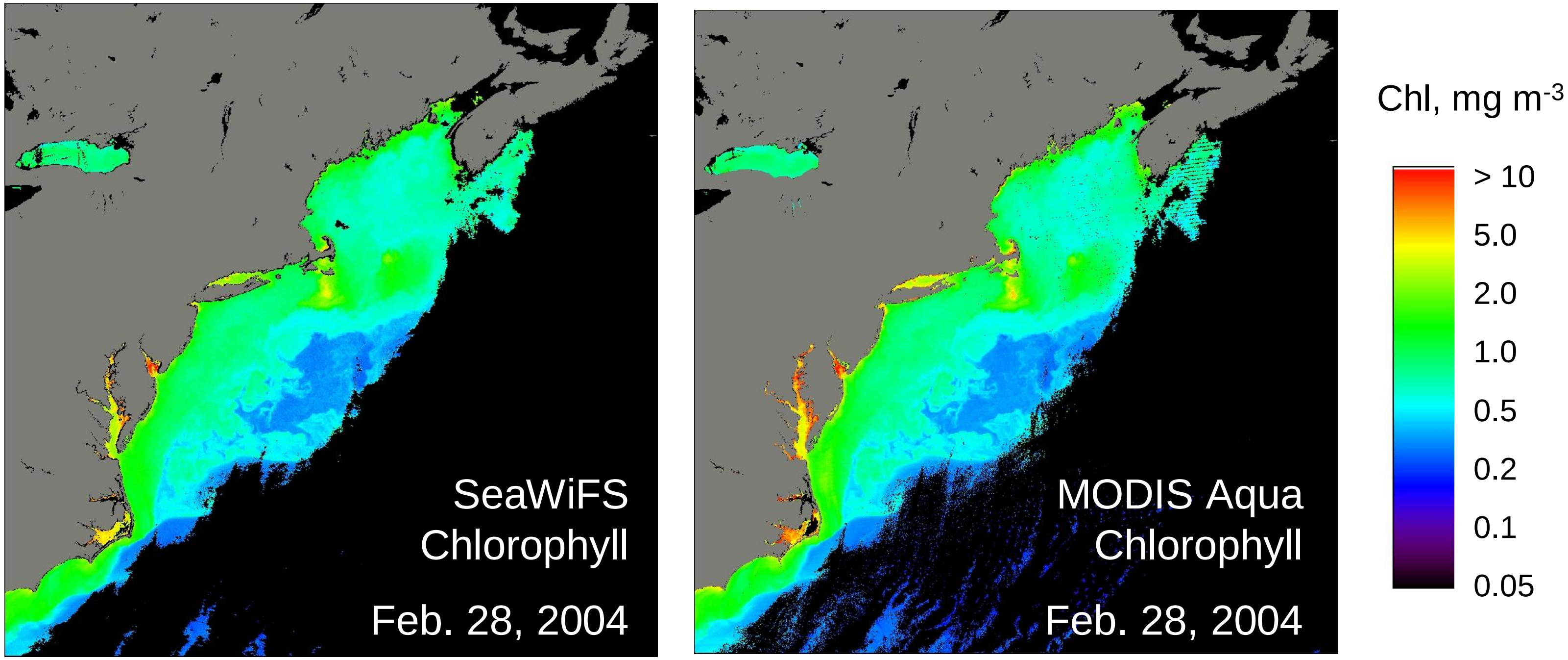
MODIS is currently producing only the “SeaWiFS-analog” chlorophyll product.

It employs the OC3M algorithm parameterized with the same data set used for the SeaWiFS OC4 algorithm (n = 2,804).





Both are described in NASA TM 2000-206892, Vol. 11 (O’Reilly et al., 2000).



Now that both data sets are being processed by the same group, we recommend: whatever is decided about the MODIS chlorophyll algorithm, the SeaWiFS chlorophyll algorithm should be consistent to ensure continuity.

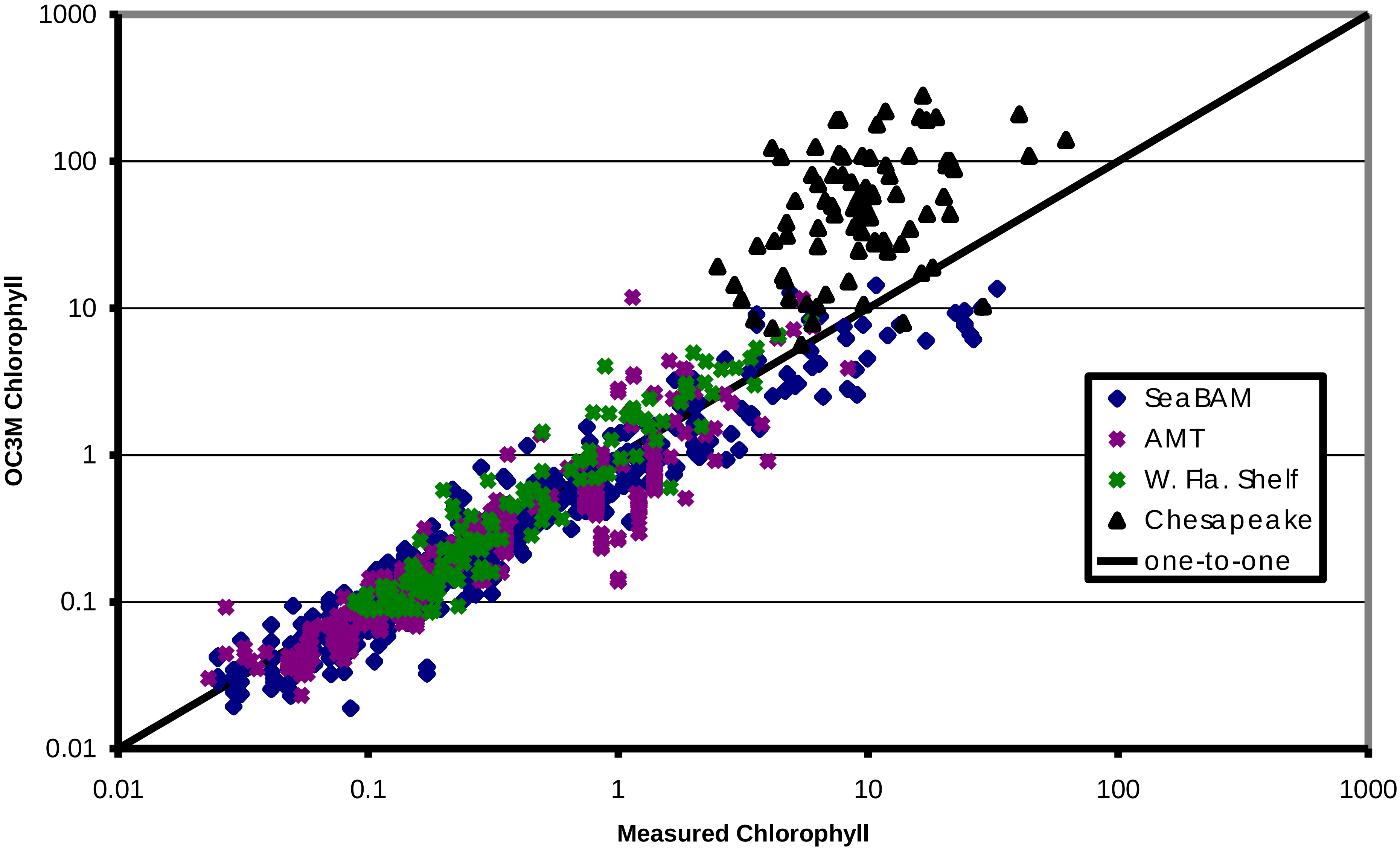
RECOMMENDATIONS

1. **The MODIS chlorophyll-a algorithm should provide continuity with the SeaWiFS chlorophyll record (1997-present).** If we arrive at another algorithm, then SeaWiFS data should also be re-processed with same or “MODIS-analog” algorithm.

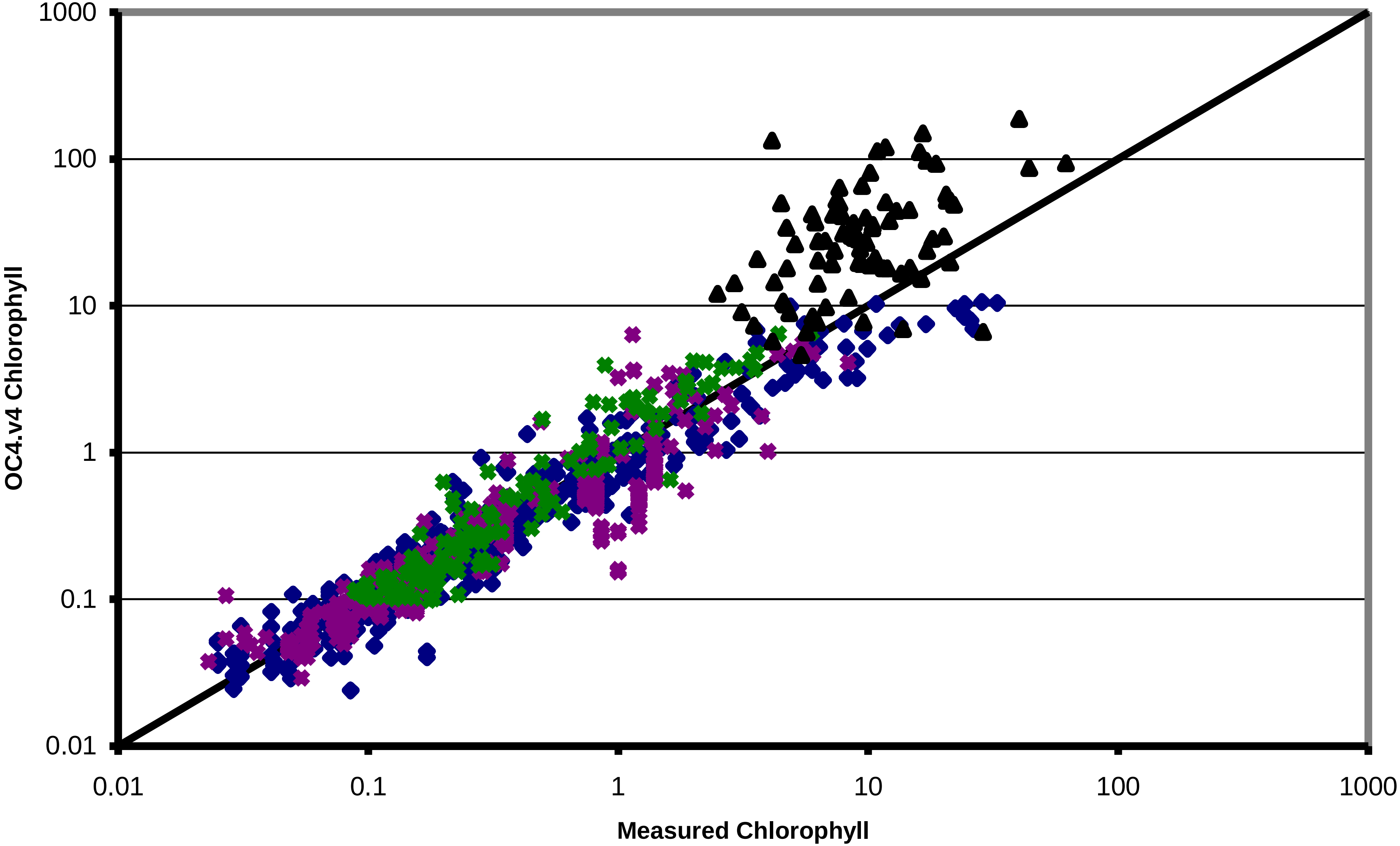
   Fortunately, reprocessing of both data sets can be achieved quickly and this should not be an obstacle …

   Congratulations to the OBPG for the recent reprocessing in record time!

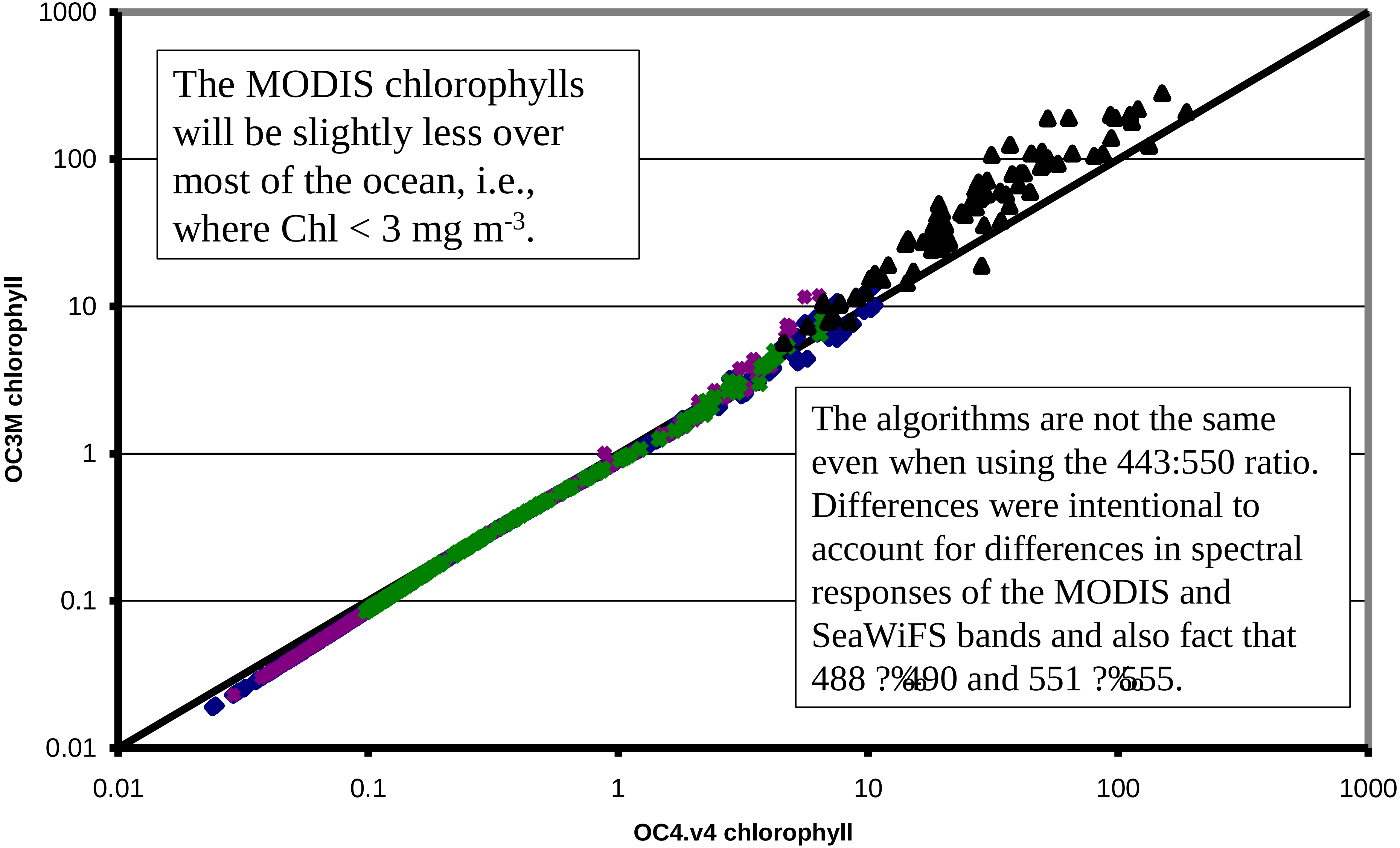
Approach: First test algorithms with *in situ* data. Four *in situ* data sets of reflectance and chlorophyll data shown here total 1,119 stations.



RMS = 0.293 (SeaBAM 0.184; AMT 0.256; W. Fla. Shelf 0.175; Ches. 0.787)


1000
100
10
1
0.1
0.01
OC4.v4 Chlorophyll
0.01
0.1
1
10
100
1000
Measured Chlorophyll

The point of this plot is that there are systematic differences between the algorithms even when applied to the same data set (assuming 448 ~ 490, 551 ~ 555)



The Algorithms: Differences are intentional

The **SeaWiFS algorithm** (OC4.v4) is:

$$\mathbf{\log_{10}(CHL) = 0.366 - 3.067R + 1.930R^2 + 0.649R^3 - 1.532R^4}$$

where

$$\mathbf{R = \log_{10}[\max(R_{rs}(443), R_{rs}(490), R_{rs}(510))/ R_{rs}(555)]}$$

The **MODIS algorithm** (OC3M) is:

$$\mathbf{\log_{10}(CHL) = 0.283 - 2.753R + 1.457R^2 + 0.659R^3 - 1.403R^4}$$

where

$$\mathbf{R = \log_{10}[\max(R_{rs}(443), R_{rs}(488))/ R_{rs}(551)]}$$

Our approach has been to test candidate algorithms first using *in situ* data, and then to evaluate them when applied to near-coincident, co-registered SeaWiFS and MODIS scenes.

Comparing chlorophyll products from near-coincident, co-registered SeaWiFS and MODIS scenes is pointless until the input radiances are consistent .. at least, until the band-to-band (ratios) are consistent.

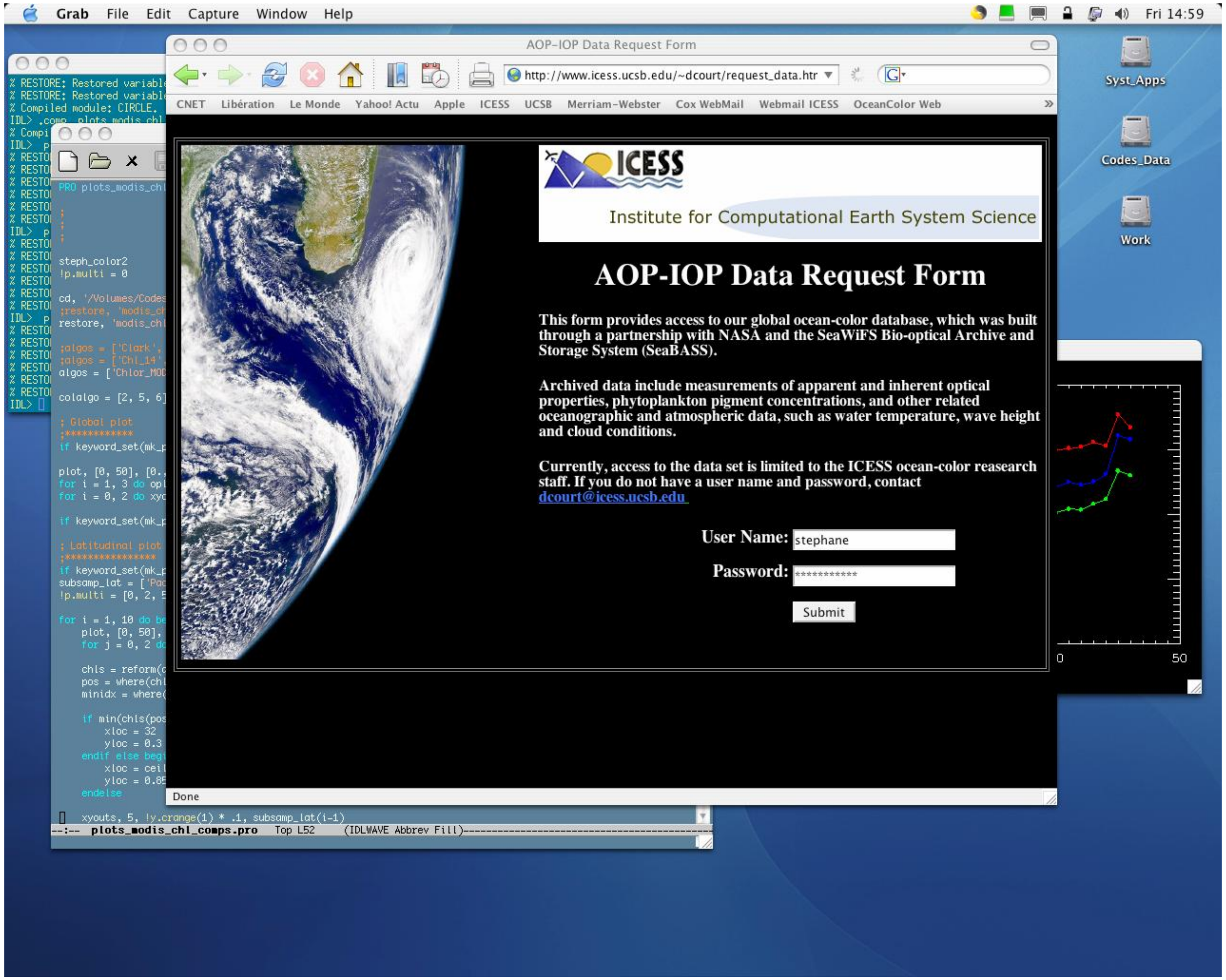
RECOMMENDATIONS

2. **Use newly created *in situ* data sets to test candidate algorithms.** I propose to host a workshop at UNH to evaluate and compare algorithms. It will be "SeaBAM 2" …

New *in situ* data sets are being assembled that include not only chlorophyll and water-leaving radiances, but also inherent and apparent optical properties, SST, and data such as latitude, longitude, day, etc. (missing from original SeaBAM data set).

Jeremy Werdell (GSFC) is the steward of a new compilation from SeaBASS.

UCSB bio-optical database for algorithm development and validation



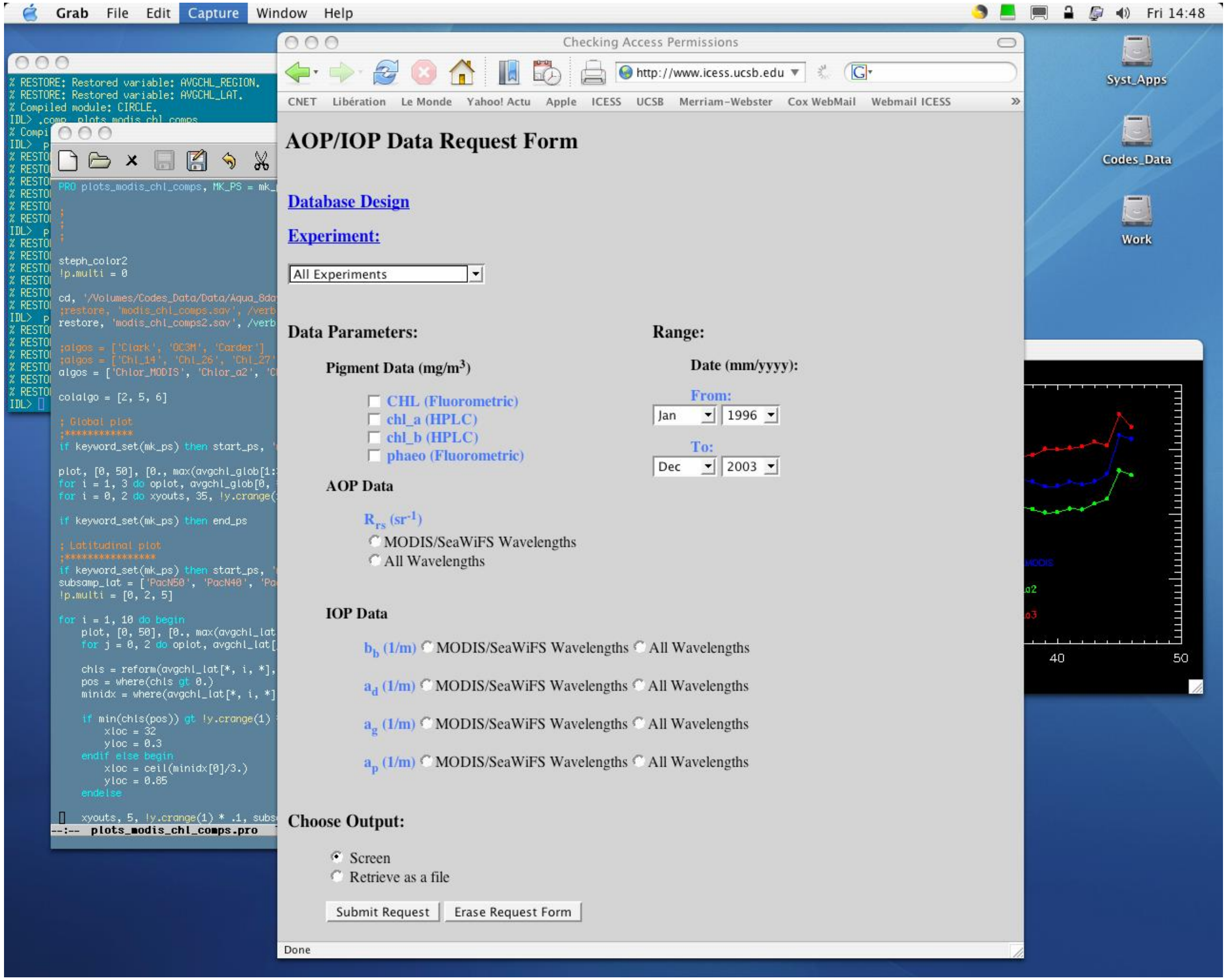
Subset of SeaBASS

* Chl
* $R_{rs}(\lambda)$
* $a_{ph}(\lambda)$, $a_d(\lambda)$, $a_g(\lambda)$
* $b_{bp}(\lambda)$
* some $K_d(\lambda)$

* Will become public soon (end of March ?)

* Data policy (access and usage) will be identical to SeaBASS

UCSB bio-optical database for algorithm development and validation



* Web-based

* Queries by:

- Variable
- Date
- Wavelength
- Experiment

UCSB database: Stations with Chl and Rrs measurements

Experiment	Number of Stations
ACE_ASIA	43
AMLR	86
BBOP	299
BIOCOMPLEXITY	39
CALCOFI	293
EcoHAB	191
INDOEX	48
JGOFS	30
Kieber_Photochemistry_02	110
LMER-TIES	242
NOAA_Gulf_of_Maine	52
Oceania	47
Okeechobee	4
ONR-MAB	85
Plumes_and_Blooms	497
Scotia_Prince_ferry	259
Sea_of_Japan	37
TOTO	74
	Total 2,436

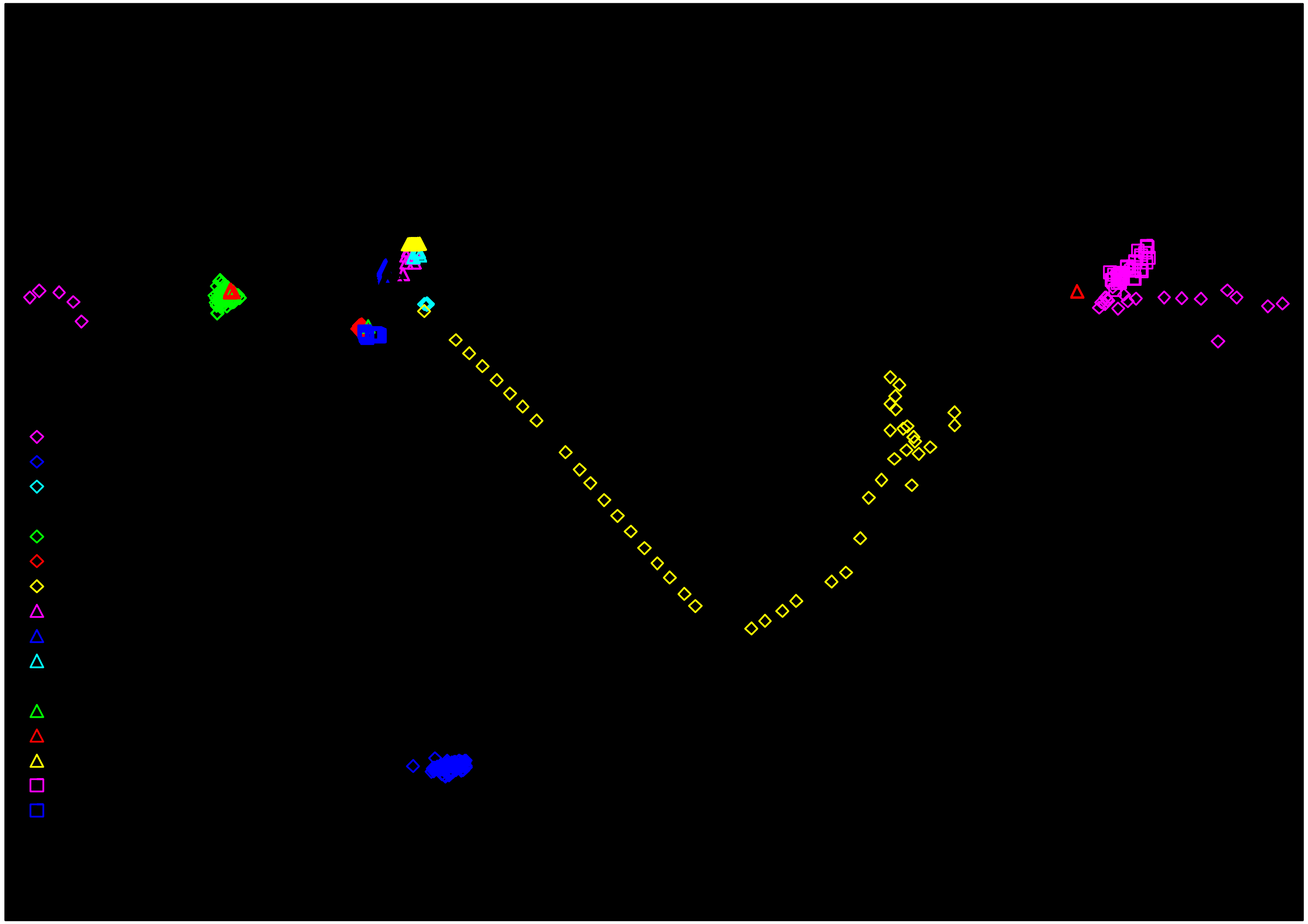
UCSB database: Stations with Chl and absorption (a_{ph}, a_d and a_g)

Experiment	Number of Stations
ACE_ASIA	46
AMLR	91
Arc00	20
BBOP	82
BIOCOMPLEXITY	35
CALCOFI	188
EcoHAB	191
GLOBEC	30
INDOEX	53
IOFFE	99
Kieber_Photochemistry_02	47
Lab96	17
LMER-TIES	93
NASA_Gulf_of_Maine	53
NOAA_Gulf_of_Maine	125
Okeechobee	4
ONR-MAB	38
Plumes_and_Blooms	497
Scotia_Prince_ferry	222
Sea_of_Japan	35
TOTO	84
	Total 2,050

UCSB database: Stations with Chl, R_{rs} and absorption (a_{ph}, a_d and a_g)

Experiment	Number of Matchups
ACE_ASIA	38
AMLR	81
BBOP	49
BIOCOMPLEXITY	27
CALCOFI	116
EcoHAB	193
INDOEX	46
Kieber_Photochemistry_02	119
LMER-TIES	108
NOAA_Gulf_of_Maine	104
Okeechobee	6
ONR-MAB	38
Plumes_and_Blooms	612
Scotia_Prince_ferry	230
Sea_of_Japan	35
TOTO	93
	Total 1,895

UCSB database: Stations location



<u>Good news</u>:
A lot of data are available

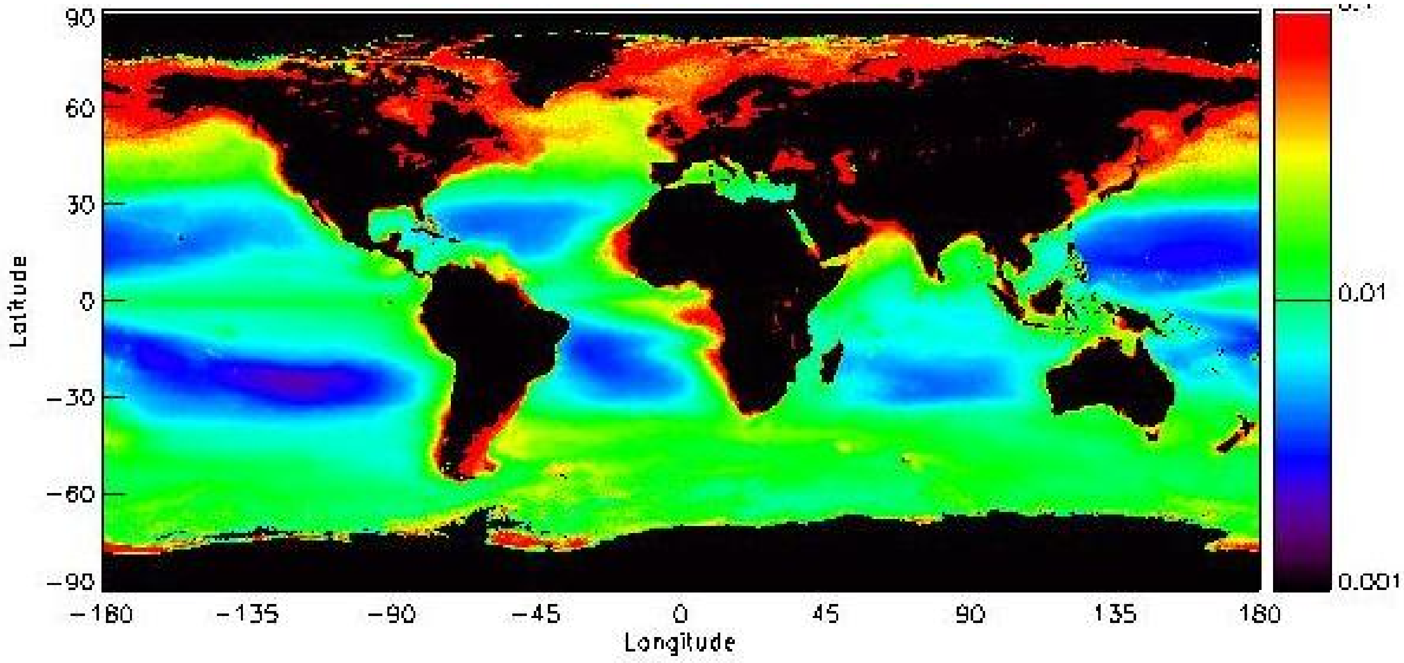
<u>Bad news</u>:
*Most of them are coastal

*Not many new data enter SeaBASS

RECOMMENDATIONS

3. **As a minimum, we should aim to develop an algorithm that can solve for CDOM and Chl-a simulaneously.** The Carder algorithm (Chlor-a3) did this, but it requires SST which isn't available with SeaWiFS. Can we use AVHRR Pathfinder data with SeaWiFS to accommodate algorithms that require SST? Or can we use an algorithm such as the Siegel, Maritorena, Nelson algorithm?

Colored Dissolved Organic Material



First view of global CDOM distribution from SeaWiFS

CDOM regulates light absorption [especially in UV]

CDOM is *the* precursor for many photochemical rxn's

CDOM may work as natural water mass tracer

Siegel, Maritorena & Nelson [UCSB]

FINAL QUESTION:

Should MODIS produce and distribute more than one chlorophyll product?

Bridging ocean color observations of the 1980's and 2000's

in search of long-term trends.

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Robert H. EVANS

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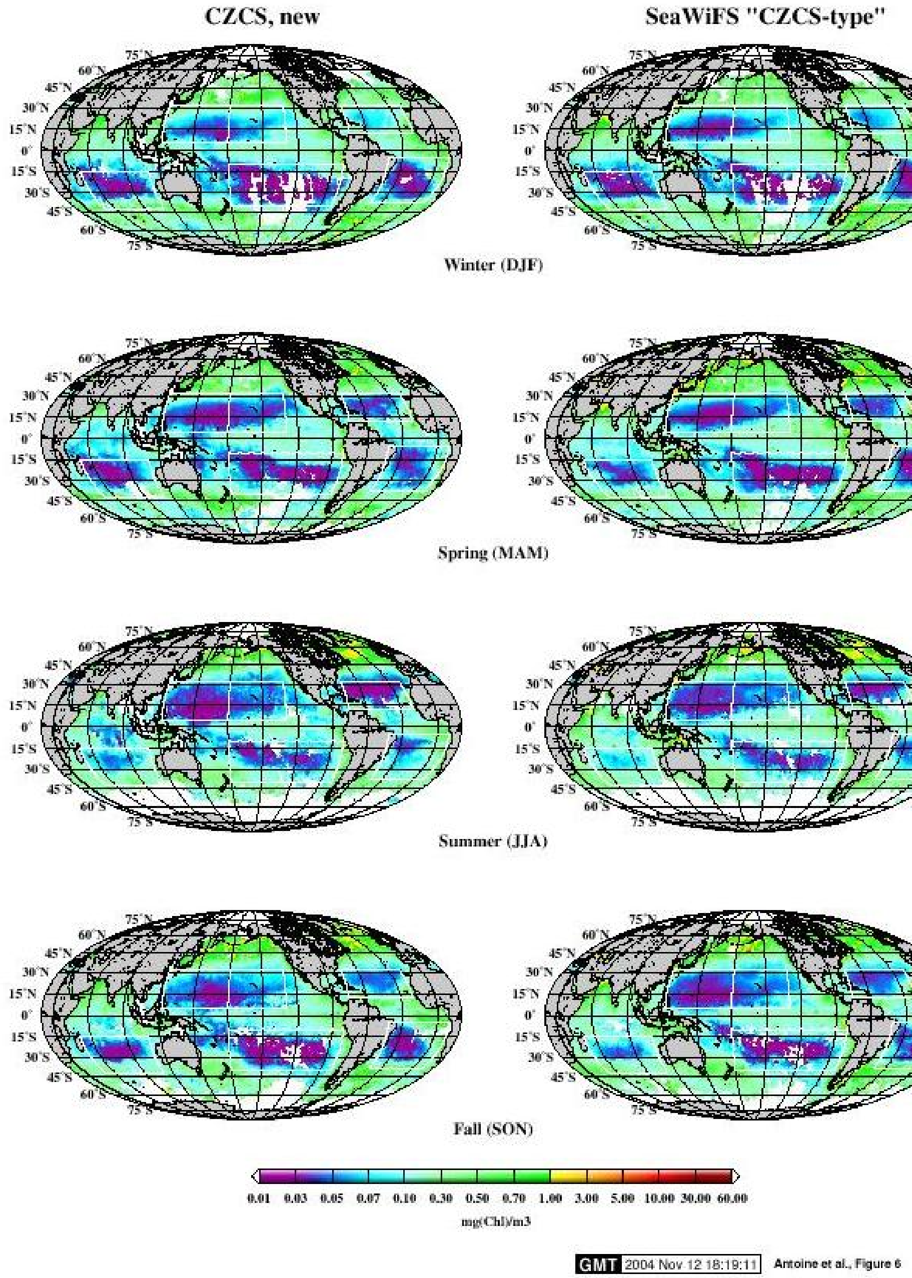
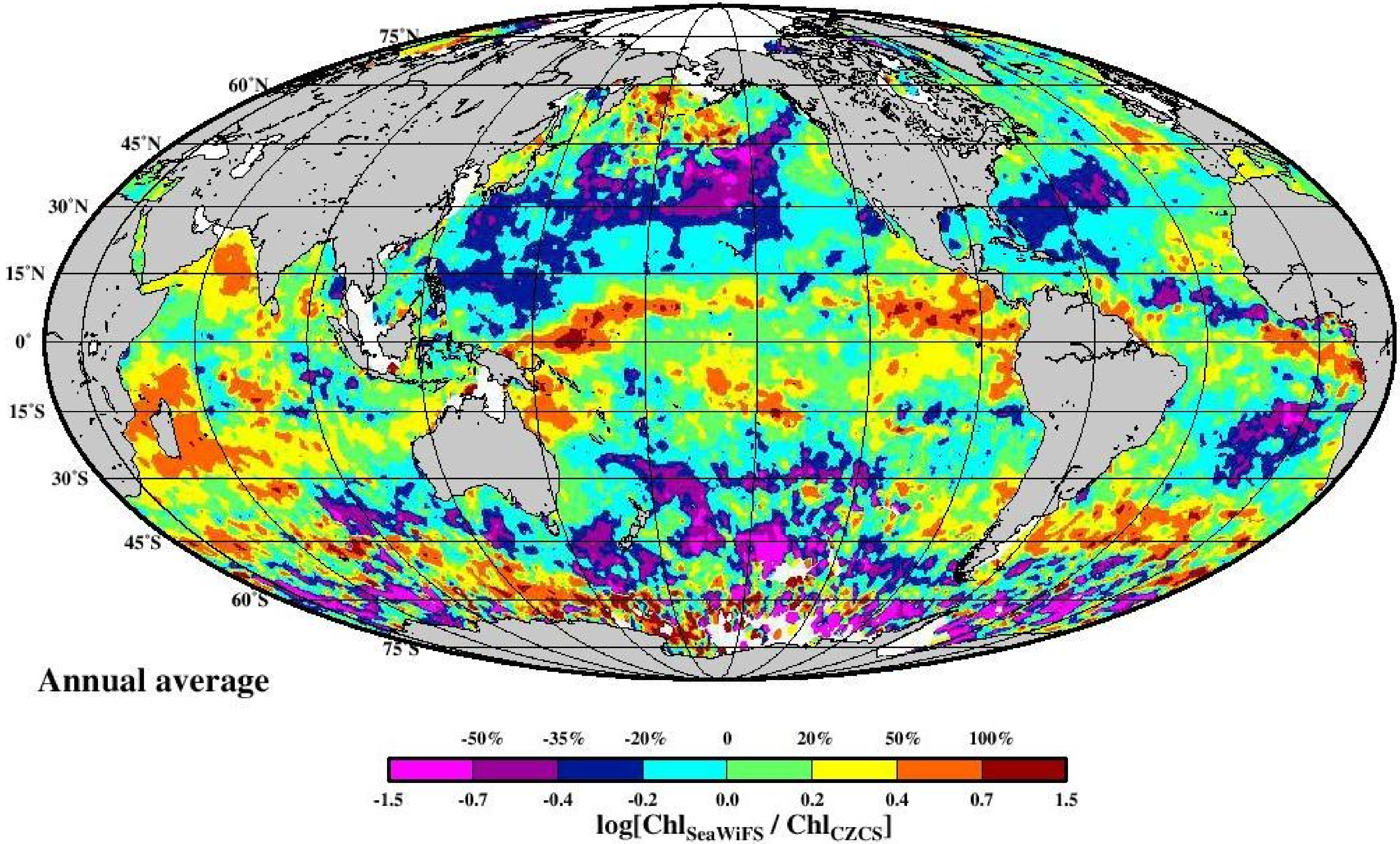
In press, JGR, March 2005



A complete re-processing of CZCS and SeaWiFS was undertaken in order to make the data sets as consistent as possible.

It would be worthwhile doing a similar reprocessing of MODIS Aqua data to extend this time series, but the resulting MODIS “CZCS-type” chlorophyll data will not be the best chlorophyll.

So question is: will the chlorophyll data in the long-term time series be same as our best contemporary product?



Antoine et al. 2005 (in press, JGR)

Bridging ocean color observations of the 1980's and 2000's in search of long-term trends.

Abstract

A comprehensive revision of the "Coastal Zone Color Scanner" (CZCS) data-processing algorithms has been undertaken to generate a revised level-2 data set from the near 8-year archive (1979-1986) collected during this "proof-of-concept" mission. The final goal of this work is to establish a baseline for a global, multi-year, multi-sensor, ocean color record, to be built from observations of past (*i.e.*, CZCS), present, and future missions. To produce an internally consistent time series, the same revised algorithms also have been applied to the first five years of the SeaWiFS ocean color observations (1998-2002). Such a data base is necessary in order to determine whether or not the ocean biogeochemistry has evolved in the past years and if so, to be able to detect near future trends. Algorithmic and calibration aspects, along with validation results presented in this paper, are tailored towards the identification of long-term trends, which mandated this reprocessing effort. The analysis of decadal changes from the CZCS to the SeaWiFS era shows an overall increase of the World ocean average chlorophyll concentration by about 25%, mainly due to large increases in the inter-tropical areas, where the seasonal cycles also substantially changed over the past two decades. Increases in higher latitudes, where seasonal cycles did not change, contribute to a lesser extent to the general trend. In contrast, oligotrophic gyres display declining concentrations.

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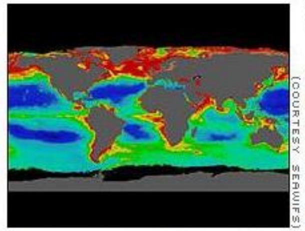
2002 Results by Watson Gregg …

Plummeting plankton linked to warmer oceans

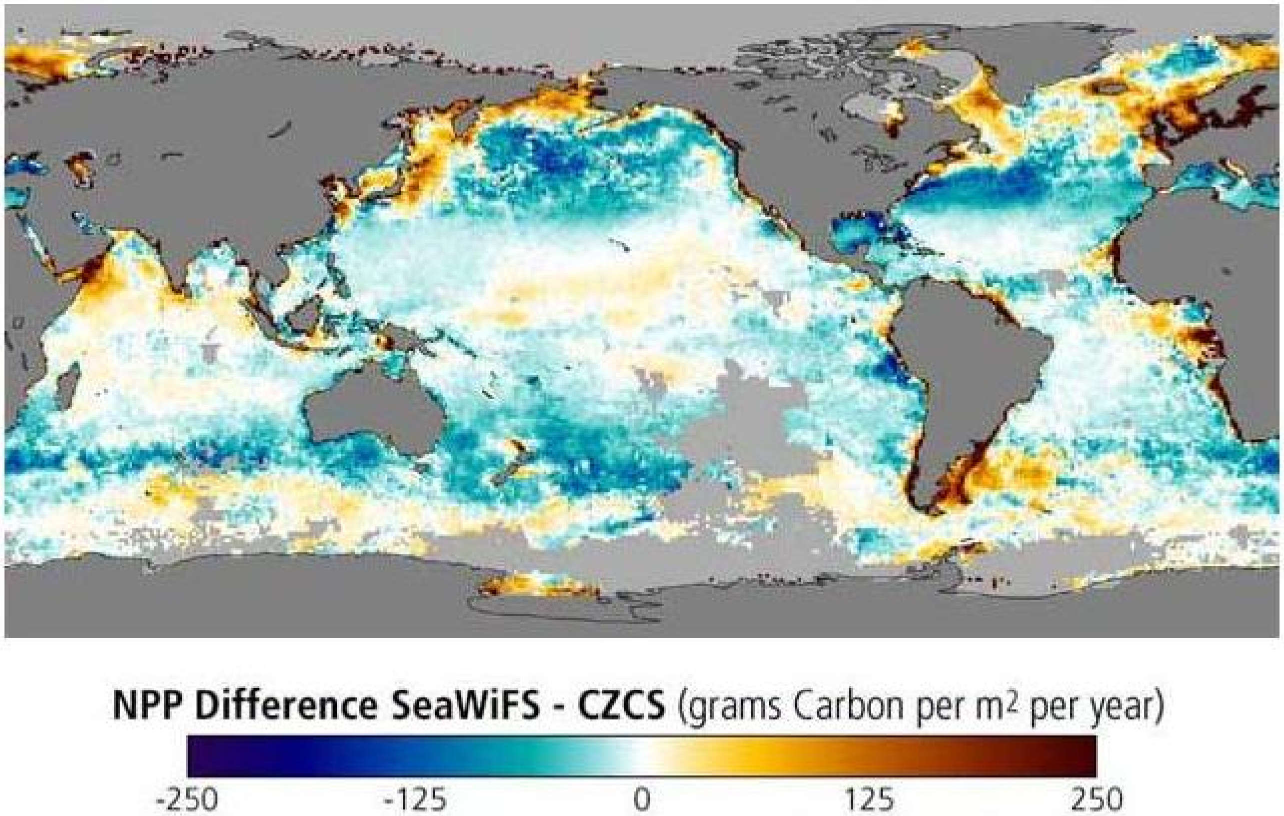
August 14, 2002 Posted: 10:50 AM EDT (1450 GMT)



This image from NASA's SeaWiFs satellite documents summer phytoplankton concentrations between 1997 and 2000. Reds,

By Richard Stenger
CNN

(CNN) -- Concentrations of microscopic plants that comprise the foundation of the ocean's food supply have fallen during the past 20 years as much as 30 percent in northern oceans, according to a satellite checkup of planetary health.



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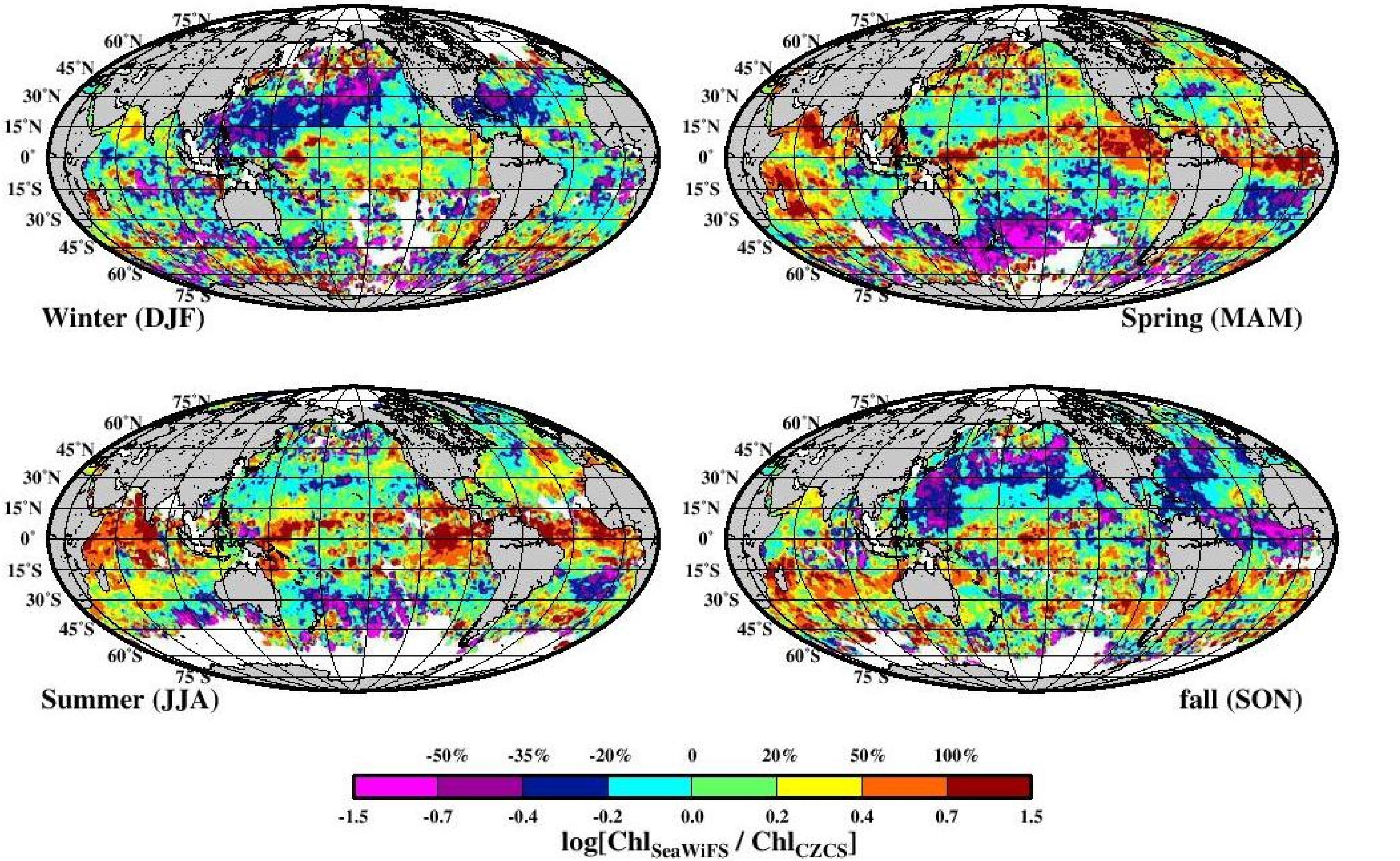
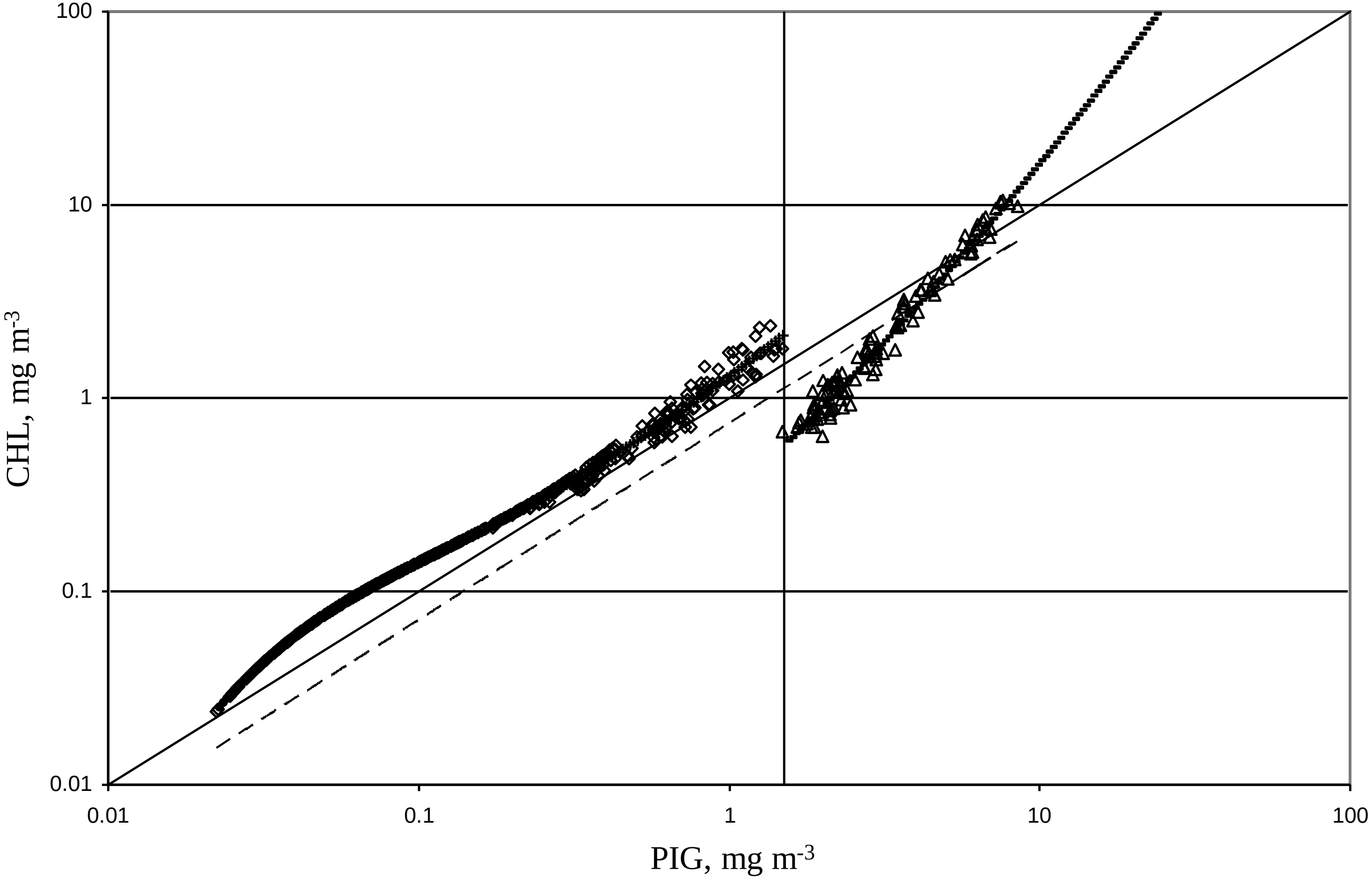
MODIS OCEAN ALGORITHM WORKING GROUPS

- Chl-a: CAMPBELL, Trees, Maritorena, Clark, O'Reilly, Carder
- IOPs: LEE, Carder, Gould, Stamnes
- AOPs: MCCLAIN, VOSS, HOOKER, CLARK, WANG, Mueller, Gordon, Carder, Evans, Kearns, Gould, Stumpf (includes L-2 processing of some 250m and 500m bands)
- FLH: LETELIER, Behrenfeld
- Kd(490): CLARK, Mueller, Trees (Provide recommendation for K(PAR)
- PP: BEHRENFELD (Provide recommendation on SeaWiFS Chl/K490 product, i.e., do we need to continue generating it?)
- POC: CLARK, Stramski
- PIC: BALCH, Gordon
- SST: MINNETT, Evans
- PAR: GREGG
- CDOM: SIEGEL, Nelson
- DOC: Hoge

I believe that we should not separate Chl-a algorithm from IOPs, CDOM, POC, PIC… because we should seek an algorithm that solves for all simulaneously.



Winter (DJF)
Spring (MAM)
Summer (JJA)
fall (SON)
75°N
60°N
45°N
30°N
15°N
0°
15°S
30°S
45°S
60°S
75°S
-50%
-35%
-20%
0
20%
50%
100%
-1.5
-0.7
-0.4
-0.2
0.0
0.2
0.4
0.7
1.5
log[Chl_SeaWiFS / Chl_CZCS]



100
10
1
0.1
0.01
0.01
0.1
1
10
100
CHL, mg m-3
PIG, mg m-3