

Using *in situ* data to support satellite ocean color calibration & validation activities

Jeremy Werdell

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

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1. *in situ* data are important for ocean color cal/val

- vicarious calibration
- data product validation
- algorithm development

2. lessons learned from maintaining SeaBASS

- overview & data policies
- data collection
- the centralized archive
- data analysis

1. *in situ* data are important for ocean color cal/val

- vicarious calibration
- data product validation
- algorithm development

overview
operational / MOBY
model-based
alternative data sources
population statistics

2. lessons learned from maintaining SeaBASS

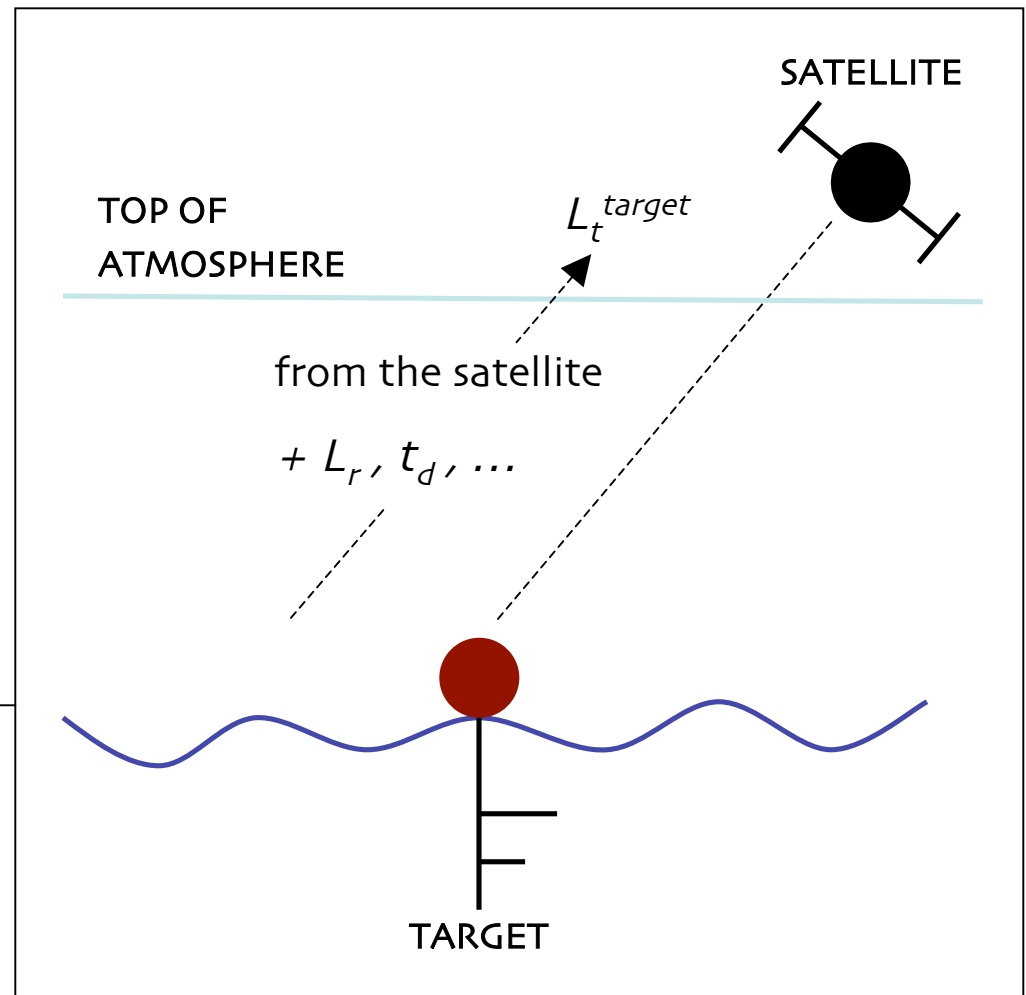
- overview & data policies
- data collection
- the centralized archive
- data analysis

vicarious calibration

what is vicarious calibration?

spectral on-orbit calibrations

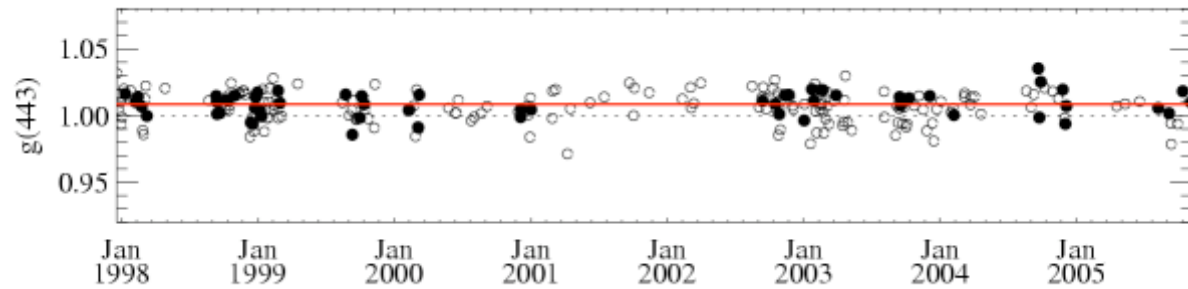
1. instrument calibration
 - e.g., focal plane temperature
2. temporal calibration
 - reference Sun or Moon
3. absolute (vicarious) calibration
 - reference Earth surface
 - final, single gain adjustment
 - calibration of the combined instrument + algorithm system



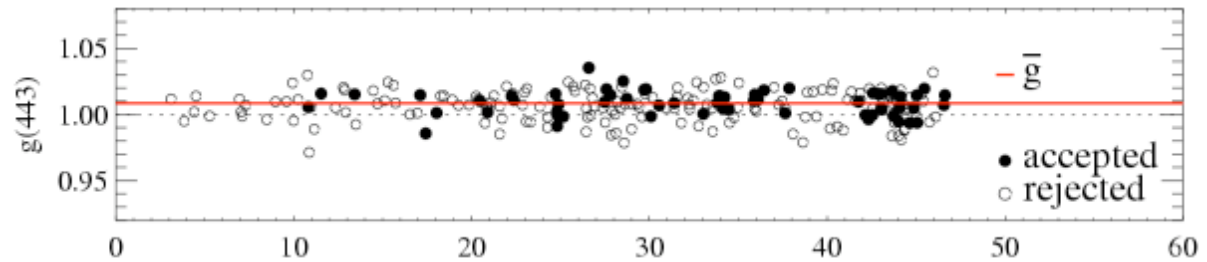
vicarious calibration

a single, spectral radiometric adjustment

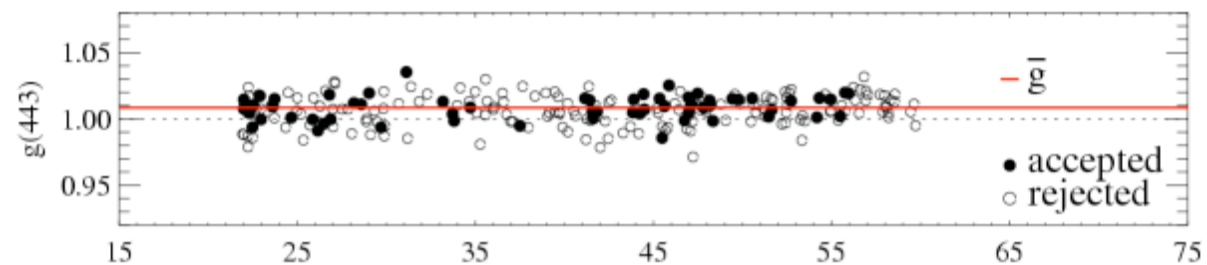
gain vs. time



gain vs. solar zenith angle



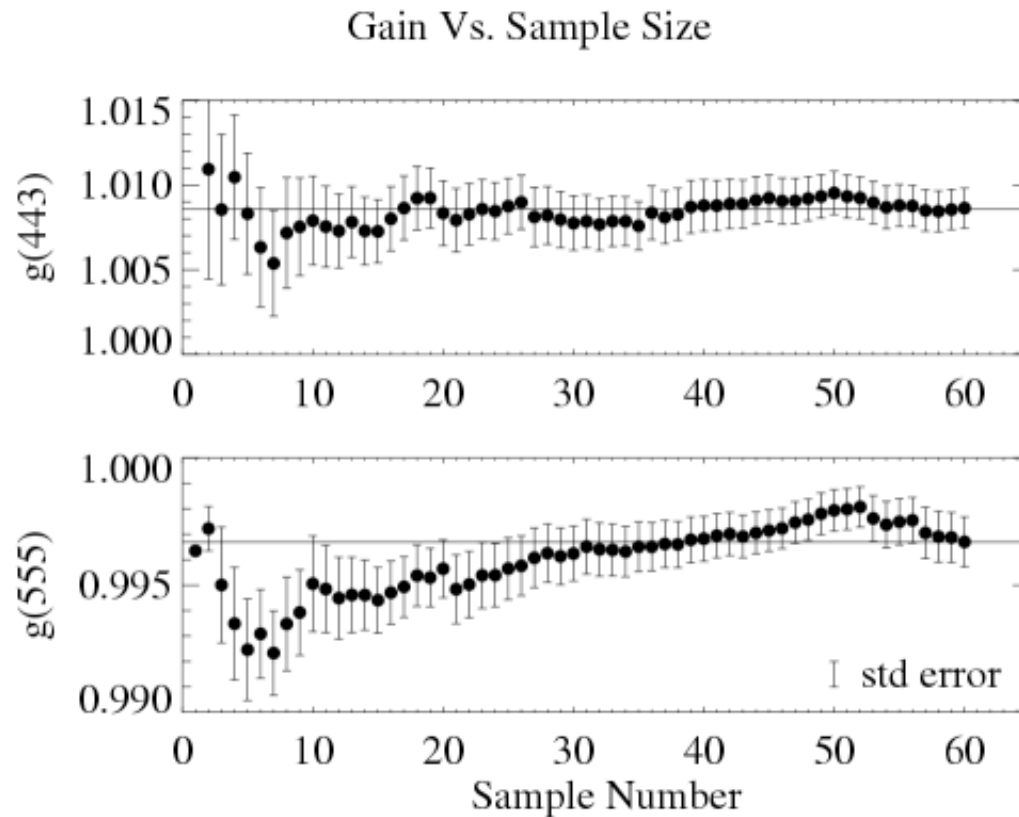
gain vs. satellite zenith angle



B.A. Franz, S.W. Bailey, P.J. Werdell, and C.R. McClain, "Sensor-independent approach to the vicarious calibration of satellite ocean color radiometry," *Applied Optics* 46, 5068-5082 (2007).

vicarious calibration

2-3 years to achieve stable vicarious calibration



B.A. Franz, S.W. Bailey, P.J. Werdell, and C.R. McClain, "Sensor-independent approach to the vicarious calibration of satellite ocean color radiometry," *Applied Optics* 46, 5068-5082 (2007).

operational vicarious calibration

MOBY - the Marine Optical Buoy

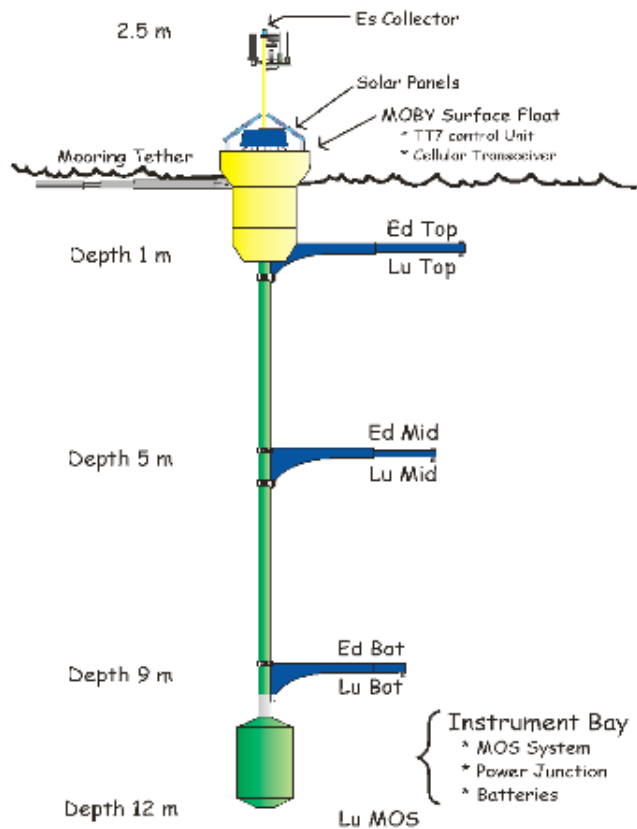


Fig. 1. Schematic diagram of MOBY.

maintained by NOAA & Moss Landing Marine Laboratory

20 miles west of Lanai, Hawaii

$L_u(\lambda)$ and $E_d(\lambda)$ at nominal depths of 1, 5, and 9 meters, plus $E_s(\lambda)$

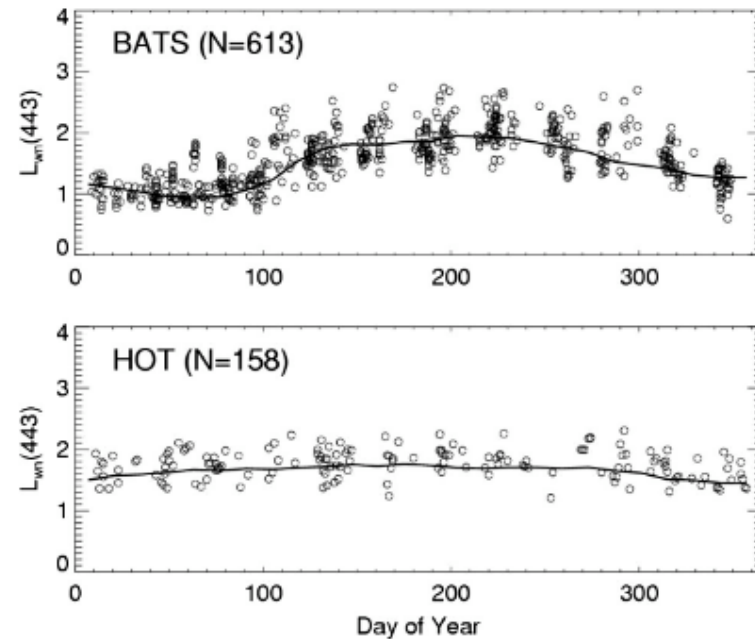
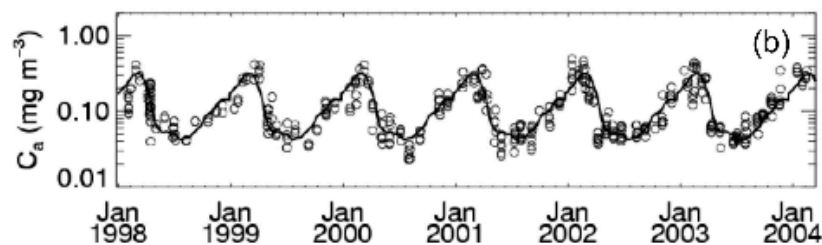
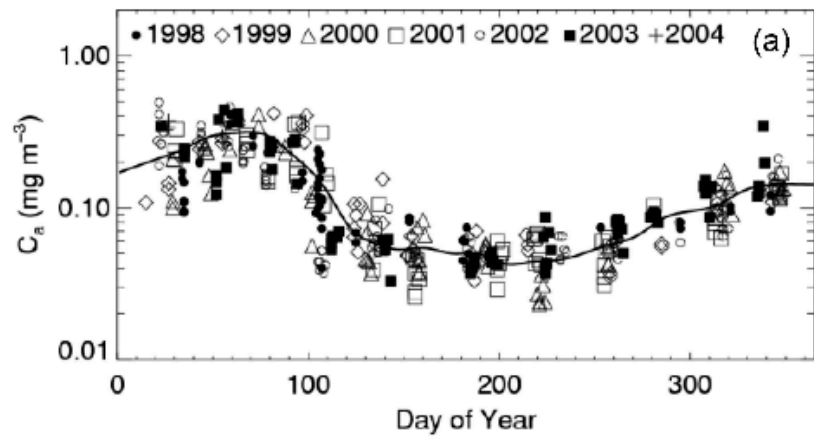
spectral range is 340-955 nm & spectral resolution is 0.6 nm

hyperspectral data convolved to specific bandpasses of each satellite

approximately 450-700 samples per year for MODIS-Aqua

model-based vicarious calibration

build a climatology using a long-term chlorophyll-a record (this is for BATS, near Bermuda) ...



... then, develop a radiometric climatology using an ocean reflectance model (e.g., Morel and Maritorena 2001)

P.J. Werdell, S.W. Bailey, B.A. Franz, A. Morel, and C.R. McClain, "On-orbit vicarious calibration of ocean color sensors using an ocean surface reflectance model," *Applied Optics* 46, 5649-5666 (2007).

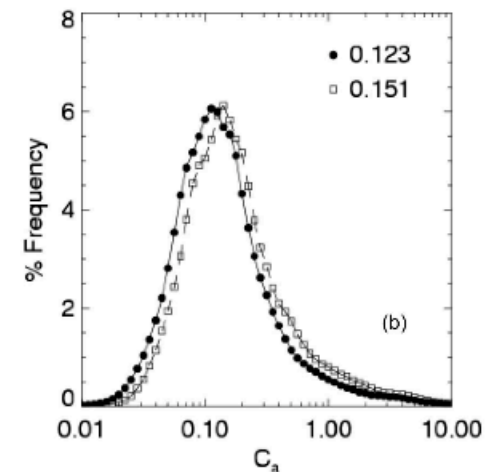
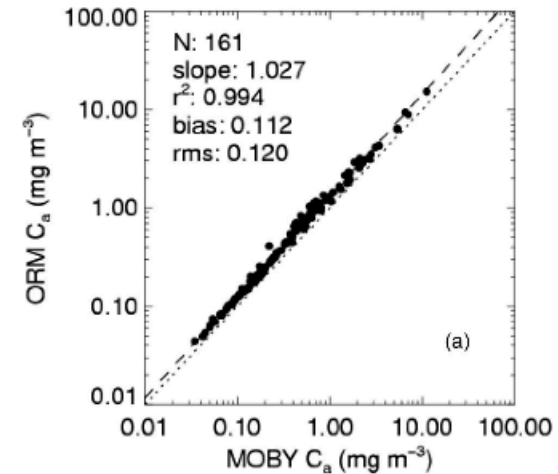
model-based vicarious calibration

Table 3. Percent Differences^a Between the MOBY and ORM \bar{g}

	412	443	490	510	555	670
BATS	-0.31	-1.18	-1.14	-0.52	0.14	-0.07
HOTS	-0.74	-0.53	-0.48	-0.14	0.44	-0.21
BATS + HOTS	-0.52	-0.86	-0.81	-0.33	0.29	-0.13

^aCalculated using $(\bar{g}_{ORM} - \bar{g}_{MOBY}) \times 100\% / \bar{g}_{MOBY}$.

model-based gains typically differ from MOBY gains by < 1%

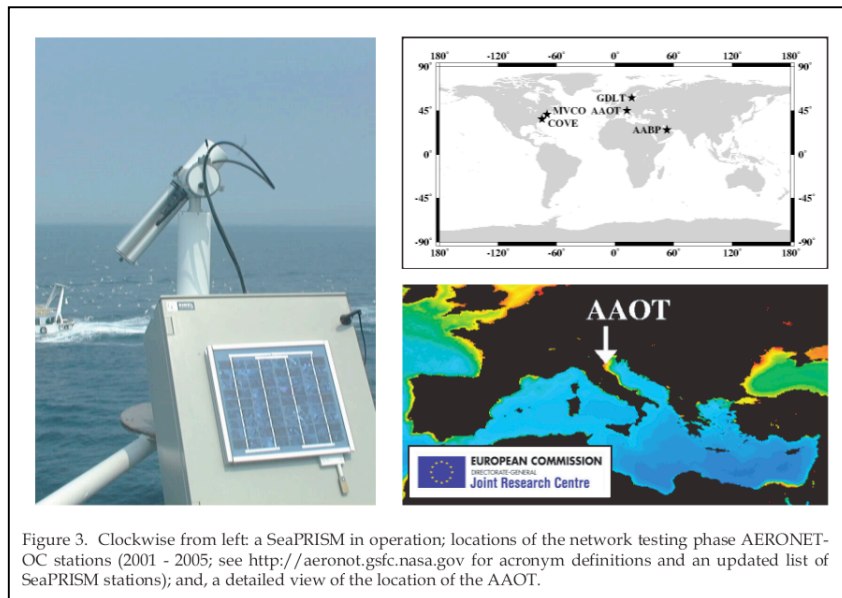


P.J. Werdell, S.W. Bailey, B.A. Franz, A. Morel, and C.R. McClain, "On-orbit vicarious calibration of ocean color sensors using an ocean surface reflectance model," Applied Optics 46, 5649-5666 (2007).

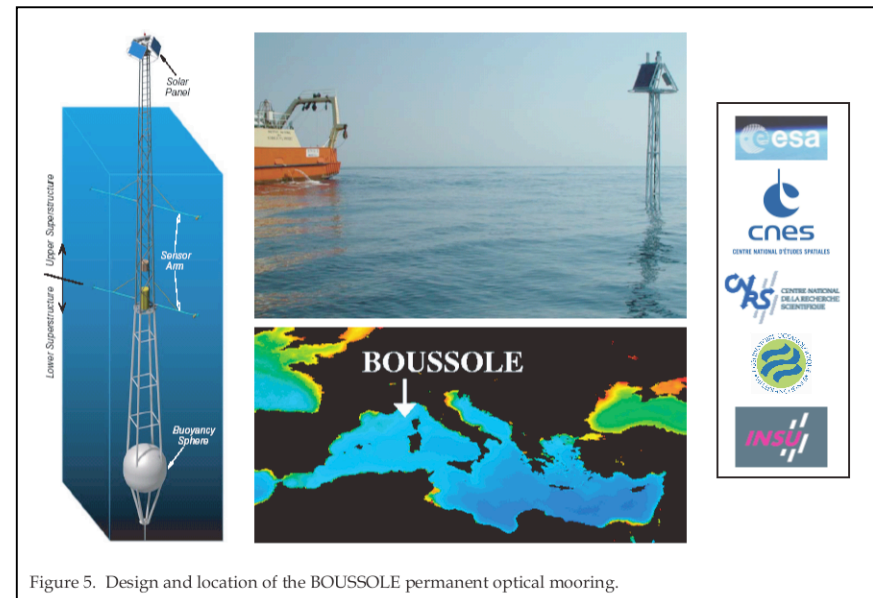
alternative *in situ* data for vicarious calibration

in situ data from other sources, such as global ship-based data sets (NOMAD), alternate buoys (BOUSSOLE), or networks of above water sensors (AERONET-OC)

AERONET-OC



BOUSSOLE



S.W. Bailey, S.B. Hooker D. Antoine, B.A. Franz, and P.J. Werdell, "Sources and assumptions for the vicarious calibration of ocean color satellite observations," *Applied Optics* 47, 4186-4203 (2008).

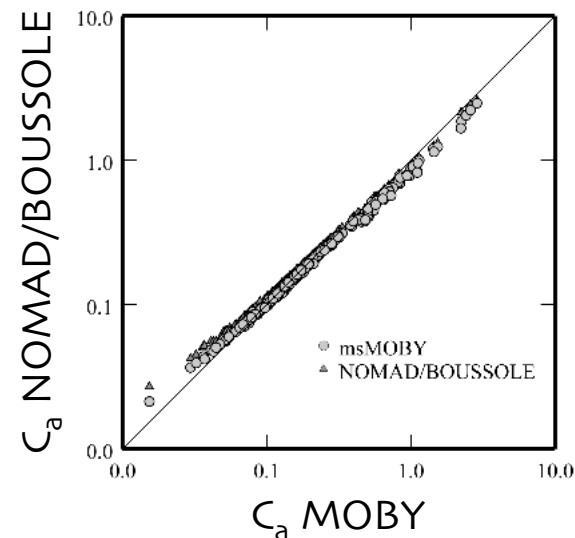
alternative *in situ* data for vicarious calibration

Table 2. Vicarious Gain Coefficients for Standard Method^a

Source	N	412	443	490	510	555	670
MOBY	166	1.0368	1.0132	0.9918	0.9982	0.9993	0.9729
(σ)		(0.009)	(0.009)	(0.008)	(0.009)	(0.009)	(0.007)
CV		1.736	1.777	1.613	1.803	1.801	1.439
NOMAD	64	1.0395	1.0135	0.9967	0.9962	0.9989	0.9693
(σ)		(0.013)	(0.013)	(0.014)	(0.017)	(0.013)	(0.009)
UPD		0.1300	0.01480	0.2464	-0.1003	-0.0200	-0.1854
BOUSSOLE ^b	46	1.0402 ^c	1.0129	0.9961	1.0015	1.0007	0.9672
(σ)		(0.005)	(0.027)	(0.033)	(0.031)	(0.021)	(0.006)
UPD		0.1637	-0.0148	0.2163	0.1650	0.0700	-0.2938

^aGain coefficients using the threshold criteria defined in [4]. The standard deviations are shown in parentheses. ^b C_a threshold increased to 0.25 mg m^{-3} for the BOUSSOLE data set to bring the N to a minimum of 40. ^cThe 412 nm data for BOUSSOLE used only 9 points.

gains calculated using
alternative *in situ* data typically
differ from MOBY by $< 0.3\%$

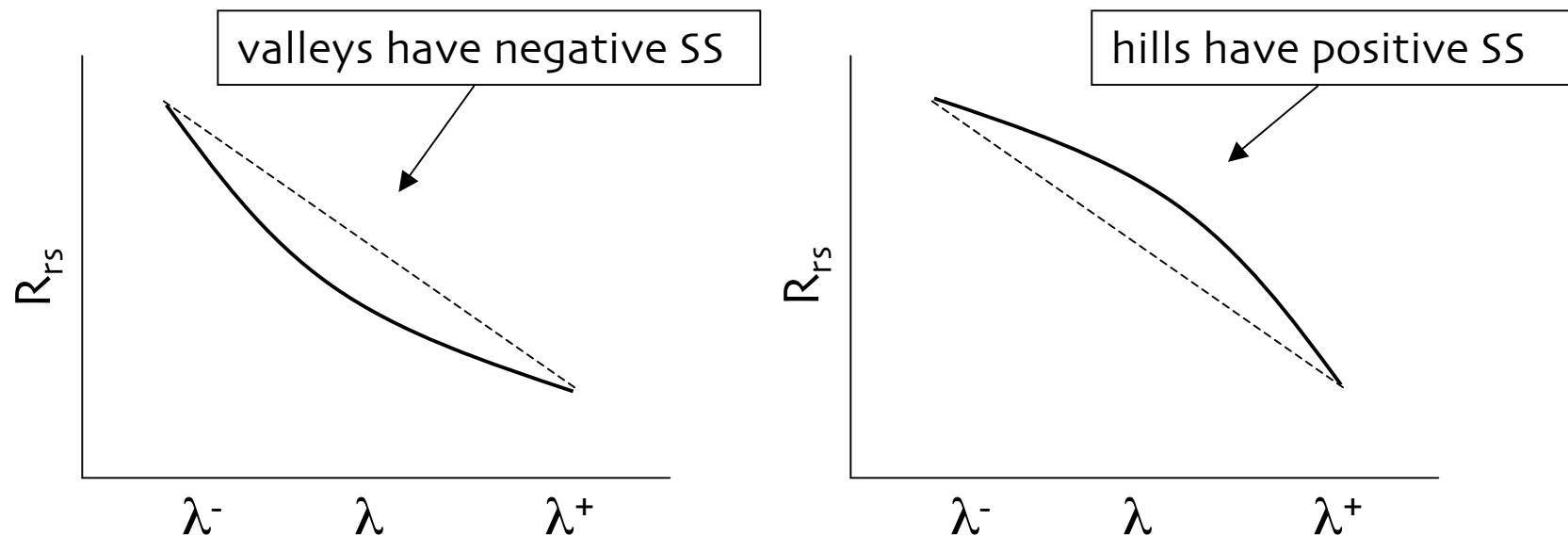


S.W. Bailey, S.B. Hooker D. Antoine, B.A. Franz, and P.J. Werdell, "Sources and assumptions for the vicarious calibration of ocean color satellite observations," Applied Optics 47, 4186-4203 (2008).

tuning vicarious calibration using population statistics

compare spectral shapes of *in situ* & satellite populations

$$SS(\lambda) = R_{rs}(\lambda) - R_{rs}(\lambda^-) - \left[R_{rs}(\lambda^+) - R_{rs}(\lambda^-) \right] \left(\frac{\lambda - \lambda^-}{\lambda^+ - \lambda^-} \right)$$

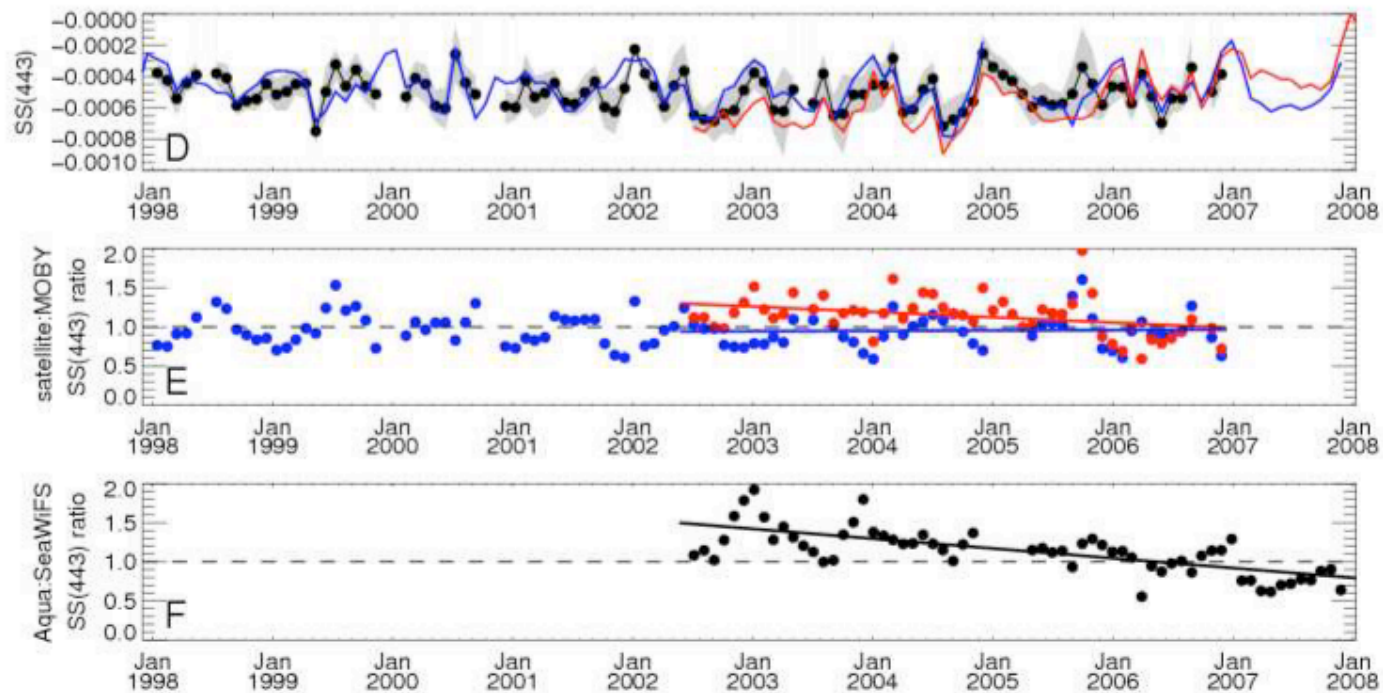


spectral shape @ 443 nm, $SS(443)$, uses $R_{rs}(412)$, $R_{rs}(443)$, & $R_{rs}(490)$

R.P. Stumpf and P.J. Werdell, "Adjustment of ocean color sensor calibration through multi-band statistics," *Optics Express* 18, 401-412 (2010)

tuning vicarious calibration using population statistics

in situ, SeaWiFS, & MODIS-Aqua spectral shapes compared at MOBY site



R.P. Stumpf and P.J. Werdell, "Adjustment of ocean color sensor calibration through multi-band statistics," *Optics Express* 18, 401-412 (2010)

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Level-2 match-ups
Level-2 time-series
community efforts

2. lessons learned from maintaining SeaBASS

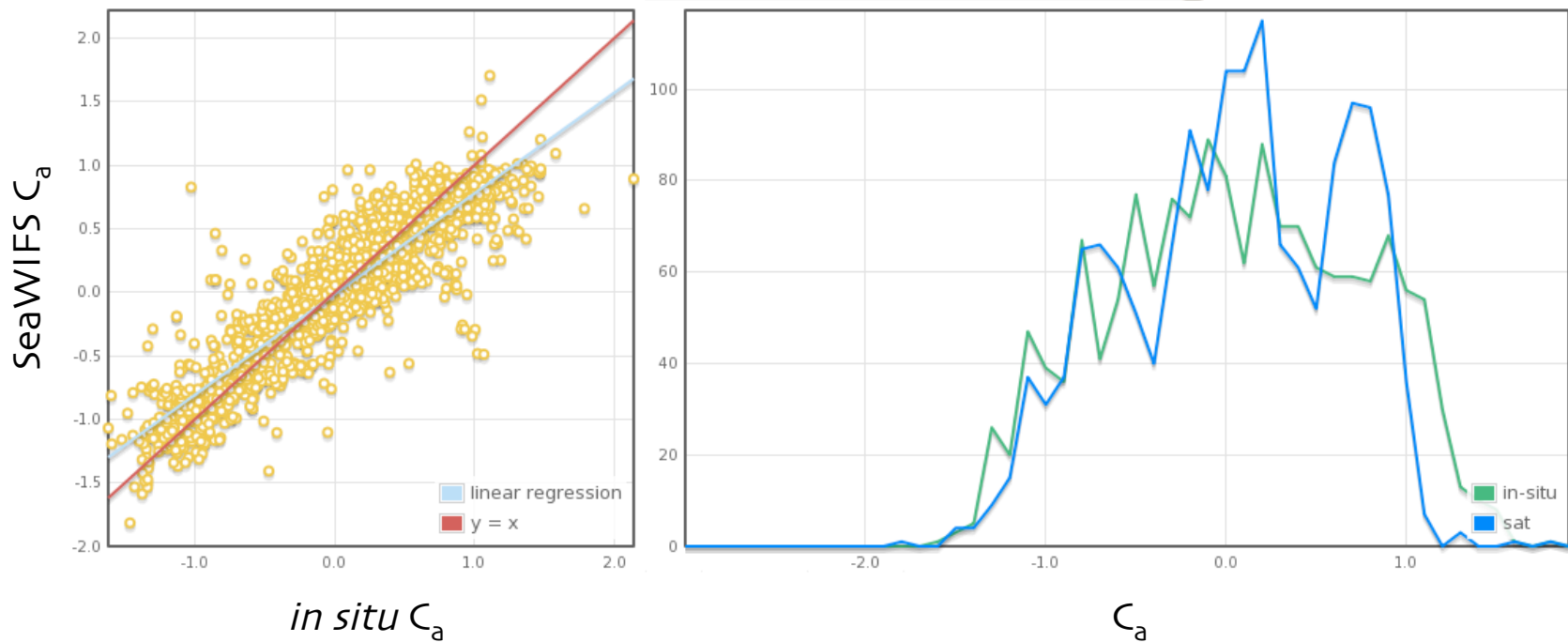
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Level-2 match-ups

comparison of “coincident” *in situ* & satellite measurements

SeaWiFS chlorophyll-a match-ups (OC4 algorithm):

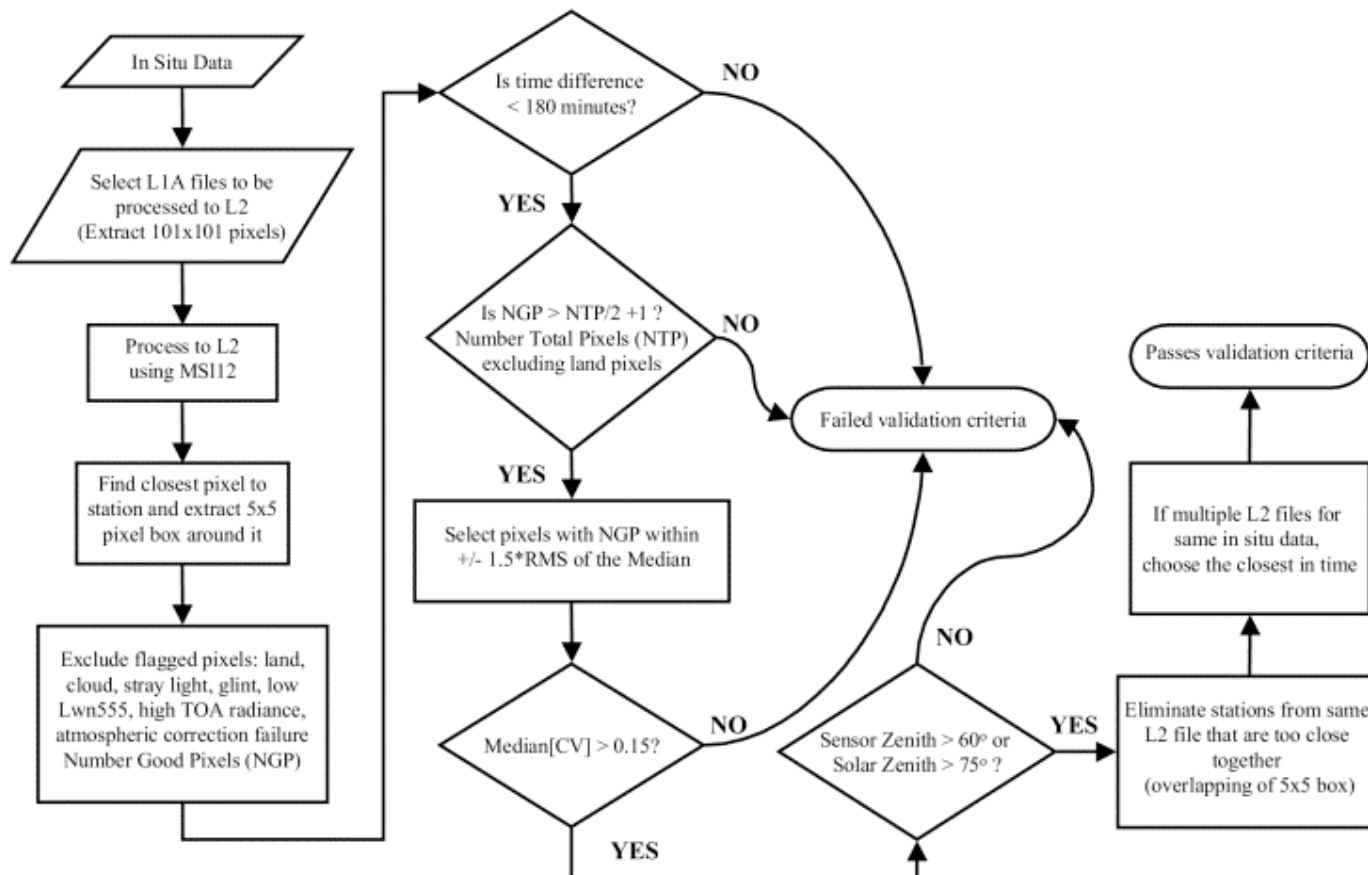
In-Situ Range	Sat Range	N	Slope	Intercept	R Squared	Median Ratio	Abs % Difference
(-1.61979, 2.14003)	(-1.81612, 1.70704)	1560	0.79275	-0.0152278	0.81477005	0.98005764	36.67182



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)

Level-2 match-ups

general flow of match-up process, with exclusion criteria



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)

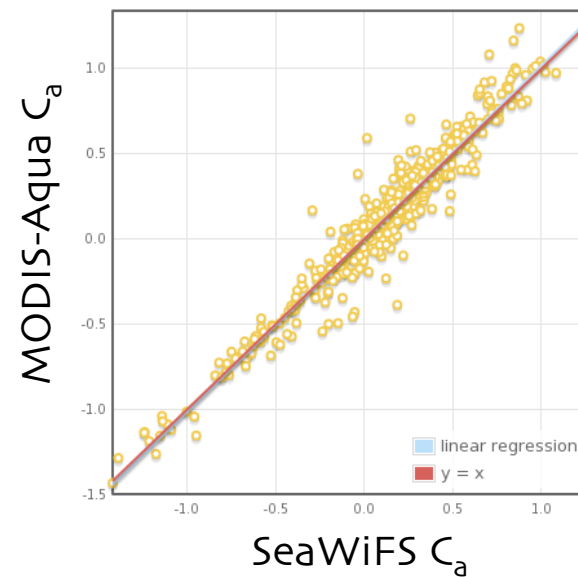
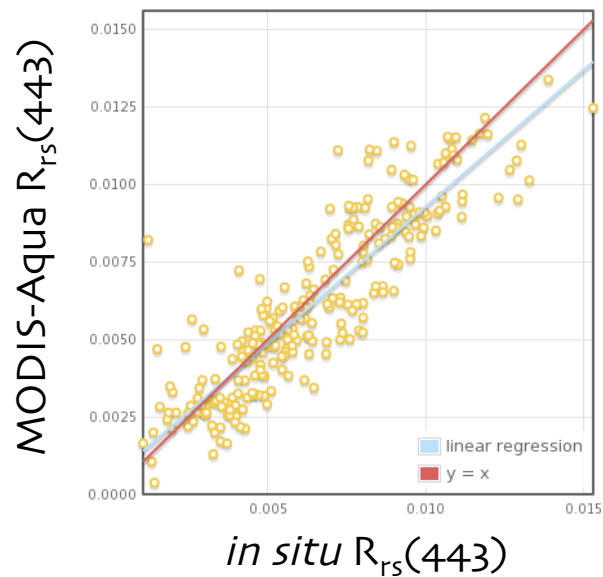
Level-2 match-ups

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



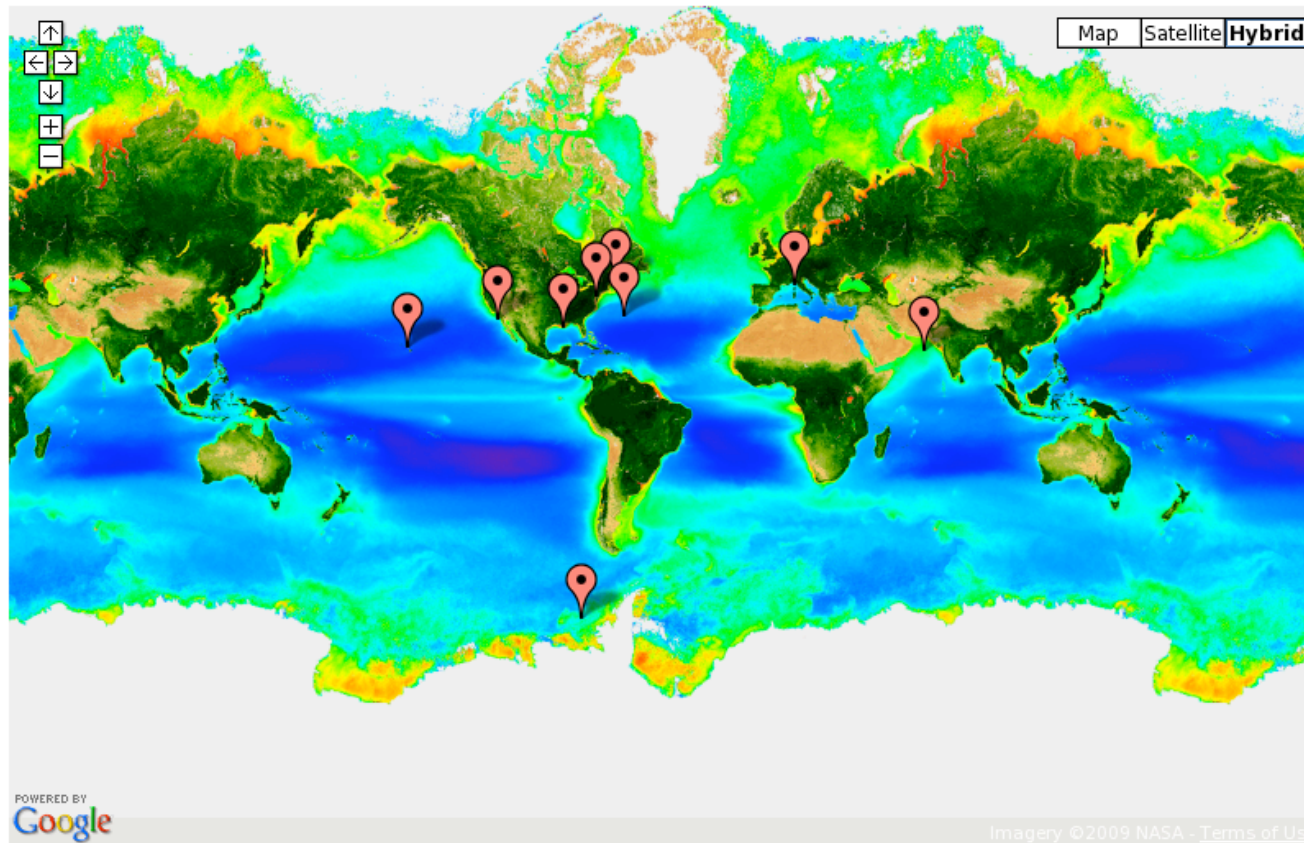
S.W. Bailey and P.J. Werdell, "A multi-sensor approach for the on-orbit validation of ocean color satellite data products," Remote Sensing of Environment 102, 12-23 (2006)

Level-2 time-series analyses

results publicly posted online at:

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

9 regions currently supported



P.J. Werdell, S.W. Bailey, L.W. Harding Jr., Gene C. Feldman, and C.R. McClain, "Regional and seasonal variability of chlorophyll-a in Chesapeake Bay as observed by SeaWiFS and MODIS-Aqua," Remote Sensing of Environment 113, 1319-1330 (2009).

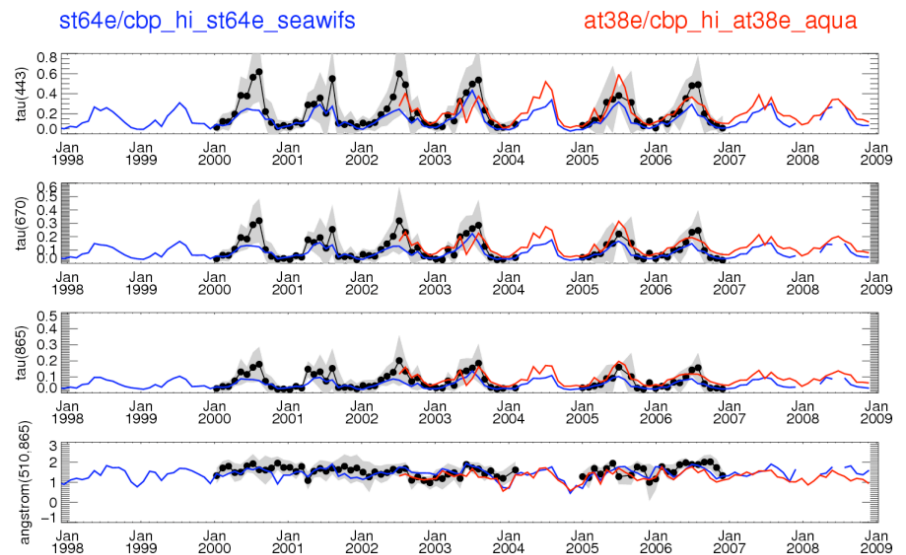
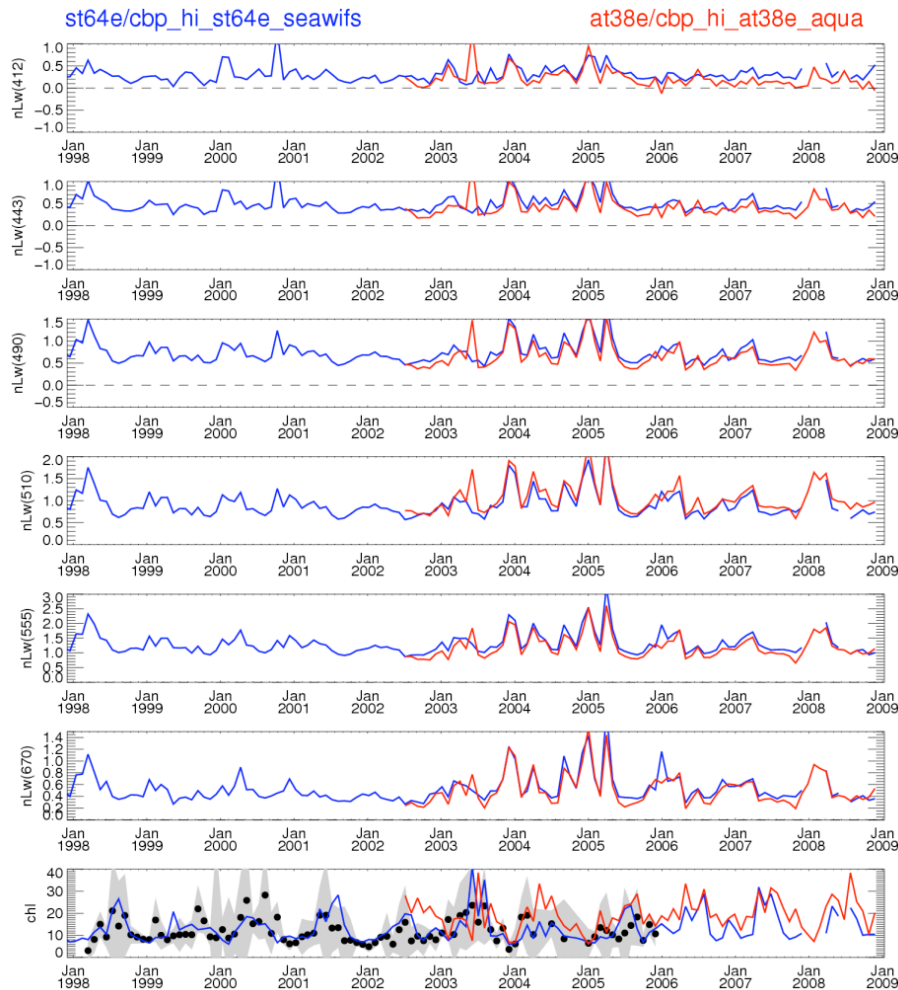
Level-2 time-series analyses

monthly time-series

SeaWiFS vs. MODIS-Aqua vs. *in situ*

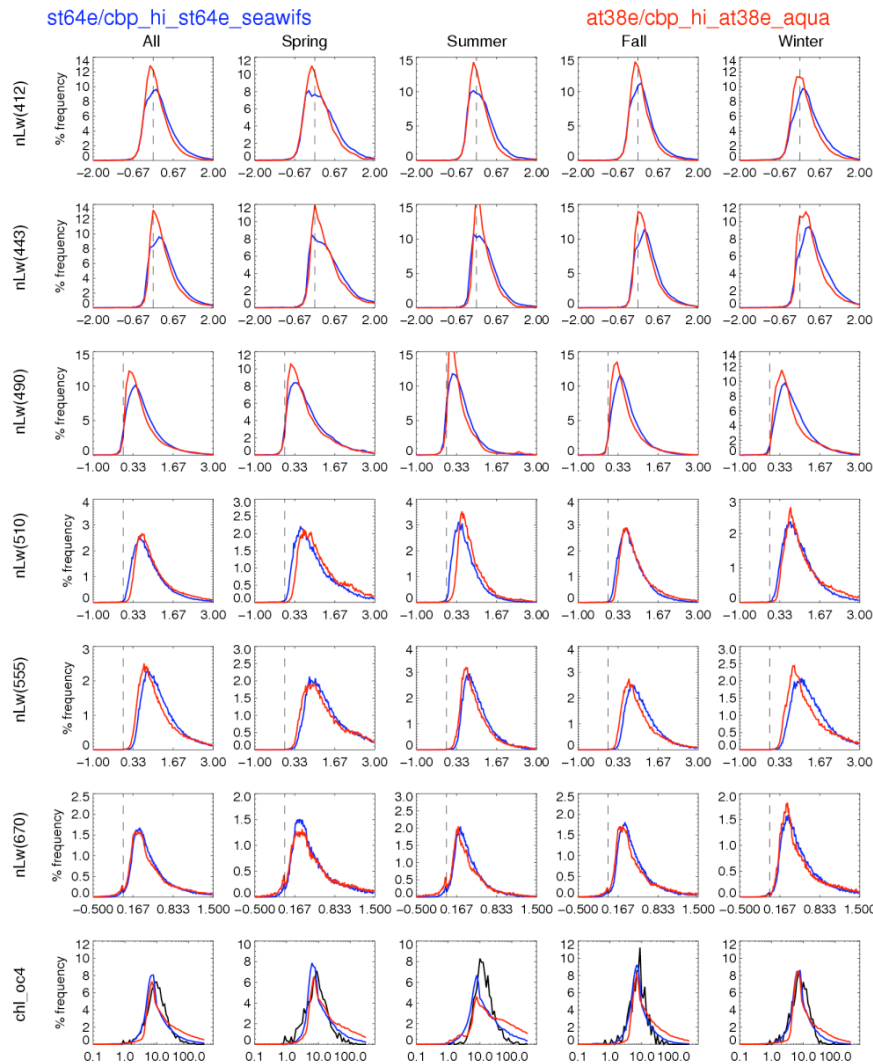
upper third of Chesapeake Bay

in situ data from Chesapeake Bay Program (C_a) & AERONET (AOTs)



P.J. Werdell, S.W. Bailey, L.W. Harding Jr., Gene C. Feldman, and C.R. McClain, "Regional and seasonal variability of chlorophyll-a in Chesapeake Bay as observed by SeaWiFS and MODIS-Aqua," Remote Sensing of Environment 113, 1319-1330 (2009).

Level-2 time-series analyses

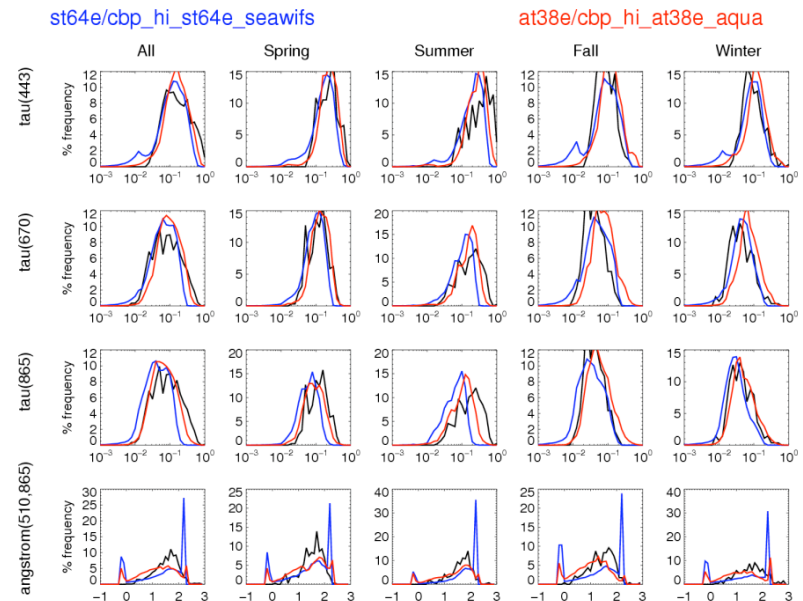


seasonal frequency distributions

SeaWiFS vs. MODIS-Aqua vs. *in situ*

upper third of Chesapeake Bay

in situ data from Chesapeake Bay Program (C_a) & AERONET (AOTs)



P.J. Werdell, S.W. Bailey, L.W. Harding Jr., Gene C. Feldman, and C.R. McClain, "Regional and seasonal variability of chlorophyll-a in Chesapeake Bay as observed by SeaWiFS and MODIS-Aqua," Remote Sensing of Environment 113, 1319-1330 (2009).

community validation efforts

ISI Web of Science search for “ocean color validation” yields 299 results

result #2 (as of 7 Jan 2010): K.N. Babu, A.K. Shukla, G.P. Matondkar, S.K. Singh, S. Sawant, “Characterization of chlorophyll-a over CAL-VAL site at Kavaratti in the Lakshadweep Sea,” *Marine Geodesy* 32, 345-354 (2009)

OBPG “match-up” Remote Sensing of Environment paper cited ~ 45 times

1. *in situ* data are important for ocean color cal/val

- vicarious calibration
- data product validation
- algorithm development

NOMAD
operational algorithms
generic IOP algorithm
atmospheric correction
community efforts

2. lessons learned from maintaining SeaBASS

- overview & data policies
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NOMAD ~ NASA bio-Optical Marine Algorithm Dataset

SeaBASS consists of original files from data collectors

radiometry, spectroscopy, pigments, and CTD all in separate files
most data are depth-resolved, i.e., no surface (o-) values!
lots of replicate data

realizing the difficulty in using these data for algorithm development, the OBPG

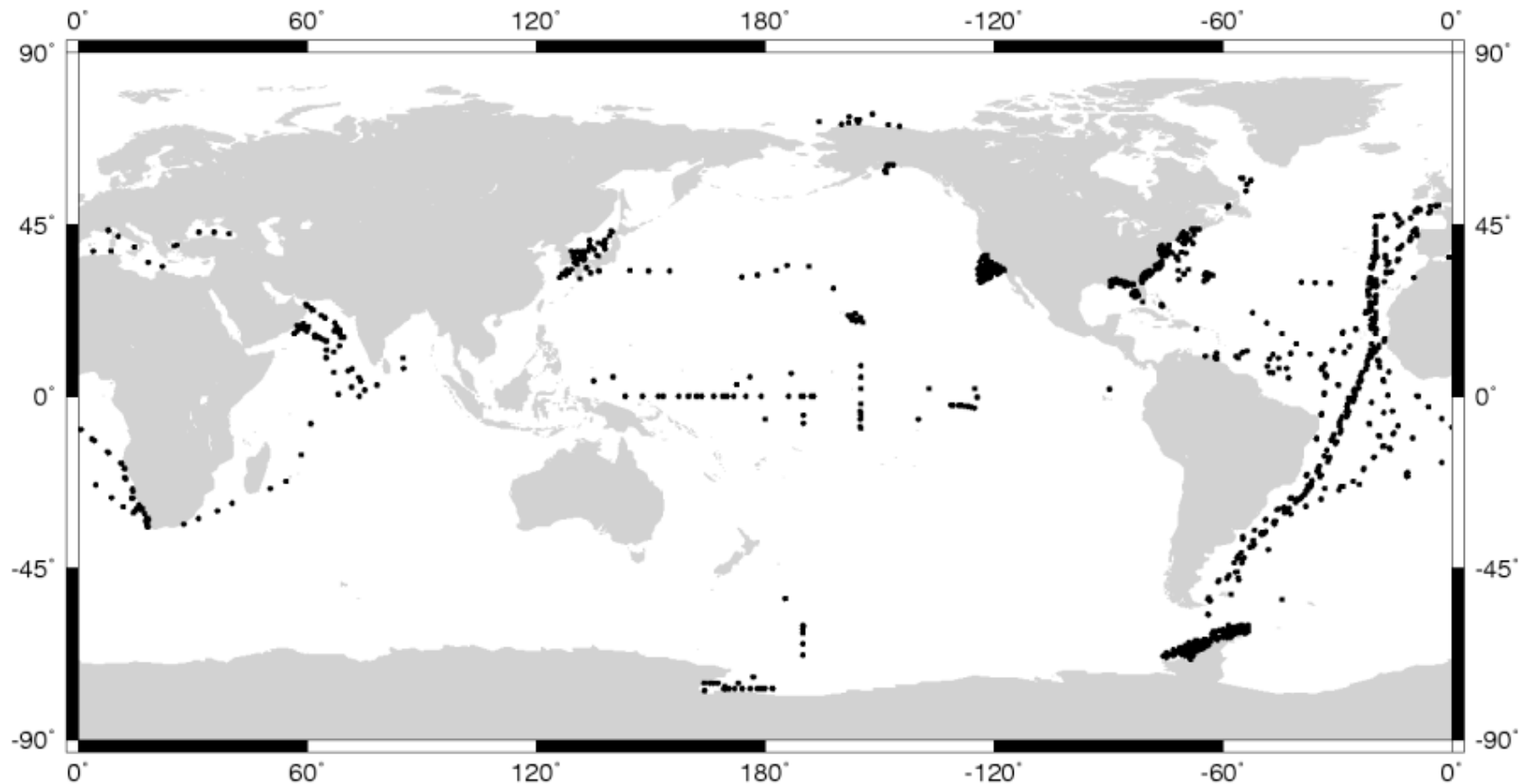
evaluated all SeaBASS radiometry, spectroscopy, pigments, and CTD
estimated surface (o-) values from these data (used for validation!)
identified coincident observations
generated a consolidated, merged data set

NOMAD is fully publicly available, as are its source data within SeaBASS

3,467 coincident observations of $L_w(\lambda)$, $E_s(\lambda)$, $K_d(\lambda)$, & C_a
Wt, Sal, $b_b(\lambda)$, and $a(\lambda)$ where available
metadata includes date, location, & cruise name
plus, NCDC OISST, NGDC ETOPO₂, & processing flags

P.J. Werdell and S.W. Bailey, "An improved in-situ bio-optical data set for ocean color algorithm development and satellite data product validation," Remote Sensing of Environment 98, 122-140 (2005)

NOMAD ~ NASA bio-Optical Marine Algorithm Dataset



NOMAD global distribution - Version 1, Mar 2005

P.J. Werdell and S.W. Bailey, "An improved in-situ bio-optical data set for ocean color algorithm development and satellite data product validation," *Remote Sensing of Environment* 98, 122-140 (2005)

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

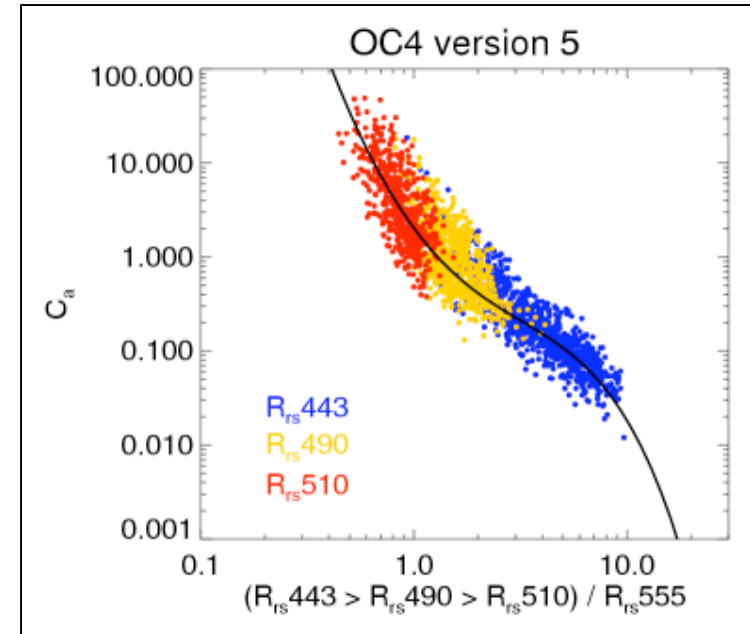


Table 1

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

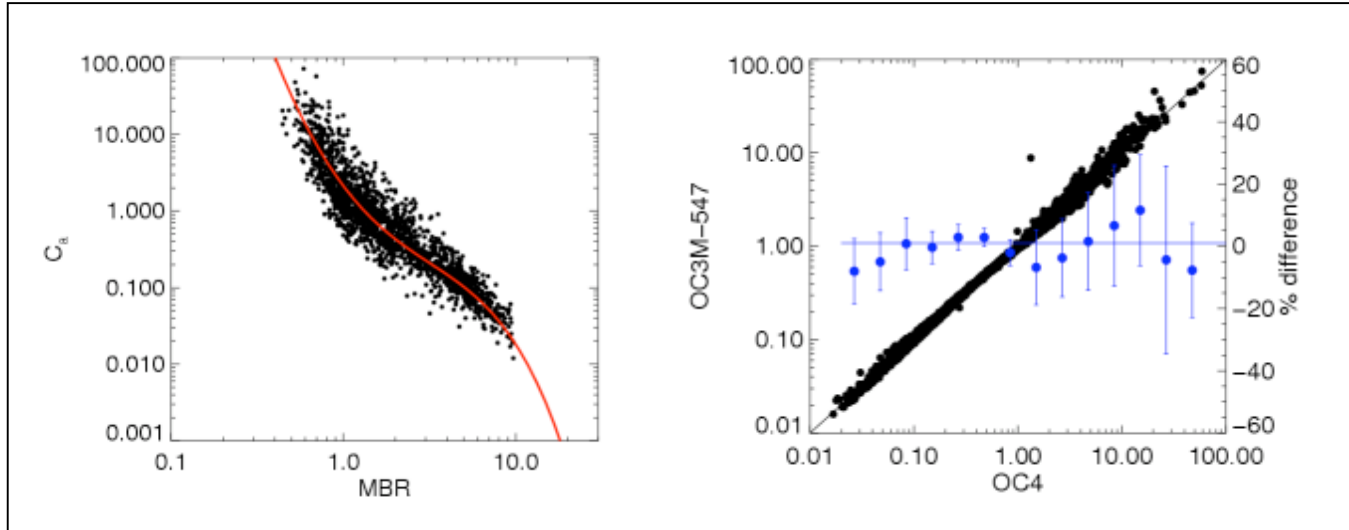
	λ_b	λ_g	c_0	c_1	c_2	c_3	c_4
OC4	443,490,510	555	0.3080	-3.0882	3.0440	-1.2013	-0.7992
OC3S ^a	443,490	555	0.2409	-2.4768	1.5296	0.1061	-1.1077
OC3M ^b	443,488	551	0.2254	-2.6354	1.8071	0.0063	-1.2931

^a For SeaWiFS.

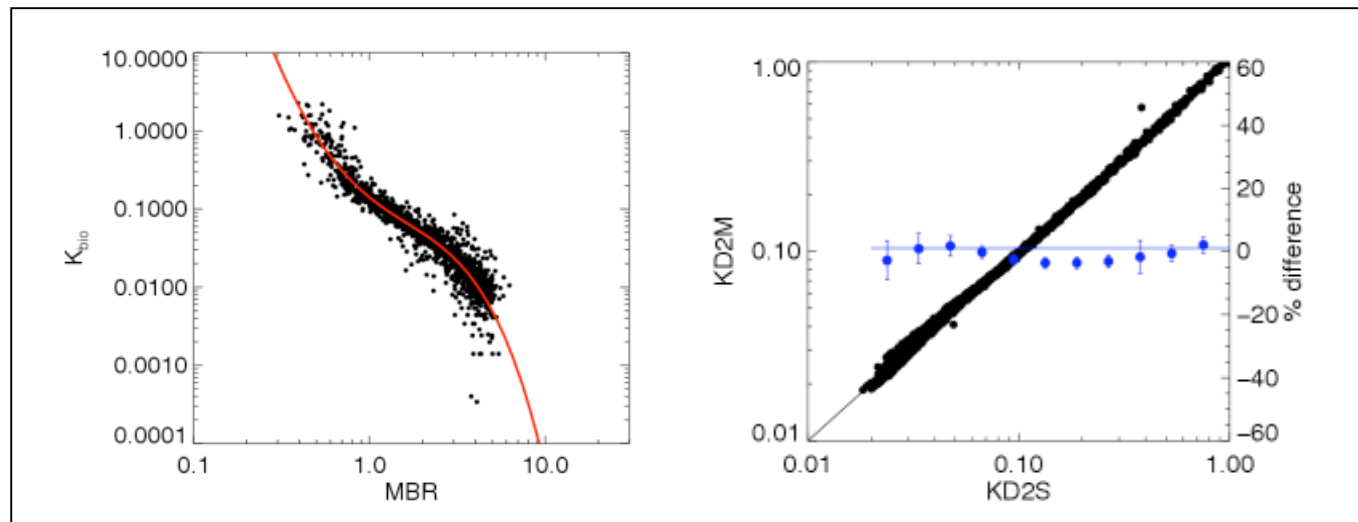
^b For MODIS-Aqua.

operational empirical algorithms

chlorophyll-a ~ <http://oceancolor.gsfc.nasa.gov/ANALYSIS/ocv6/>



$K_d(490)$ ~ <http://oceancolor.gsfc.nasa.gov/ANALYSIS/kdv4/>

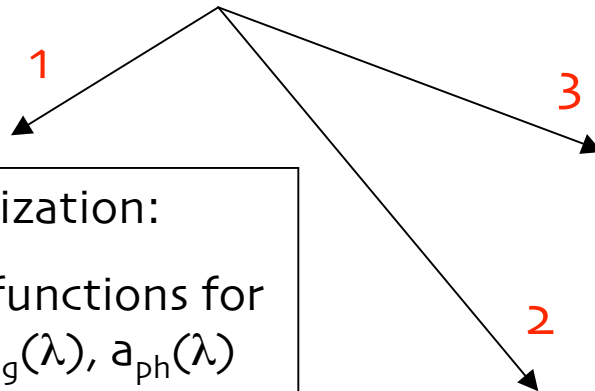


the Generic IOP model (GIOP)

construction (& deconstruction) of an semi-analytic algorithm ...

$$R_{rs} \approx \text{func} \left(\frac{b_b}{a + b_b} \right)$$

satellite provides $R_{rs}(\lambda)$
 $a(\lambda)$ and $b_b(\lambda)$ are desired products



Spectral Optimization:

- * define shape functions for (e.g.) $b_{bp}(\lambda)$, $a_{dg}(\lambda)$, $a_{ph}(\lambda)$
- * solution via L-M, matrix inversion, etc.
- * ex: RP95, HL96, GSM

Bulk Inversion:

- * no predefined shapes
- * piece-wise solution: $b_{bp}(\lambda)$, then $a(\lambda)$, via (empirical) $K_d(\lambda)$ via RTE
- * ex: LSo0

Spectral Deconvolution:

- * partially define shape functions for $b_{bp}(\lambda)$, $a_{dg}(\lambda)$
- * piece-wise solution: $b_{bp}(\lambda)$, then $a(\lambda)$, then $a_{dg}(\lambda) + a_{ph}(\lambda)$
- * ex: QAA, PML, NIWA

the Generic IOP model (GIOP)

specify sensor wavelengths to fit

e.g., 412,443,490,510,555

select a_{ph} form and set params

tabulated: λ , $a_{ph}^*(\lambda)$

dynamic: Bricaud, Ciotti, Lee

select a_{dg} form and set params

exponential: λ_o , S

dynamic: QAA, OBPG

select b_{bp} form and set params

power law: λ_o , η

dynamic: QAA, LSoo, Ciotti, Morel

select $r_{rs}[o-]$ to $b_b/(a+b_b)$

quadratic

f/Q: Morel (tbd: PML, Lee)

specify inversion method

Levenburg-Marquardt

Amoeba (downhill simplex)

Lower-Upper Decomposition

Singular-Value Decomposition

specify output products

$a(\lambda)$, $a_{ph}(\lambda)$, $a_{dg}(\lambda)$, $b_b(\lambda)$, $b_{bp}(\lambda)$

λ = any sensor wavelength(s)

C_a (given a_{ph}^* at λ_o)

η , S (dynamic model params)

internal flags

<http://oceancolor.gsfc.nasa.gov/MEETINGS/OOXIX/IOP/>

atmospheric correction

in situ data ... it's not just for in-water algorithm development anymore

- development of new aerosol tables (via AERONET)

Z. Ahmad, B.A. Franz, C.R. McClain, E.J. Kwiatkowska, P.J. Werdell, E. Shettle, and B.N. Holben, "Aerosol models for the retrieval of aerosol optical thickness and normalized water-leaving radiances from the SeaWiFS and MODIS sensors over coastal regions and open oceans," to be submitted to Applied Optics

- refinement of the correction for non-zero R_{rs} (NIR)

S.W. Bailey, B.A. Franz, P.J. Werdell, "Estimation of near-infrared water-leaving reflectance for satellite ocean color data processing," submitted to Optics Express

- refinement of the correction bidirectional effects (f/Q)

- evaluation of the correction for spectral bandpass effects

community algorithm development efforts

International Ocean Color Coordinating Group (IOCCG)

- working group "Ocean-Colour Algorithms" (Report 5)
- working group "Phytoplankton Functional Types"
- proposed working group "Regional bio-Optical algorithms Initiative (ROI)"

Optical Water Type classification

T.S. Moore, J.W. Campbell, and M.D. Dowell, "A class-based approach to characterizing and mapping the uncertainty of the MODIS ocean chlorophyll product," Remote Sensing of Environment 113, 2424-2430 (2009)

how to summarize the 100's of other bio-optical algorithm development papers?

NOMAD Remote Sensing of Environment paper cited ~ 40 times

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philosophy & data policies

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

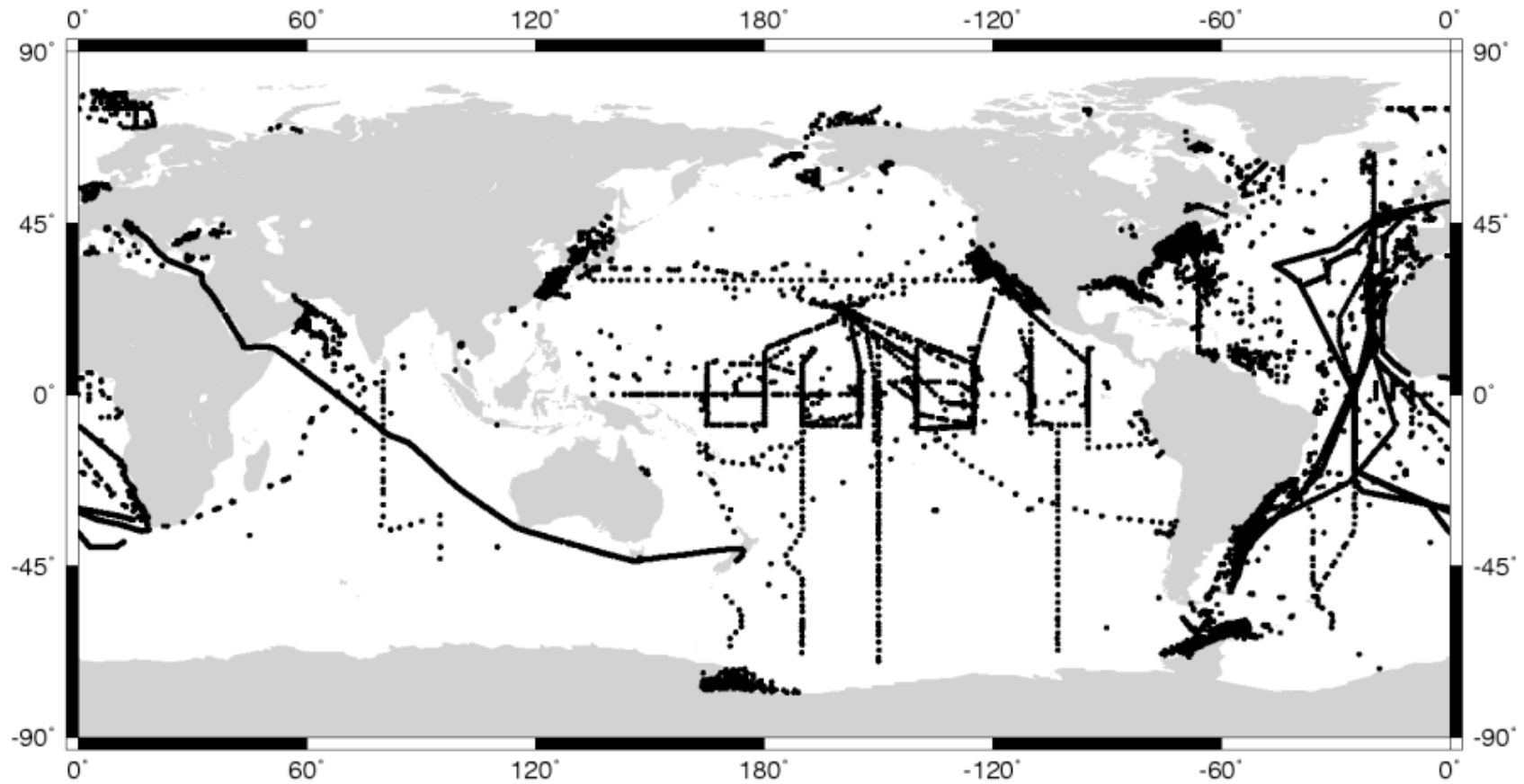
all data are accessible online:

- publicly available via SeaBASS Web site
- periodically released to National Oceanographic Data Center

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

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).

philosophy & data policies



SeaBASS AOPs, IOPs, and Chl, Jan 2008

philosophy & data policies

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**

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data collection

all data to be collected (whenever possible) following community-vetted protocols prescribed in NASA Technical Memoranda Series (6 Volumes)

- Ocean Optics Protocols for Ocean Color Sensor Validation
- <http://oceancolor.gsfc.nasa.gov/DOCS/TechMemo/>

all OB&B funded high performance liquid chromatography (HPLC) samples processed by Horn Point Laboratory @ the University of Maryland

organization & participation in international data collection & processing round robins & workshops (e.g., SeaHARRE & SIRREX)

NASA Calibration & Validation Office (CVO)

- participation in field campaigns
- instrument development
- refinement of data collection & processing protocols
- organization of instrument round

“complete” data sets ~ validation vs. algorithm development vs. science

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- data product validation
- algorithm development

2. lessons learned from maintaining SeaBASS

- overview & data policies
- data collection
- the centralized archive
- data analysis

benefits of a centralized archive

consolidated ...

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

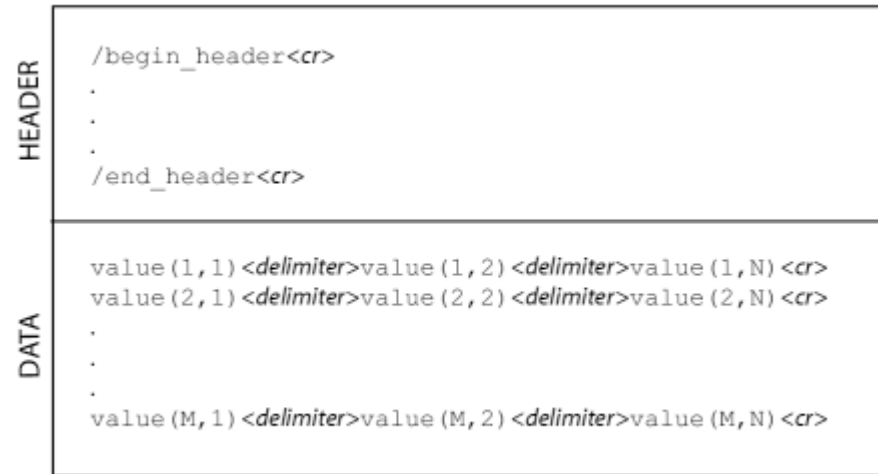
facilitates ...

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

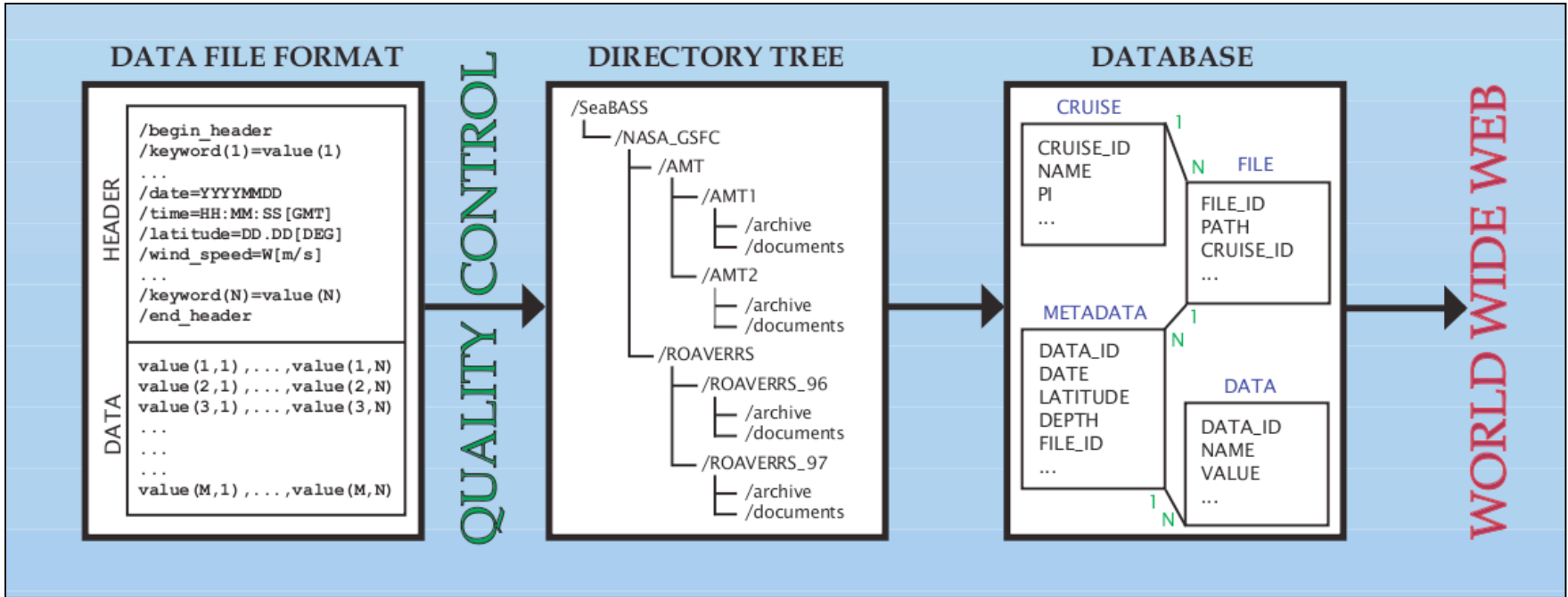
SeaBASS infrastructure

- SeaBASS file format:
- ASCII text for platform independence
 - matrix of data preceded by predefined metadata headers

```
/begin_header
/Investigators=John_Smith,Mary_Johnson
/Affiliations=State_University
/Contact=jsmith@state.edu
/Experiment=CalCOFI
/Cruise=cal0101
/Station=93.26
/Data_File_Name=pigments_cal0101.dat
/Original_File_Name=pigments_cal0101.xls
/Documents=cal0101_readme.txt
/Calibration_Files=turner_cals_0012.txt
/Data_Type=pigment
/Data_Status=final
/Parameters=CHL,PHAE0,Tpg
/Start_Date=20010314
/End_Date=20010314
/Start_Time=16:01:30[GMT]
/End_Time=16:30:45[GMT]
/North_Latitude=42.135[DEG]
/South_Latitude=42.055[DEG]
/East_Longitude=-72.375[DEG]
/West_Longitude=-72.420[DEG]
/Water_Depth=250
/Measurement_Depth=NA
/Secchi_Depth=4.5
/Cloud_Percent=50
/Wind_Speed=5.0
/Wave_Height=1.0
|
| COMMENTS
|
| Slightly overcast, with large cumulous on horizon. Wind from NE.
|
| Turner fluorometer last calibrated: 12 December 2000
|
/missing=-999
/delimiter=tab
/fields=time,depth,CHL,PHAE0,Tpg
/units=hh:mm:ss,m,ng/m^3,ng/m^3,ng/m^3
/end_header
16:01:30      0      2.355  0.785  3.140
16:03:45      5      2.180  1.005  3.185
...
...
```



SeaBASS infrastructure



physical storage at
NASA Goddard
Space Flight Center

relational database
management
system (MySQL)

SeaBASS infrastructure



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.

SeaBASS infrastructure

NOMAD & validation data are available via the OBPG Level 1/2 Browser

SeaWiFS User Login

Wednesday, 3 July 2002 through Wednesday, 15 August 2007

Chlorophyll

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: _____
 Find swaths

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

Select only scenes having in situ matchups.

Display results 10 at a time. Reconfigure page

M i s s i o n	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

June 2007							July 2007							August 2007						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
					1	2	1	2	3	4	5	6	7				1	2	3	4
					xxx	aaa	xxx	xxx	xxx	aaa	aaa	aaa	aaa				xxx	xxx	xxx	xxx
3	4	5	6	7	8	9	8	9	10	11	12	13	14	5	6	7	8	9	10	11
aaa	aaa	aaa	aaa	aaa	aaa	aaa	aaa	aaa	aaa	aaa	000	000	000	aaa	aaa	aaa	aaa	aaa	aaa	aaa
10	11	12	13	14	15	16	15	16	17	18	19	20	21	12	13	14	15	16	17	18
000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
17	18	19	20	21	22	23	22	23	24	25	26	27	28	19	20	21	22	23	24	25
000	000	000	000	000	000	000	000	000	000	000	000	000	xxx	000	000	000	000	000	000	000
24	25	26	27	28	29	30	29	30	31					26	27	28	29	30	31	
***	***	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx					***	***	***	xxx	xxx	xxx	

SeaBASS infrastructure

NOMAD & validation data are available via the OBPG Level 1/2 Browser

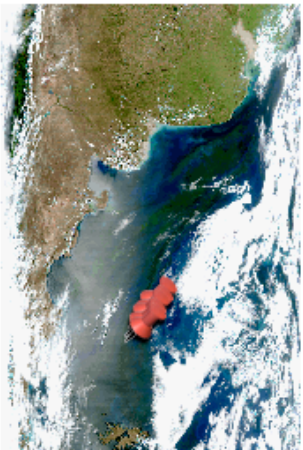
TC
CHL
SST
SST4
SeaWiFS User Login

Comment
Help

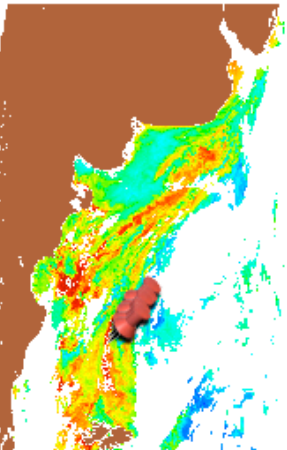
[A2004311180500.L0_LAC](#) 296,724,909 bytes
[A2004311180500.L1A_LAC](#) 61,399,371 bytes
[A2004311180500.L2_LAC](#) 18,323,939 bytes
[A2004311180500.L2_LAC_SST](#) 4,723,221 bytes
 (The above hyperlinks point to [bzipped HDF files](#).
 Documentation on these products can be found [HERE](#).)

[Select this scene](#)

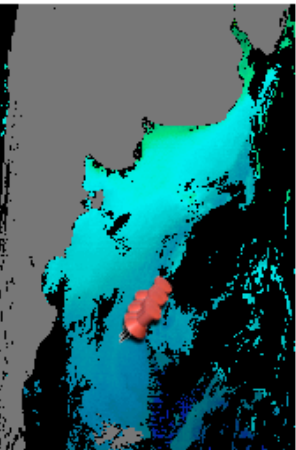
Quasi True Color



Chlorophyll

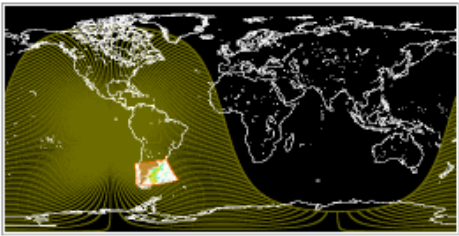


Sea Surface Temperature (11 μ)



Saturday, 6 November 2004

2004311



Search Criteria
Time Period: 18 Jul 2004 through 18 Jun 2005 (daytime)
Sensors: MODIS(Aqua)
Scenes must have coincident in situ data.
Area of Interest: entire globe
Percentage of AOI that swaths must include: Any part
Number of swaths: 86th of 182 swaths

In Situ Data Records							
Date	Time	Latitude	Longitude	Cruise	Wavelength	Name	Value
6 Nov 2004	11:00:00 UT	-46.8593	-60.5378	patex_i		chl	8.01
6 Nov 2004	11:00:00 UT	-46.8593	-60.5378	patex_i	443	es	69.2882
					490	es	81.873
					555	es	60.4403
					412	lw	0.150998
					443	lw	0.154459
					490	lw	0.216648
					510	lw	0.216675
555	lw	0.250206					
670	lw	0.077676					
683	lw	0.087835					

1. *in situ* data are important for ocean color cal/val

- vicarious calibration
- data product validation
- algorithm development

2. lessons learned from maintaining SeaBASS

- overview & data policies
- data collection
- the centralized archive
- data analysis

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

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

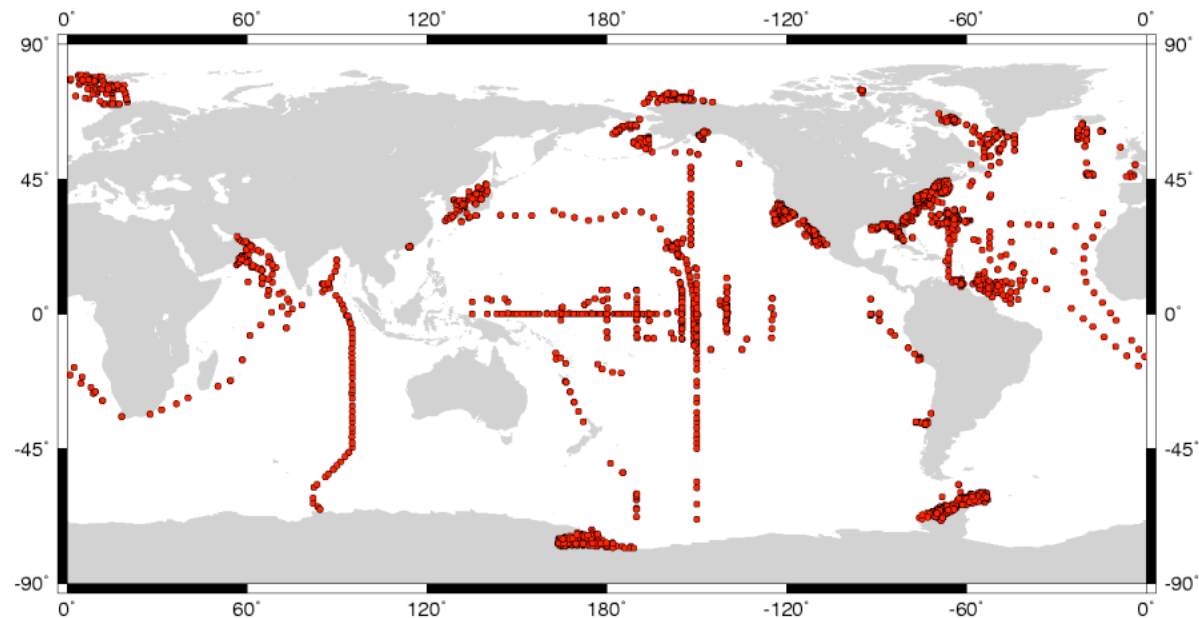
coincidence requirement

data analysis

SeaBASS includes ~12,000 AOP depth profiles ...

... collected on ~850 field campaigns ...

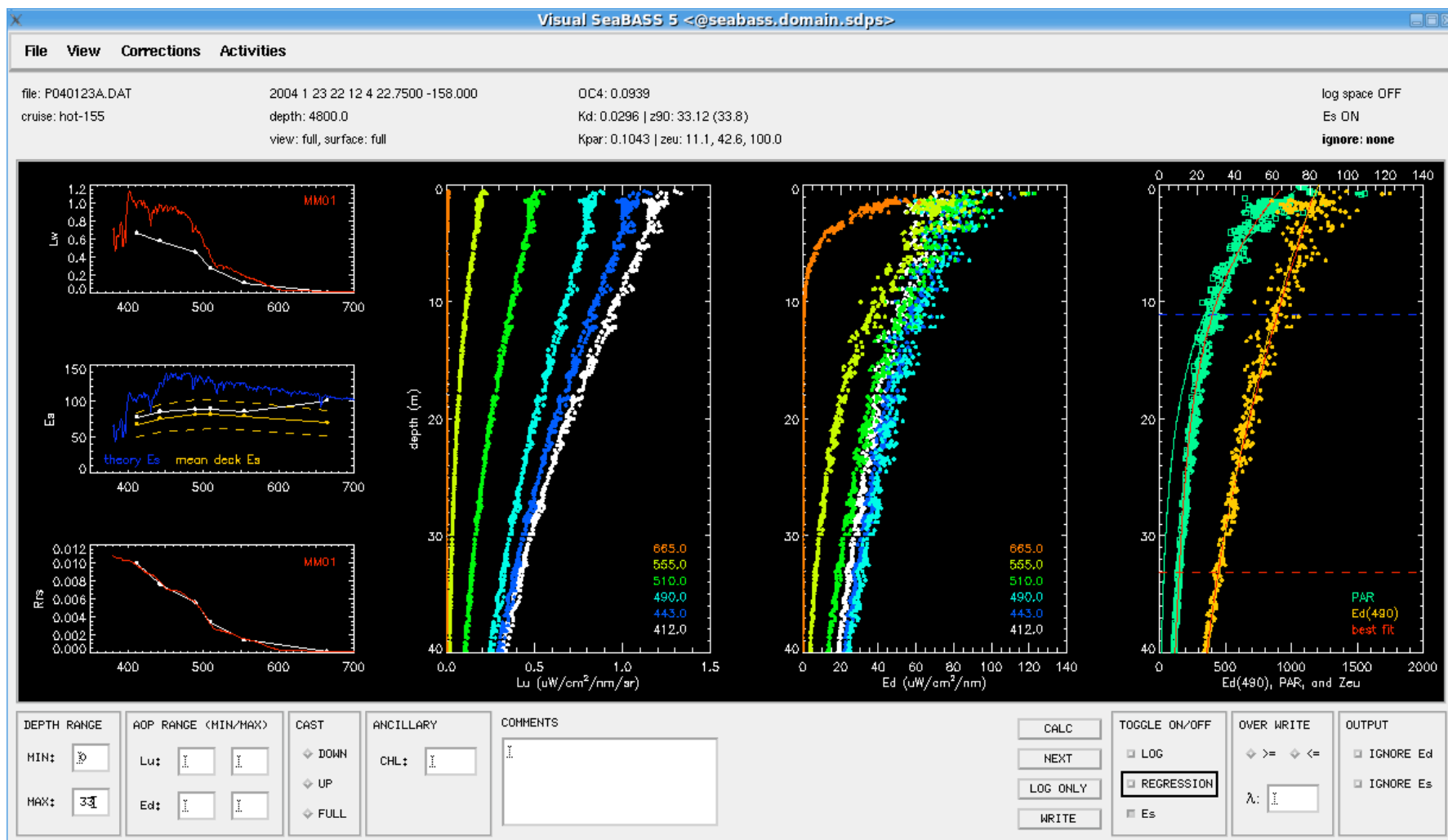
... by ~30 different PIs & a variety of instruments



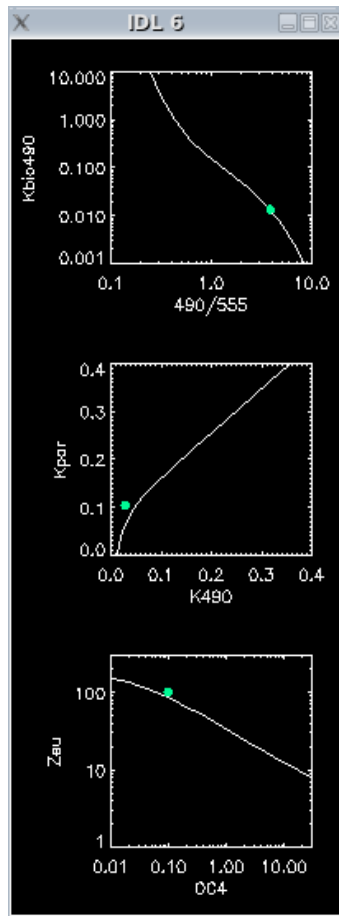
want generic post-processor to minimize PI / instrument differences

data analysis

Visual SeaBASS (VSB): main window



Visual SeaBASS (VSB): features

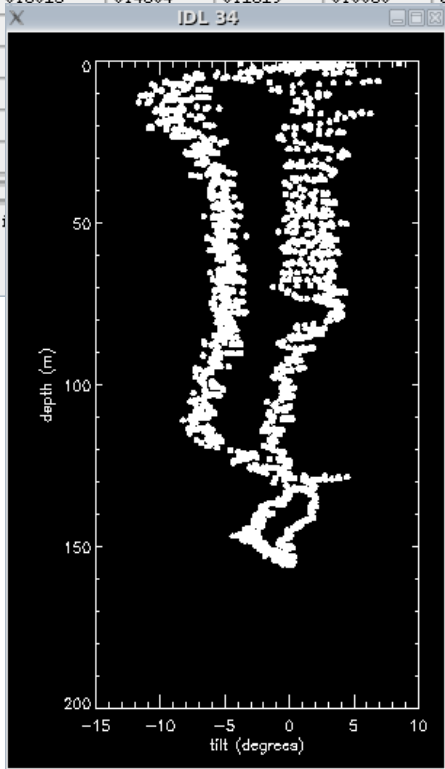
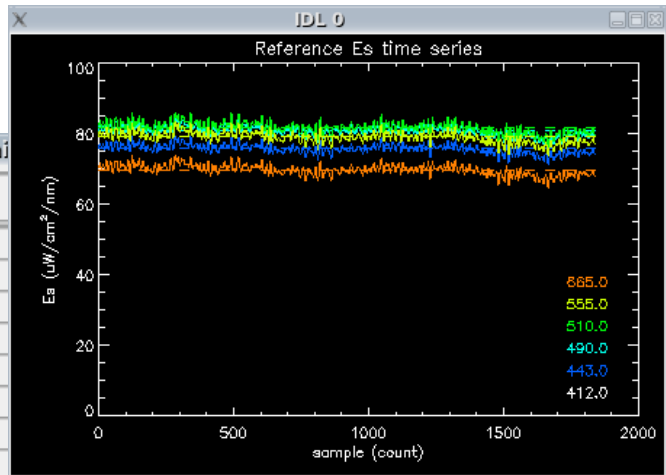


VSB Reduced Data <@seabass.domain>

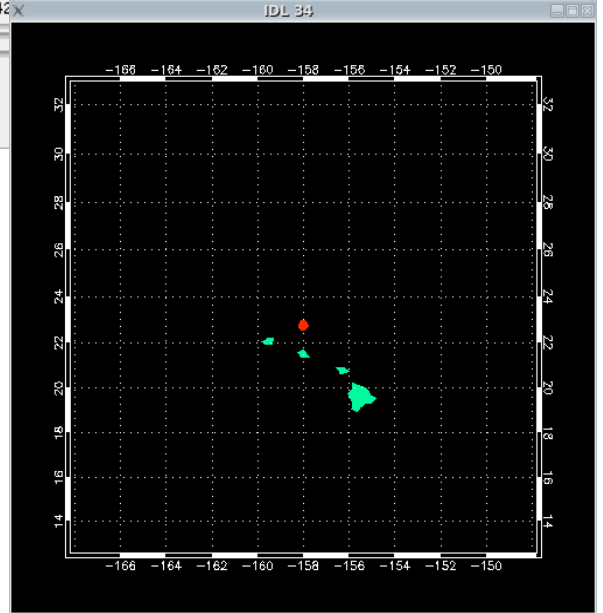
	LU412	LU443	LU490	LU510	LU555	LU665
0.745219	1.3365	1.1616	0.8936	0.5544	0.2298	0.0171
0.632569	1.3151	1.1428	0.8865	0.5478	0.2209	0.0149
0.557470	1.2998	1.1286	0.8794	0.5348	0.2120	0.0132
0.795286	1.2540	1.0955	0.8510	0.5174	0.2036	0.0136
1.10821	1.2510	1.0861	0.8439	0.5109	0.2015	0.0128
1.37107	1.2510	1.0908	0.8463	0.5196	0.2070	0.0113
1.58386	1.2571	1.0908	0.8486	0.5196	0.2072	0.0110
1.82170	1.2418	1.0813	0.8392	0.5152	0.2055	0.0107
1.99695	1.2083	1.0530	0.8179	0.4935	0.1910	0.0085
2.37249	1.1777	1.0246	0.8013	0.4804	0.1819	0.0080
2.83568	1.1869	1.0388				
3.24880	1.2083	1.0530				
3.54926	1.2113	1.0624				
3.92485	1.2235	1.0719				
4.05005	1.2083	1.0577				

The table does not reflect over-wr...

EXIT



58,9137	65,9184	66,8468	65,2200
62,8665	68,1575	70,3891	70,5435
65,7673	101,0723	101,1965	95,2822
73,6784	83,3834	89,8182	87,1404
77,0499	87,0779	92,0724	88,9149
77,7474	86,8540	90,7843	85,3659



data analysis

calculate & report:

$$L_W(\lambda)$$

$$E_D(o^+, \lambda), E_S(\lambda)$$

$$K_D(\lambda), z_{90}(\lambda) \text{ [Mueller 2000; } E_D(z_{90}) = E_D(o^-) e^{-1} \text{]}$$

$$K_{PAR}, z_{PAR}(37,10,1\%) \text{ [Morel et al. 2007]}$$

regression statistics [incl. near-surface $K_D(\lambda)$ & $K_{LU}(\lambda)$]

processing flags

processing notes, extrapolation intervals, & statistics logged

output written to SeaBASS-style file (usually 1 file per cruise)

~30% (\pm 20%) data files fail various exclusion criteria [TBD]

replicates remain & are addressed elsewhere

YOYO: replicate cast reduction software

eabass.dorr

b01_biome.env.all

Window: 3600

Define stations

Stations: 1

Plot station

Compare Es

View locations

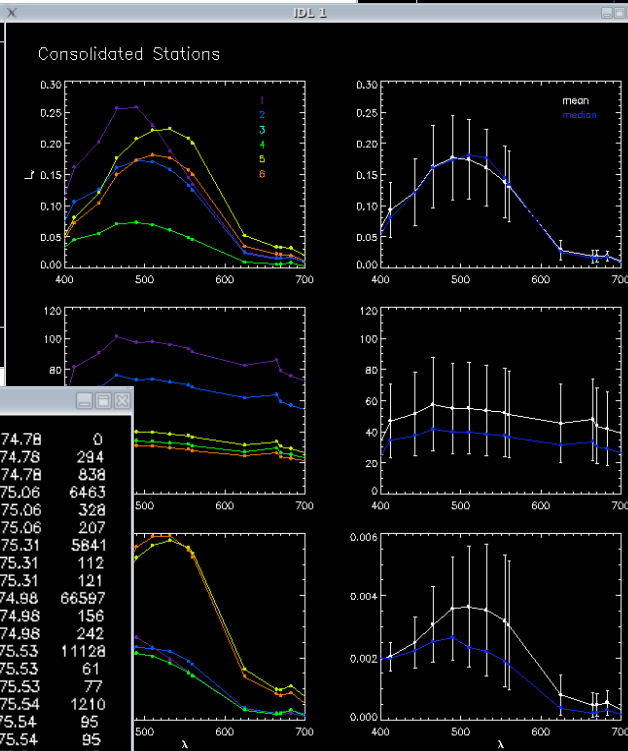
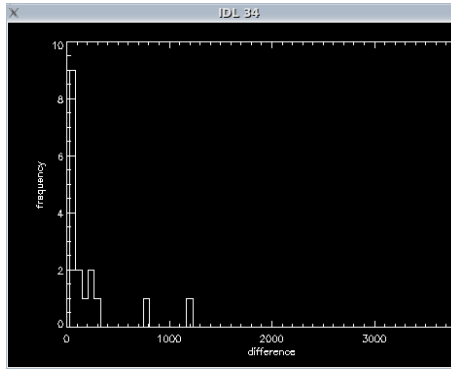
Map locations

Plot all data

Es Es

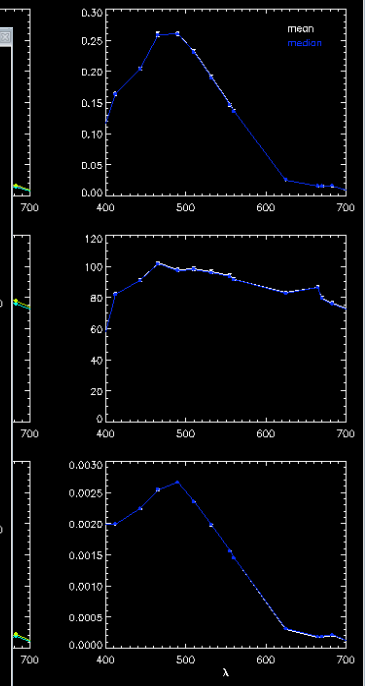
Consolidate

QUIT



IDL 33

1	2005	3	31	15	58	19	36.85	-74.78	0
1	2005	3	31	16	3	13	36.85	-74.78	294
1	2005	3	31	16	17	11	36.85	-74.78	838
2	2005	3	31	18	4	54	36.93	-75.06	6463
2	2005	3	31	18	10	22	36.93	-75.06	328
2	2005	3	31	18	13	49	36.93	-75.06	207
3	2005	3	31	19	51	10	36.99	-75.31	5841
3	2005	3	31	19	53	2	36.99	-75.31	112
3	2005	3	31	19	55	3	36.99	-75.31	121
4	2005	4	1	14	25	0	37.35	-74.98	66597
4	2005	4	1	14	27	36	37.35	-74.98	156
4	2005	4	1	14	31	38	37.35	-74.98	242
5	2005	4	1	17	37	6	37.47	-75.53	11128
5	2005	4	1	17	38	7	37.47	-75.53	61
5	2005	4	1	17	39	24	37.47	-75.53	77
5	2005	4	1	17	59	34	37.47	-75.54	1210
5	2005	4	1	18	1	9	37.47	-75.54	95
5	2005	4	1	18	2	44	37.47	-75.54	95
5	2005	4	1	18	4	19	37.47	-75.54	95
6	2005	4	1	20	55	15	37.78	-75.27	10258
6	2005	4	1	20	56	50	37.78	-75.27	95
6	2005	4	1	20	58	34	37.78	-75.27	104
6	2005	4	1	21	0	0	37.78	-75.27	86



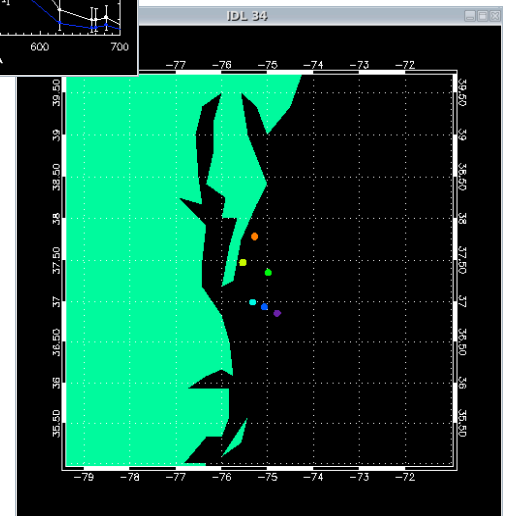
YOYO <@seabass.domain.sdps> <2>

Consolidate stations

1 (3): 1 3 (3): NA 5 (7): 5 6 (4): median

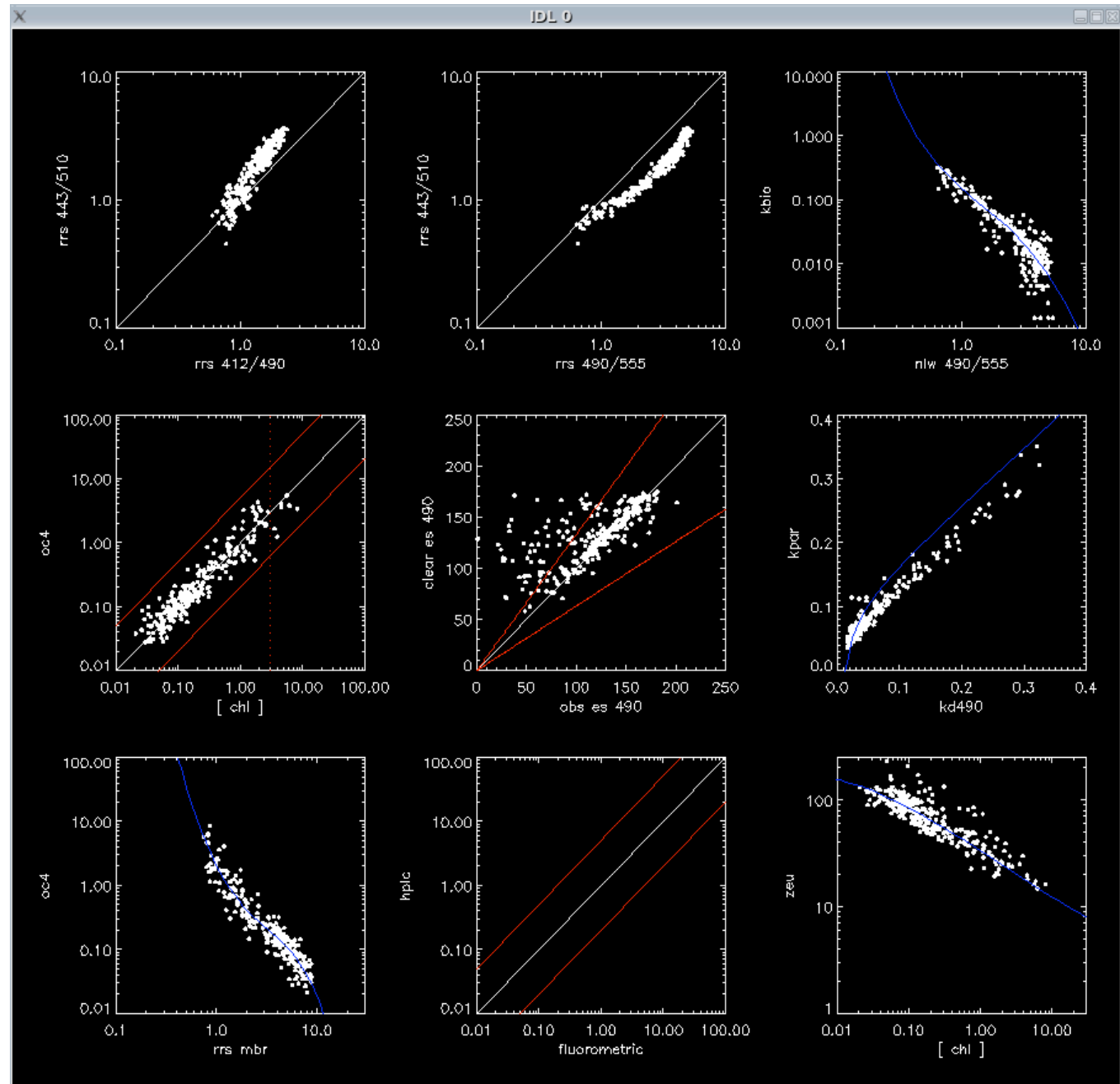
2 (3): 2 4 (3): mean

CANCEL PLOT REVERT ACCEPT



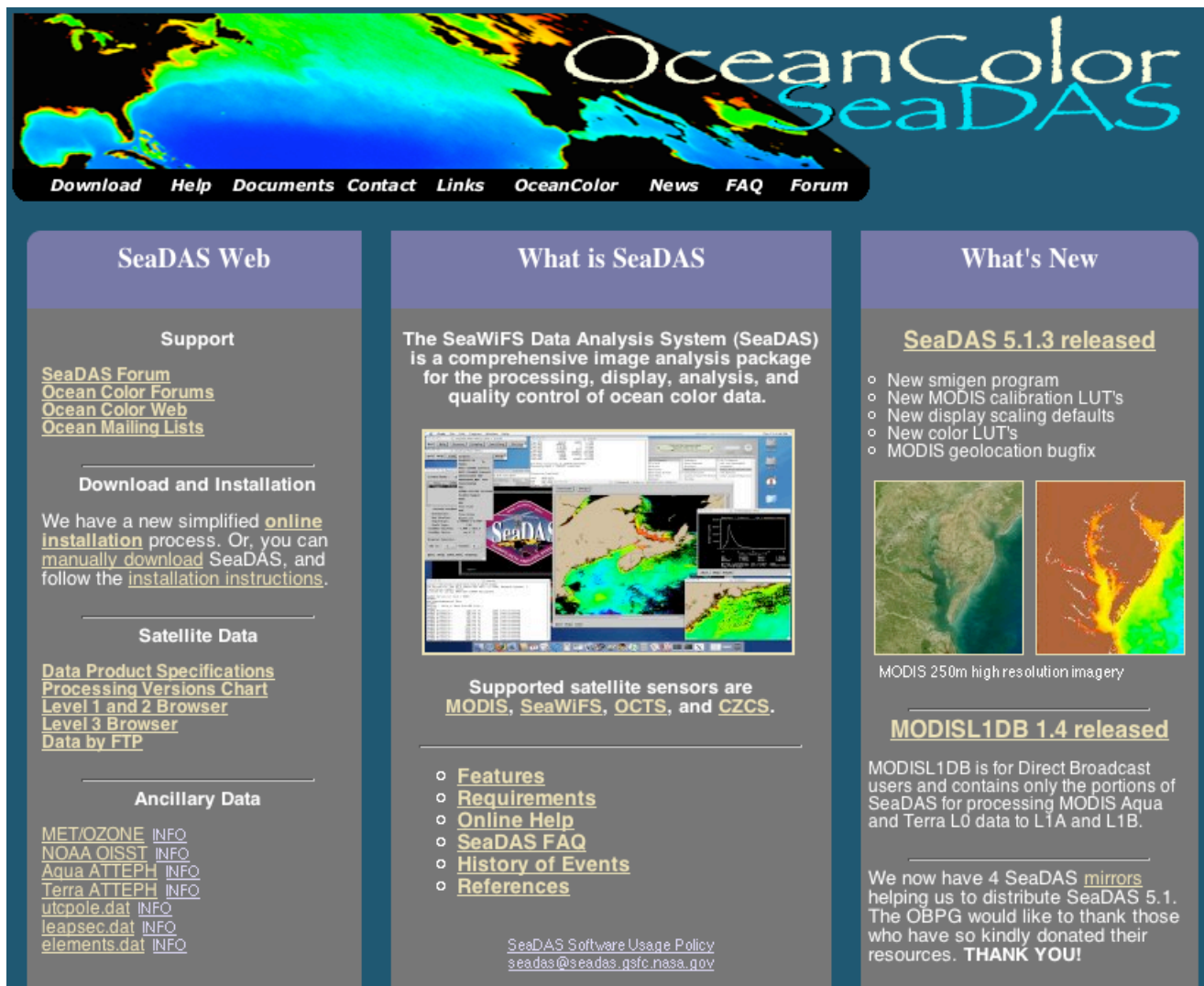
evaluation at
the cruise level:

AMT 1 - 8



SeaDAS

many of these capabilities will be included in future releases of the **SeaWiFS Data Analysis System (SeaDAS)**



OceanColor SeaDAS

[Download](#) [Help](#) [Documents](#) [Contact](#) [Links](#) [OceanColor](#) [News](#) [FAQ](#) [Forum](#)

SeaDAS Web

Support

- [SeaDAS Forum](#)
- [Ocean Color Forums](#)
- [Ocean Color Web](#)
- [Ocean Mailing Lists](#)

Download and Installation

We have a new simplified [online installation](#) process. Or, you can [manually download](#) SeaDAS, and follow the [installation instructions](#).

Satellite Data

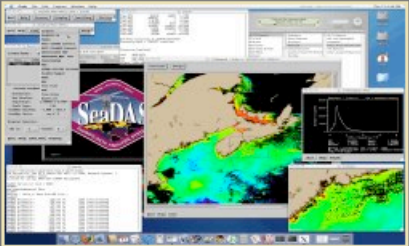
- [Data Product Specifications](#)
- [Processing Versions Chart](#)
- [Level 1 and 2 Browser](#)
- [Level 3 Browser](#)
- [Data by FTP](#)

Ancillary Data

- [MET/OZONE](#) [INFO](#)
- [NOAA OISST](#) [INFO](#)
- [Aqua ATTEPH](#) [INFO](#)
- [Terra ATTEPH](#) [INFO](#)
- [utcpole.dat](#) [INFO](#)
- [leapsec.dat](#) [INFO](#)
- [elements.dat](#) [INFO](#)

What is SeaDAS

The SeaWiFS Data Analysis System (SeaDAS) is a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.



Supported satellite sensors are MODIS, SeaWiFS, OCTS, and CZCS.


- [Features](#)
- [Requirements](#)
- [Online Help](#)
- [SeaDAS FAQ](#)
- [History of Events](#)
- [References](#)

[SeaDAS Software Usage Policy](#)
seadas@seadas.gsfc.nasa.gov

What's New

SeaDAS 5.1.3 released

- New smigen program
- New MODIS calibration LUT's
- New display scaling defaults
- New color LUT's
- MODIS geolocation bugfix



MODIS 250m high resolution imagery

MODISL1DB 1.4 released

MODISL1DB is for Direct Broadcast users and contains only the portions of SeaDAS for processing MODIS Aqua and Terra L0 data to L1A and L1B.

We now have 4 SeaDAS [mirrors](#) helping us to distribute SeaDAS 5.1. The OBPB would like to thank those who have so kindly donated their resources. **THANK YOU!**

1. *in situ* data are important for ocean color cal/val

- vicarious calibration
- data product validation
- algorithm development

2. lessons learned from maintaining SeaBASS

- overview & data policies
- data collection
- the centralized archive
- data analysis

thank you!

vicarious calibration

why do we need a vicarious calibration?

because uncertainties remain after direct calibration

MODIS absolute radiometric accuracy

reflective solar bands (0.41–2.1 μm): $\pm 2\%$ in reflectance and $\pm 5\%$ in radiance

MODIS relative accuracy over time

reflective solar bands (0.41–2.1 μm): $\pm 0.2\%$ in reflectance

alternative *in situ* data for vicarious calibration

preliminary analysis using alternative *in situ* data sources for vicarious calibration

	n	412	443	490	510	555	670
MOBY	32	1.0360	1.0126	0.9910	0.9956	0.9939	0.9627
SSRM	28	1.0395 (0.34)	1.0108 (-0.18)	0.9883 (-0.27)	0.9864 (-0.92)	0.9907 (-0.32)	0.9659 (0.33)
SeaPRISM	8	1.0487 (1.23)	1.0163 (0.37)	1.0013 (1.04)	1.0198 (2.43)	1.0068 (1.30)	0.9838 (2.19)
BOUSSOLE	18	1.0008 (-3.40)	1.0149 (0.23)	0.9968 (0.59)	1.0010 (0.54)	0.9998 (0.59)	0.9623 (-0.04)

Table 2. SeaWiFS vicarious gains for MOBY and the three alternate L_{wn} sources. Relative differences (%) in parentheses. Gains with the lowest absolute differences are **highlighted in red**. For SeaPRISM, **$g(490)$ and $g(510)$ were calculated using $L_{wn}(501)$** , which impacts its C_a validation results in Figure 4.

S.W. Bailey, S.B. Hooker D. Antoine, B.A. Franz, and P.J. Werdell, "Sources and assumptions for the vicarious calibration of ocean color satellite observations," Applied Optics 47, 4186-4203 (2008).