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

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21 January 2010 @ SAC

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

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   - data collection
   - the centralized archive
   - data analysis

vicarious calibration

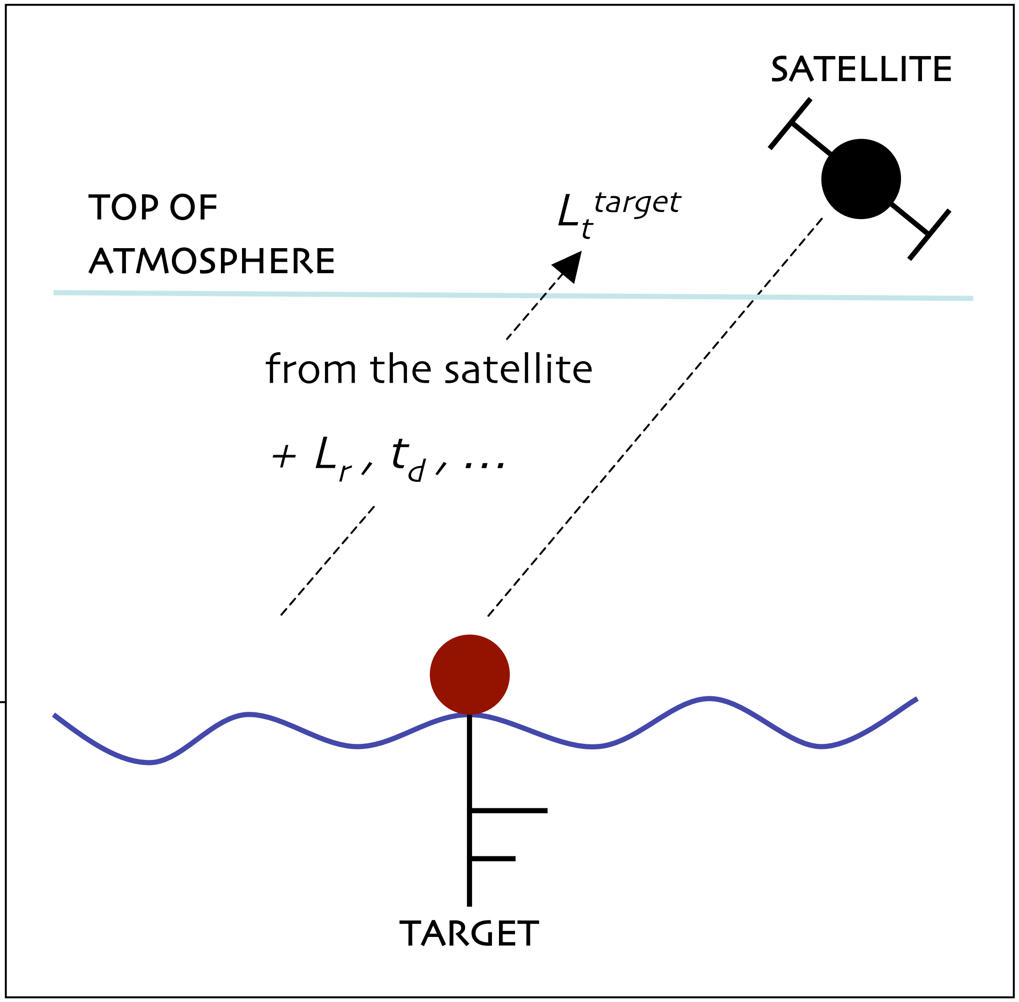
what is vicarious calibration?

<u>spectral on-orbit calibrations</u>

1. instrument calibration
   - e.g., focal plane temperature

2. temporal calibration
   - reference Sun or Moon

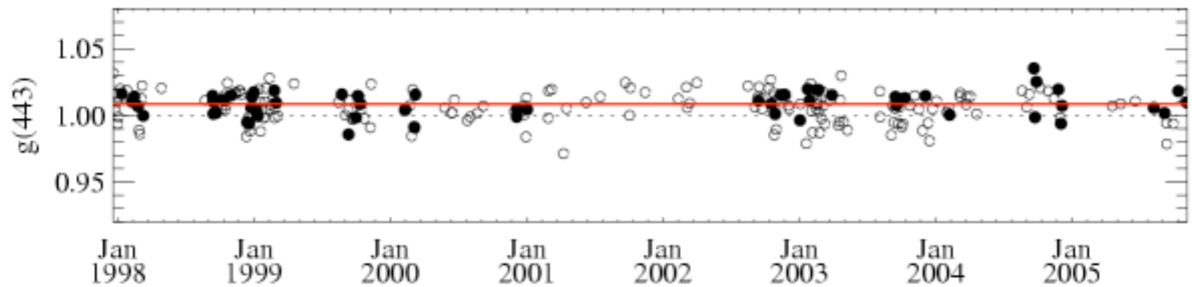
3. absolute (vicarious) calibration
   - reference Earth surface
   - final, single gain adjustment
   - calibration of the combined instrument + algorithm system



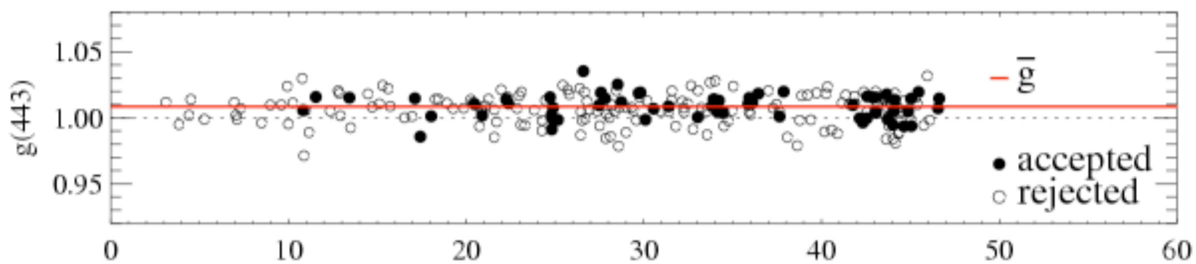
vicarious calibration

a single, spectral radiometric adjustment

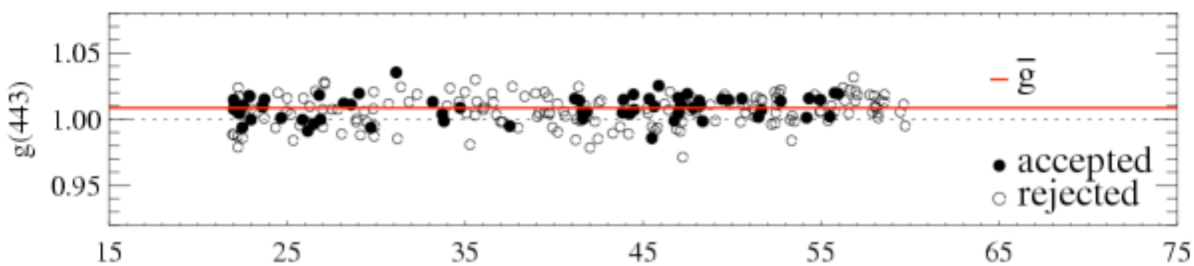
gain vs. time



gain vs. solar zenith angle



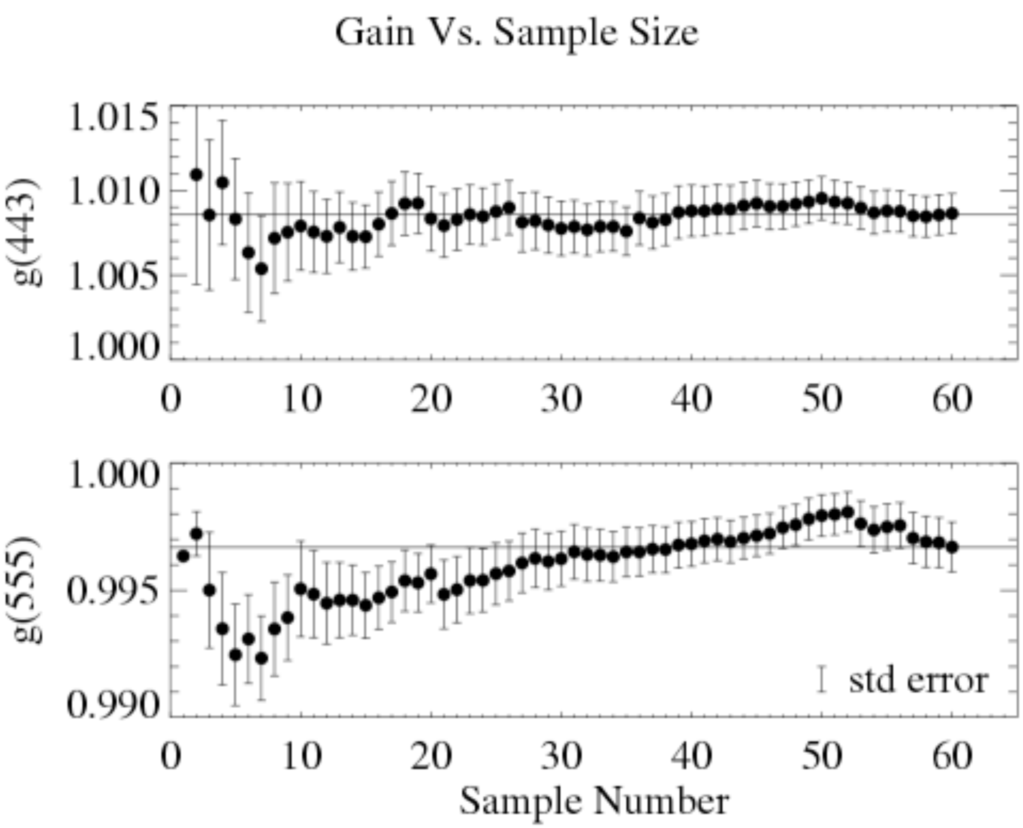
gain vs. satellite zenith angle



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

operational vicarious calibration

MOBY - the Marine Optical BuoY

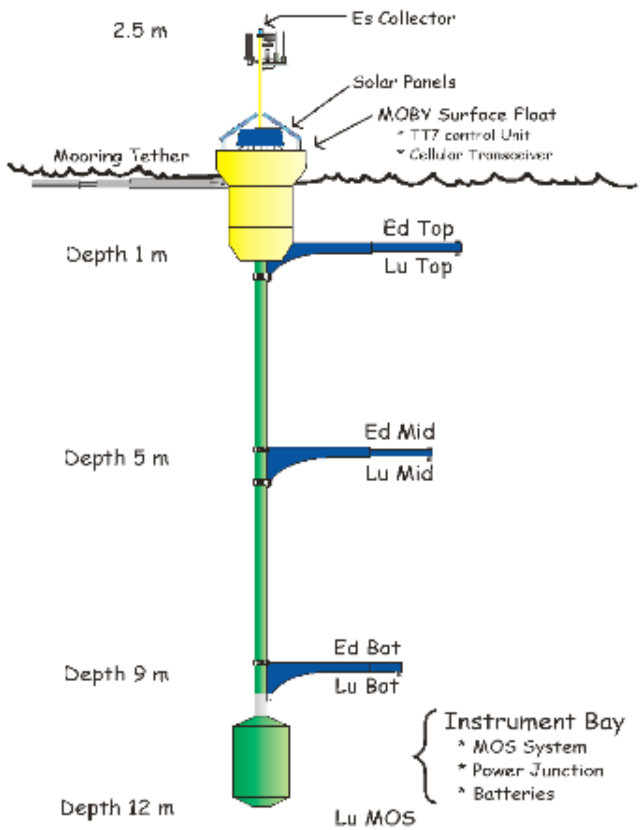


Fig. 1. Schematic diagram of MOBY.

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 $E_s(\lambda)$

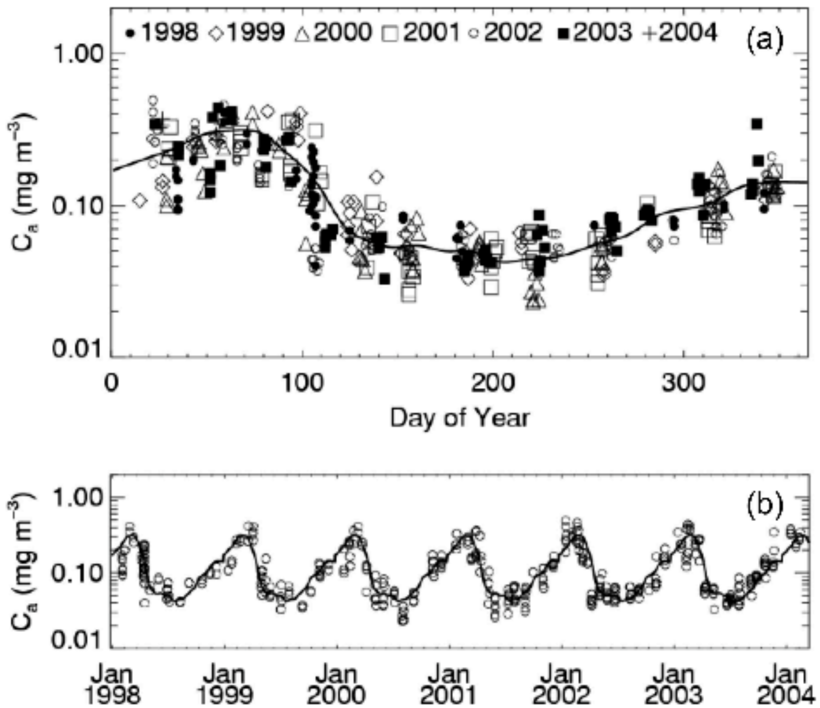
spectral range is 340-955 nm & spectral resolution is 0.6 nm

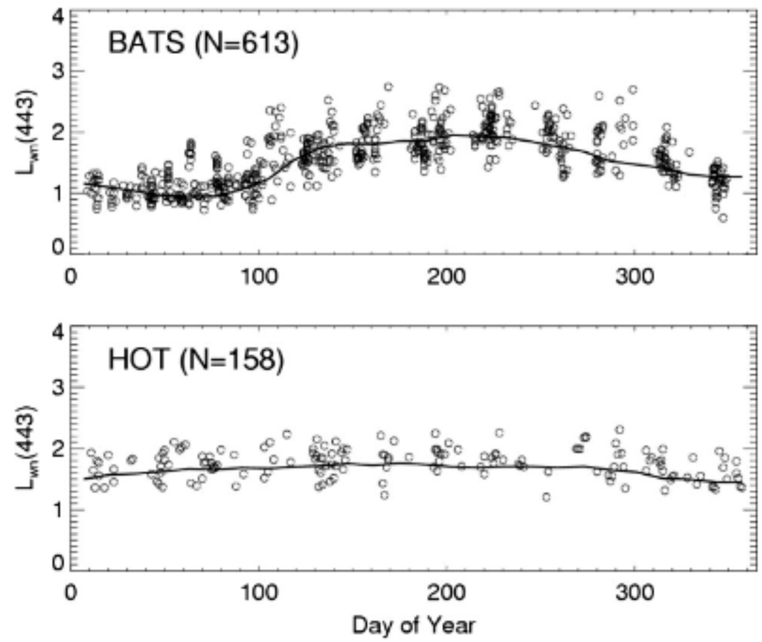
hyperspectral data convolved to specific bandpasses of each satellite

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)

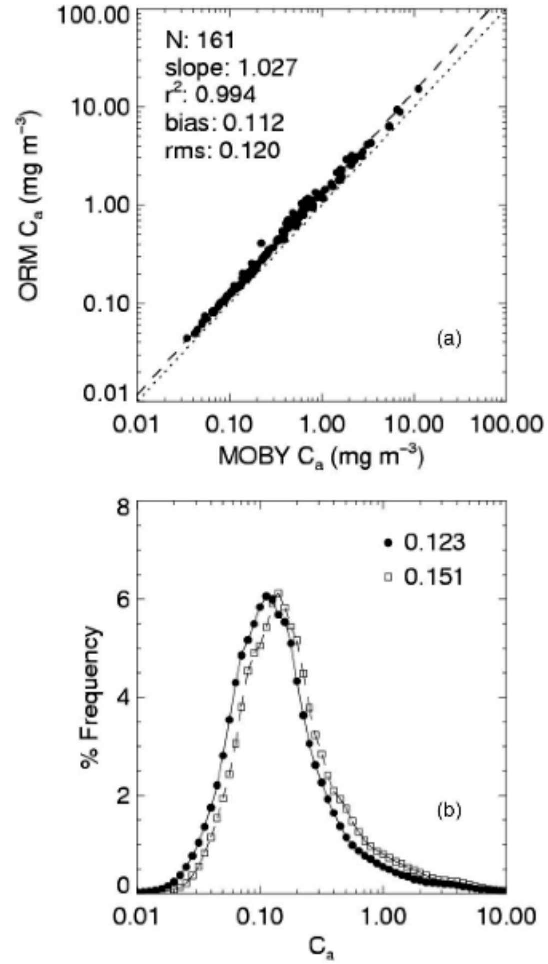
P.J. Werdell, S.W. Bailey, B.A. Franz, A. Morel, and C.R. McClain, "On-orbit vicarious calibration of ocean color sensors using an ocean surface reflectance model," Applied Optics 46, 5649-5666 (2007).

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

[a]Calculated 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

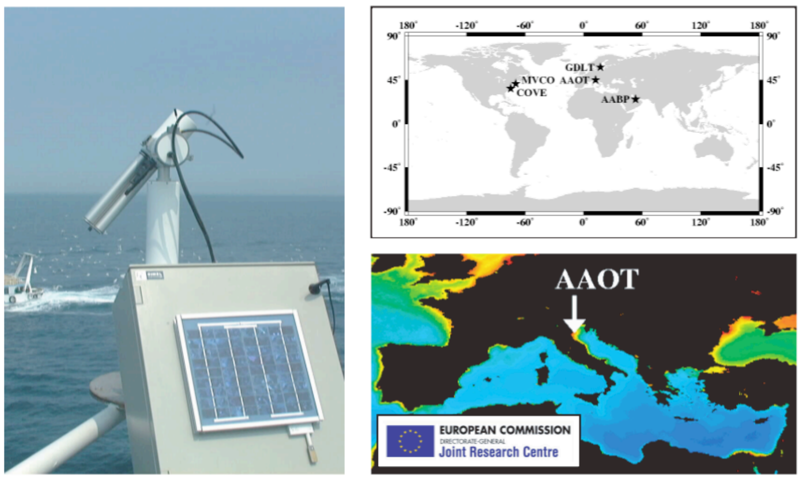


Figure 3. Clockwise from left: a SeaPRISM in operation; locations of the network testing phase AERONET-OC stations (2001 - 2005; see http://aeronot.gsfc.nasa.gov for acronym definitions and an updated list of SeaPRISM stations); and, a detailed view of the location of the AAOT.

BOUSSOLE

Figure 5. Design and location of the BOUSSOLE permanent optical mooring.

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).

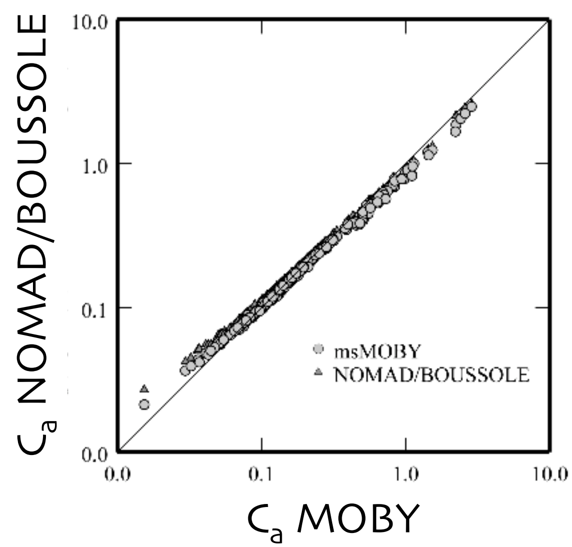
alternative *in situ* data for vicarious calibration

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

[a] Gain 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. [c] The 412 nm data for BOUSSOLE used only 9 points.

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

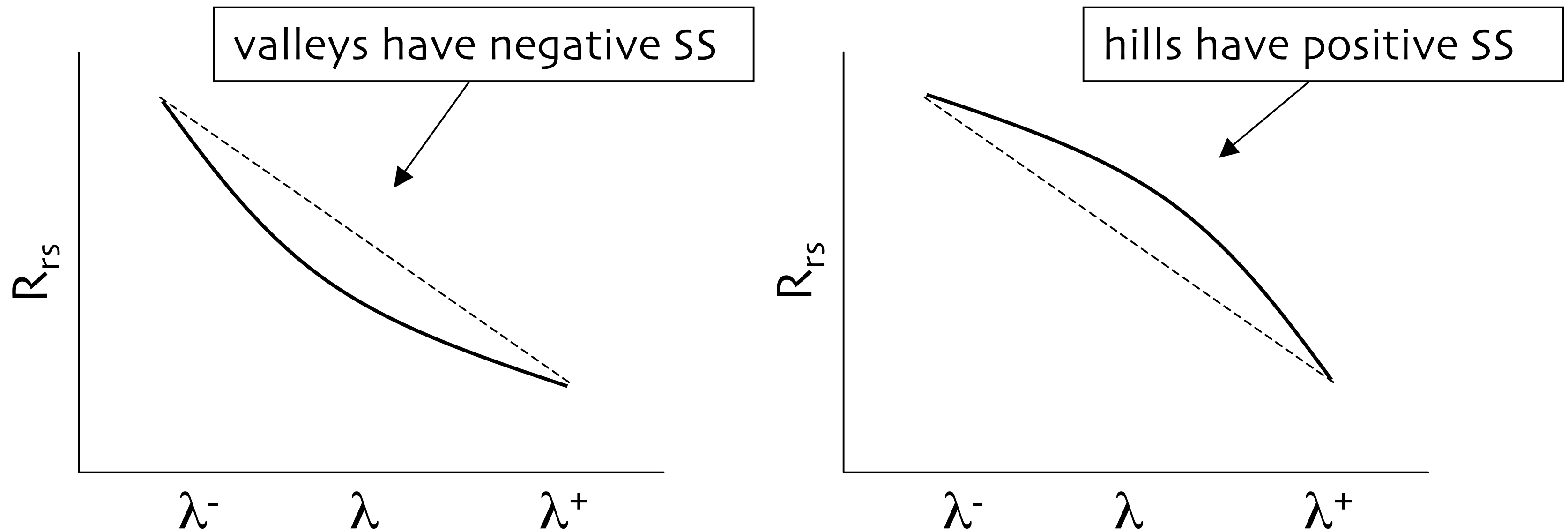


S.W. Bailey, S.B. Hooker D. Antoine, B.A. Franz, and P.J. Werdell, "Sources and assumptions for the vicarious calibration of ocean color satellite observations," Applied Optics 47, 4186-4203 (2008).

tuning vicarious calibration using population statistics

compare spectral shapes of *in situ* & satellite populations

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

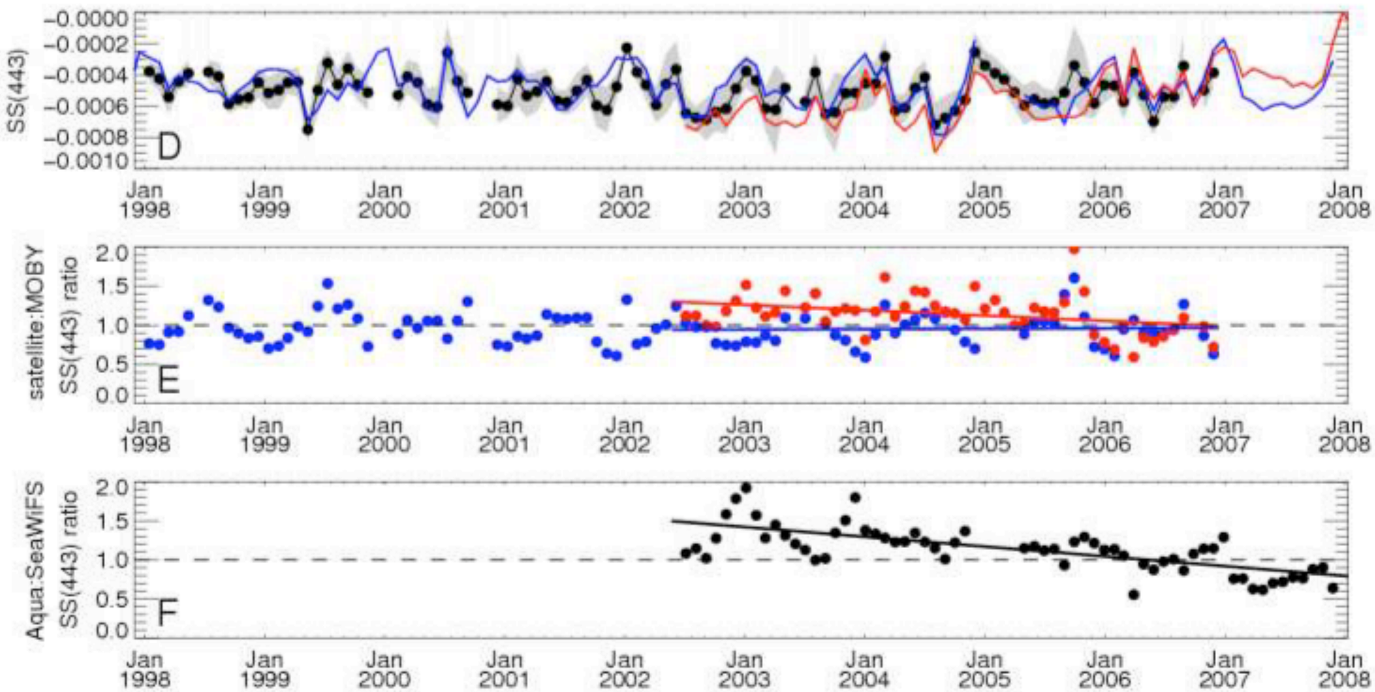


spectral shape @ 443 nm, SS(443), uses $R_{rs}(412)$, $R_{rs}(443)$, & $R_{rs}(490)$

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

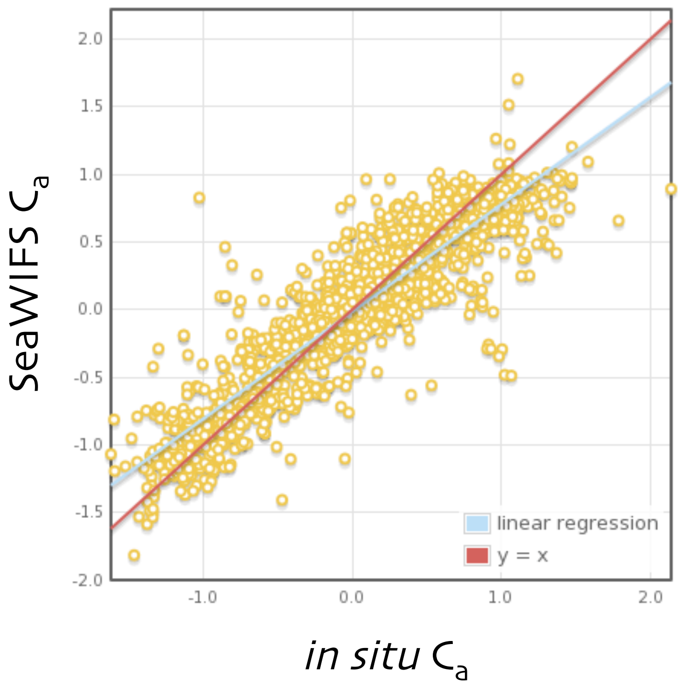
- overview & data policies
- data collection
- the centralized archive
- data analysis

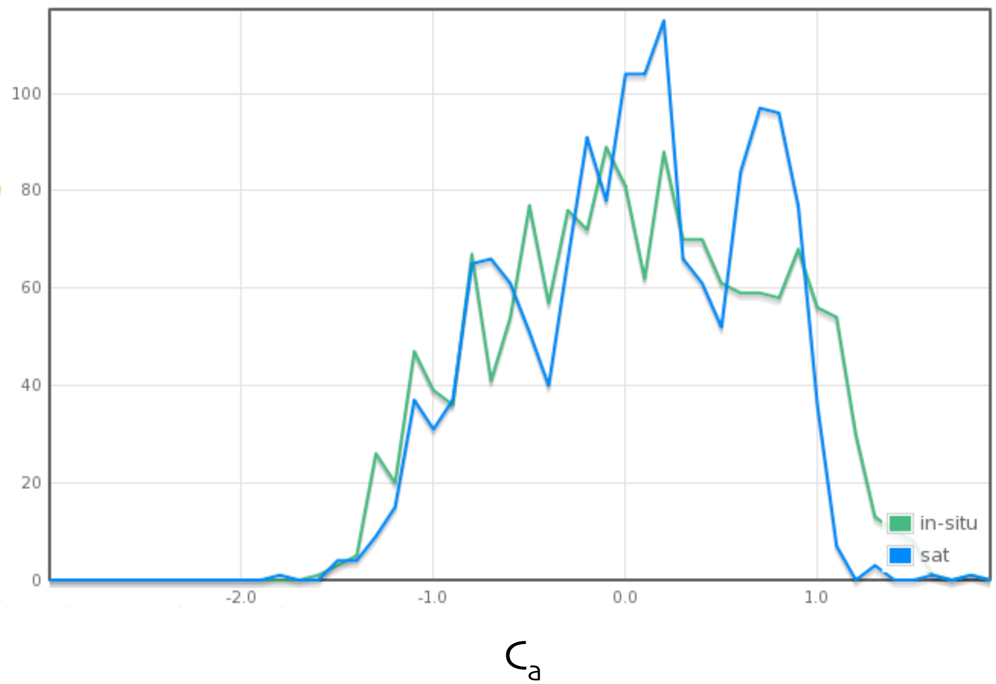
Level-2 match-ups

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

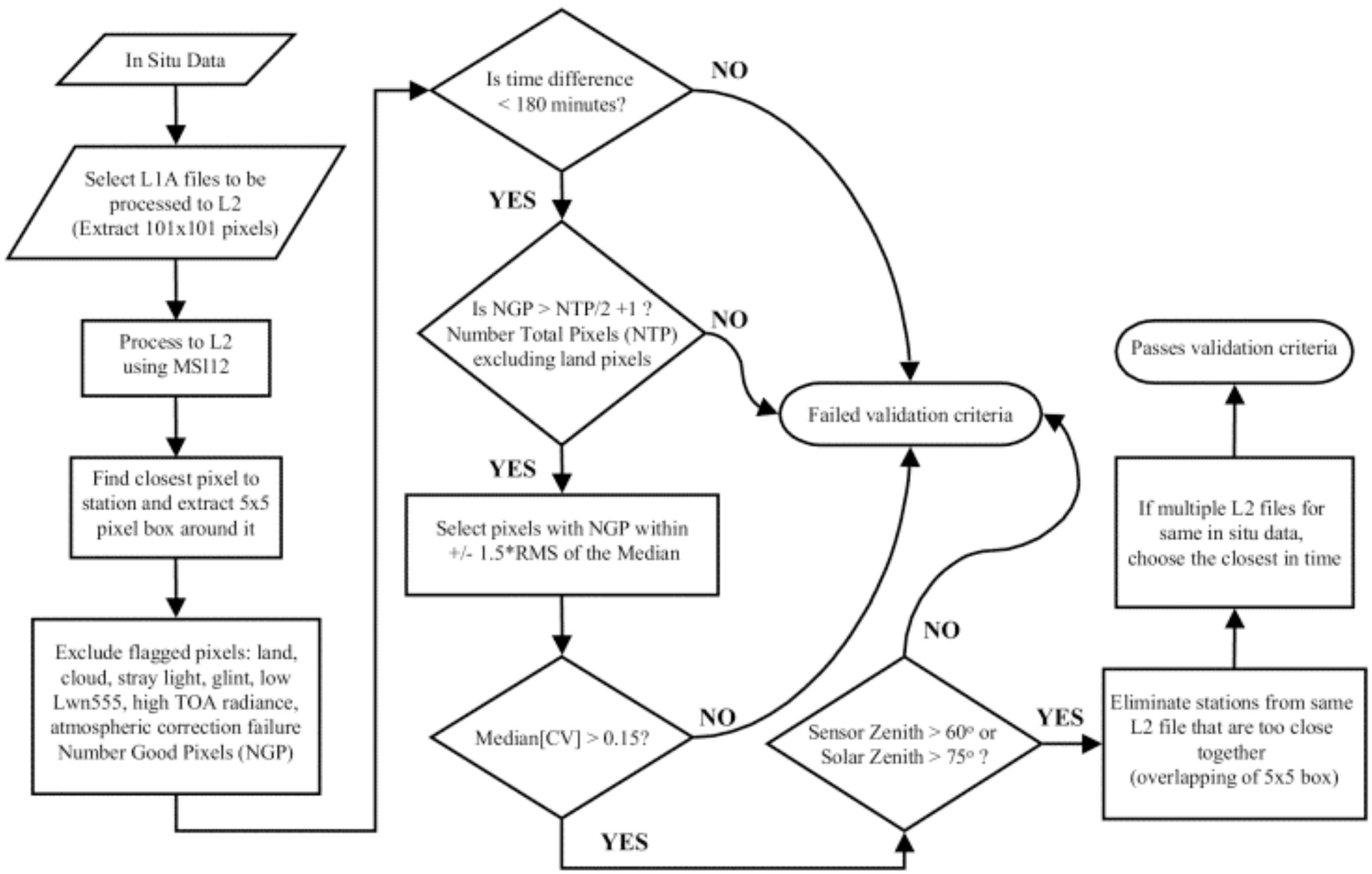




S.W. Bailey and P.J. Werdell, "A multi-sensor approach for the on-orbit validation of ocean color satellite data products," Remote Sensing of Environment 102, 12-23 (2006)

Level-2 match-ups

general flow of match-up process, with exclusion criteria



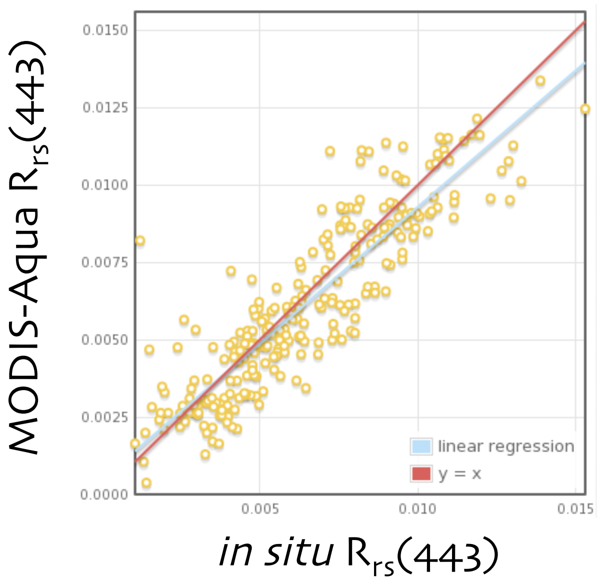
S.W. Bailey and P.J. Werdell, "A multi-sensor approach for the on-orbit validation of ocean color satellite data products," Remote Sensing of Environment 102, 12-23 (2006)

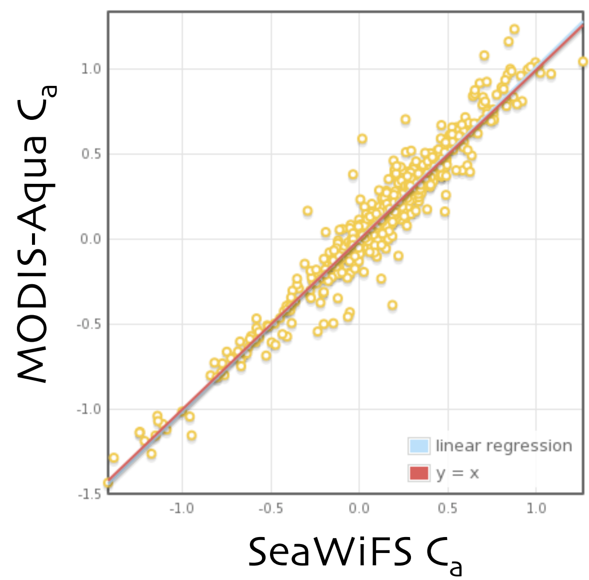
Level-2 match-ups

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



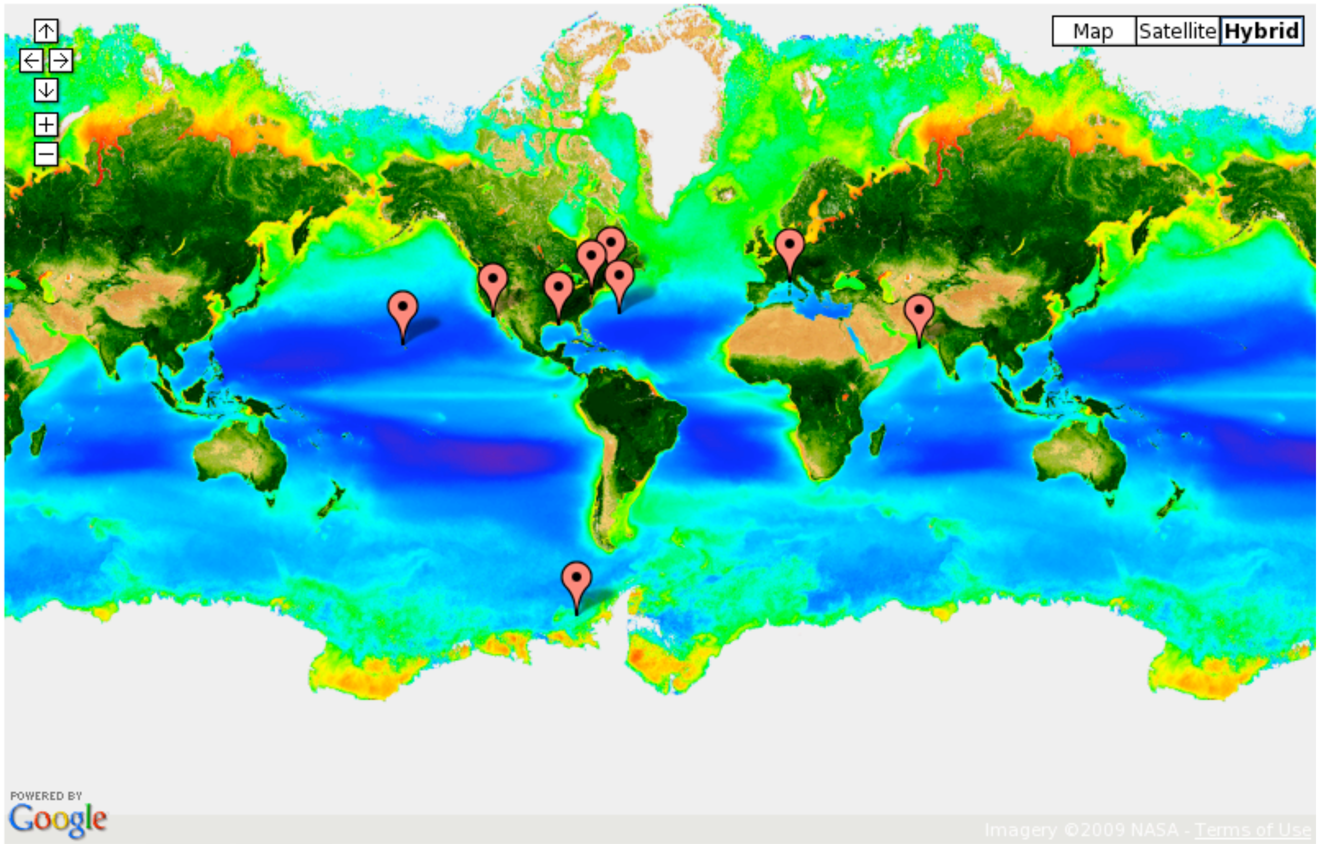


S.W. Bailey and P.J. Werdell, "A multi-sensor approach for the on-orbit validation of ocean color satellite data products," Remote Sensing of Environment 102, 12-23 (2006)

Level-2 time-series analyses

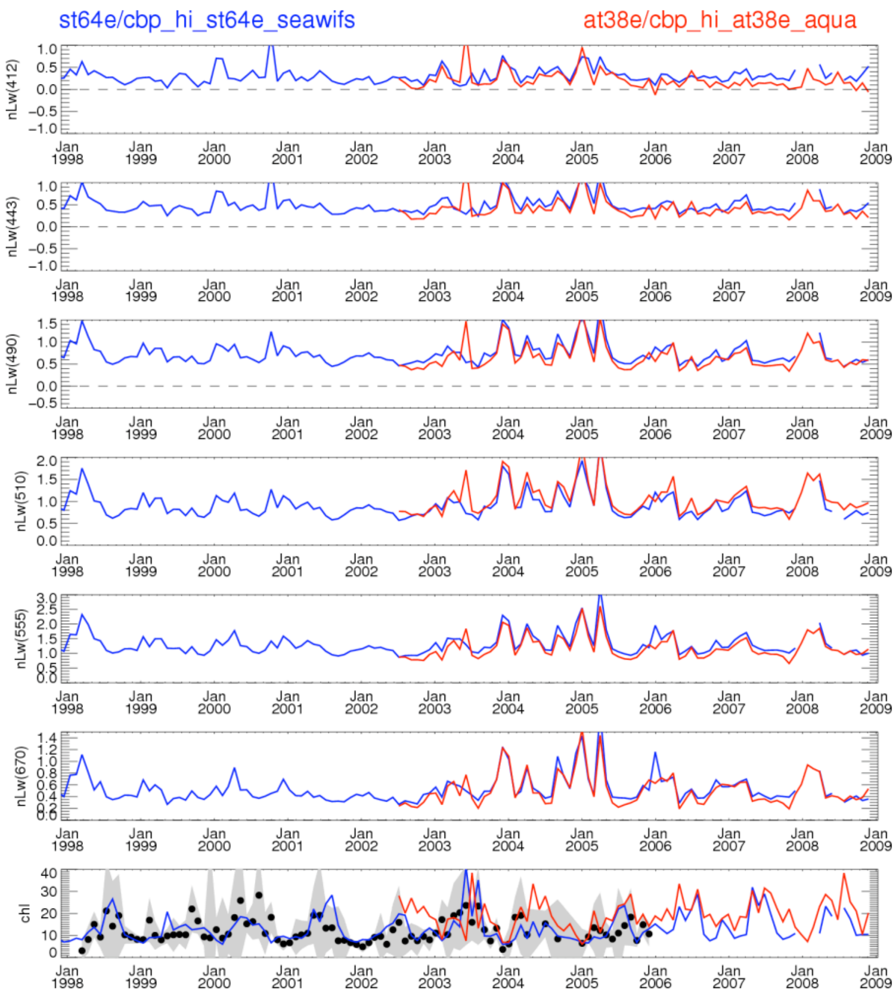
results publicly posted online at:
http://oceancolor.gsfc.nasa.gov/cgi/regions.cgi

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 chorophyll-a in Chesapeake Bay as observed by SeaWiFS and MODIS-Aqua," Remote Sensing of Environment 113, 1319-1330 (2009).

Level-2 time-series analyses

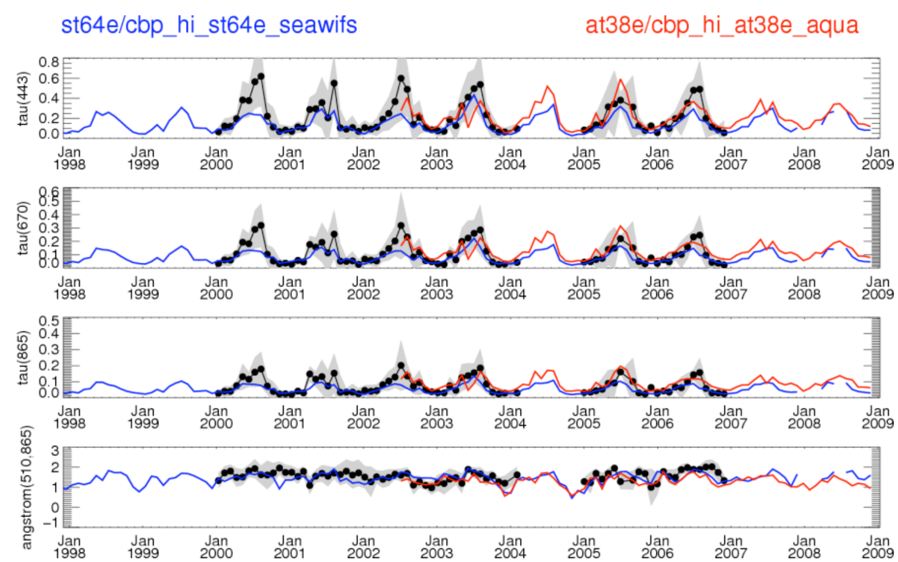


monthly time-series

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

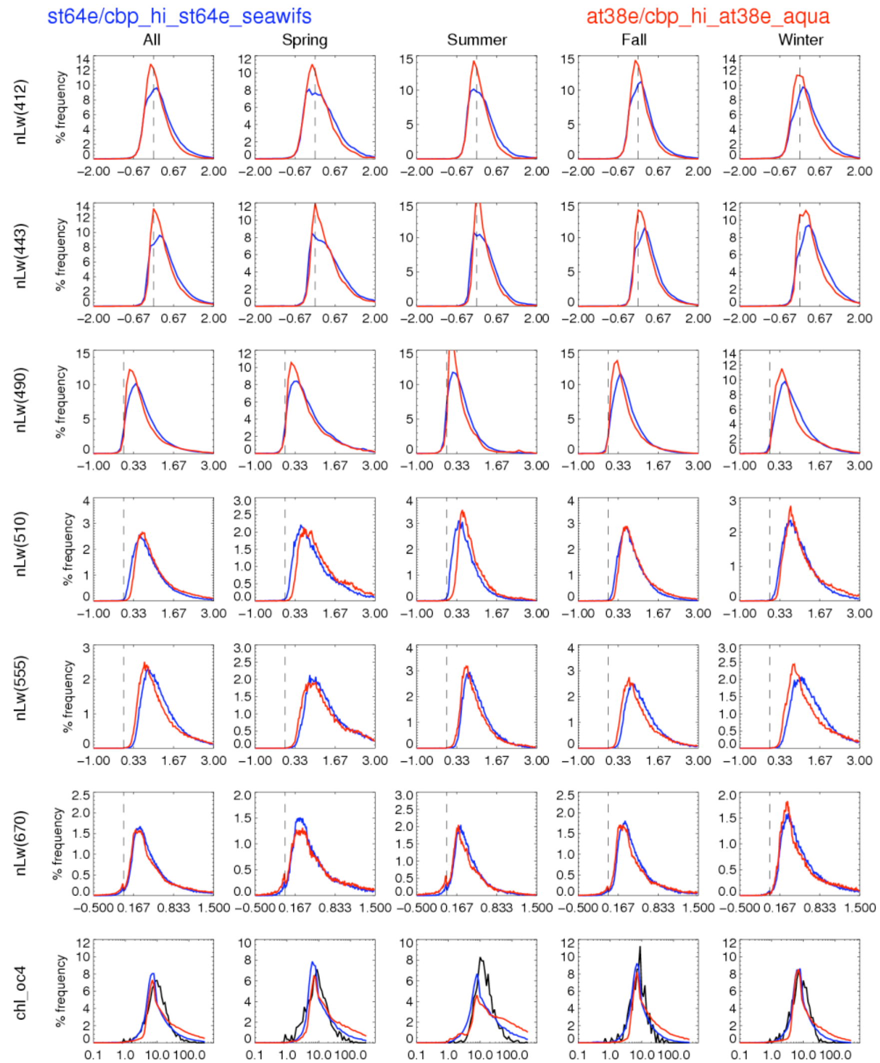
upper third of Chesapeake Bay

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 chorophyll-a in Chesapeake Bay as observed by SeaWiFS and MODIS-Aqua," Remote Sensing of Environment 113, 1319-1330 (2009).

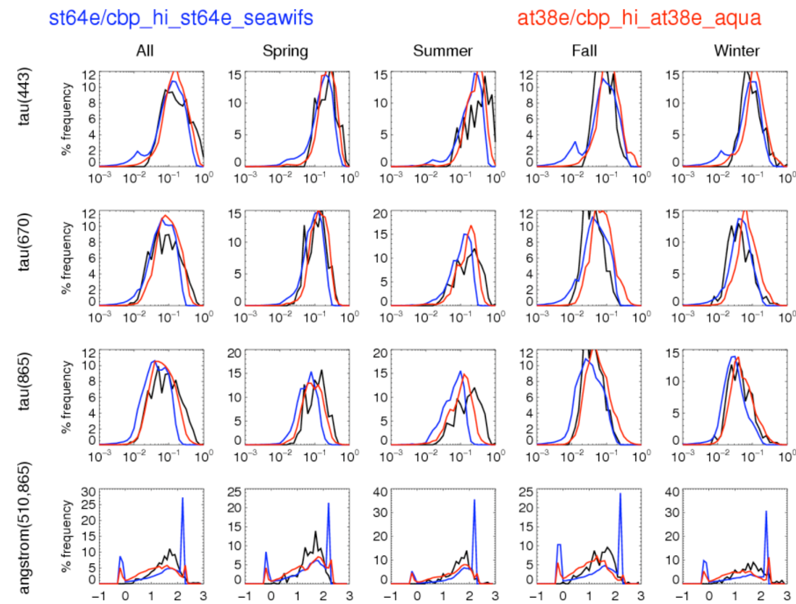
Level-2 time-series analyses



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 chorophyll-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

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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 (0-) values!
lots of replicate data

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

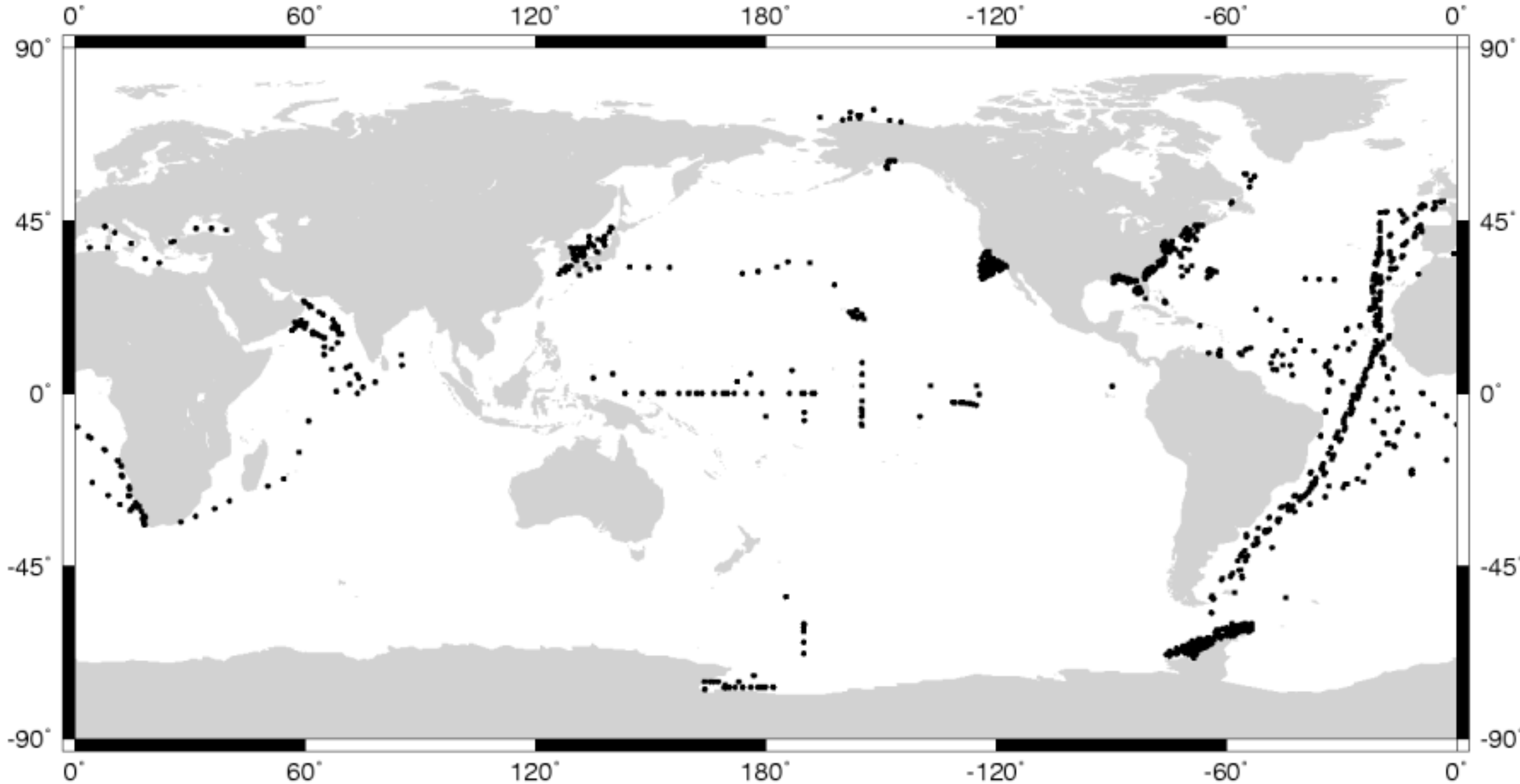
evaluated all SeaBASS radiometry, spectroscopy, pigments, and CTD
estimated surface (0-) values from these data (used for validation!)
identified coincident observations
generated a consolidated, merged data set

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 OBPG, plus POC, TSM, etc. algorithms developed elsewhere

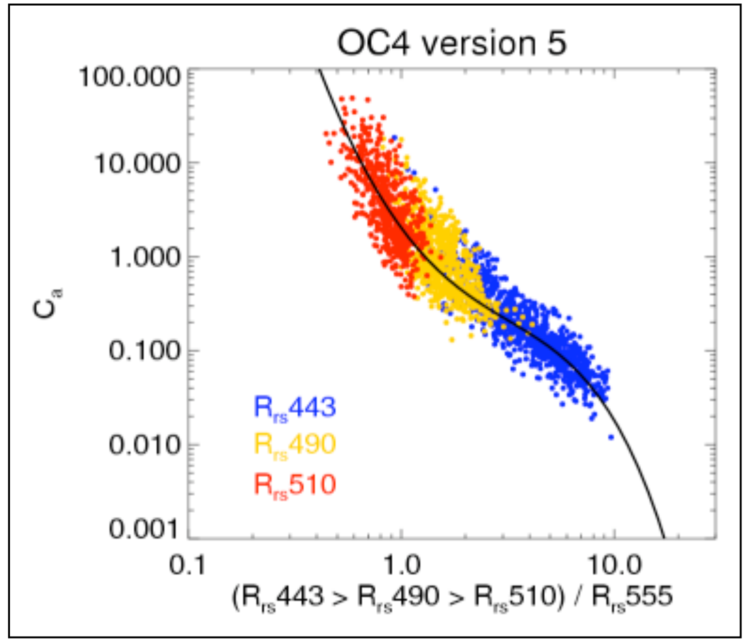


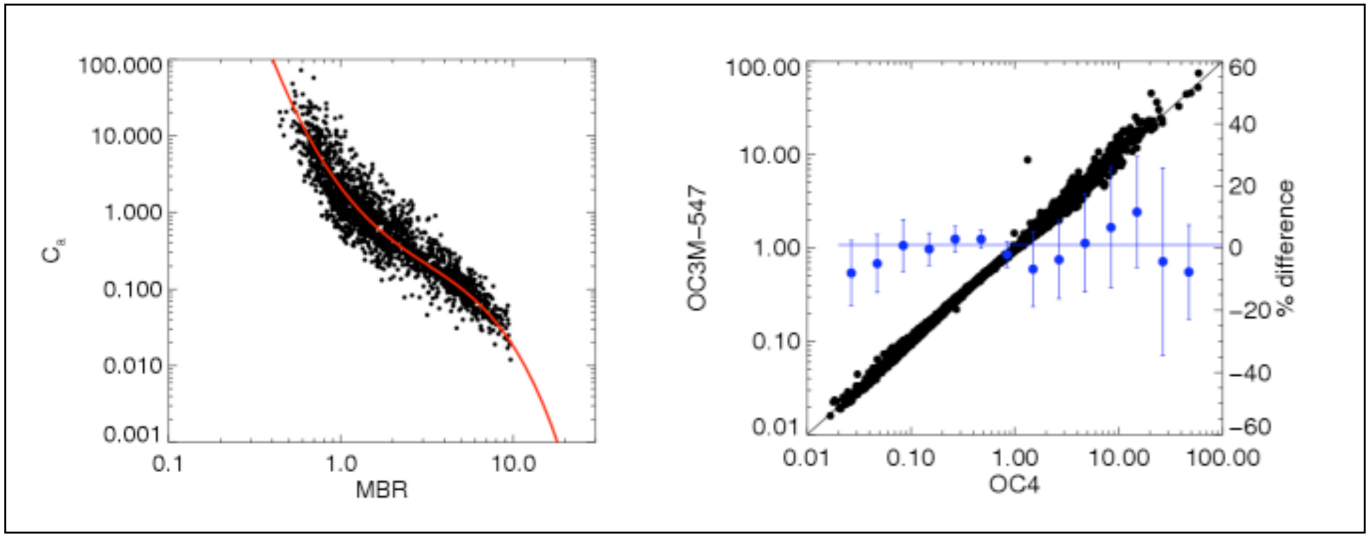
Table 1
Coefficients for the OC version 5 algorithms (O'Reilly, personal communication).

	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

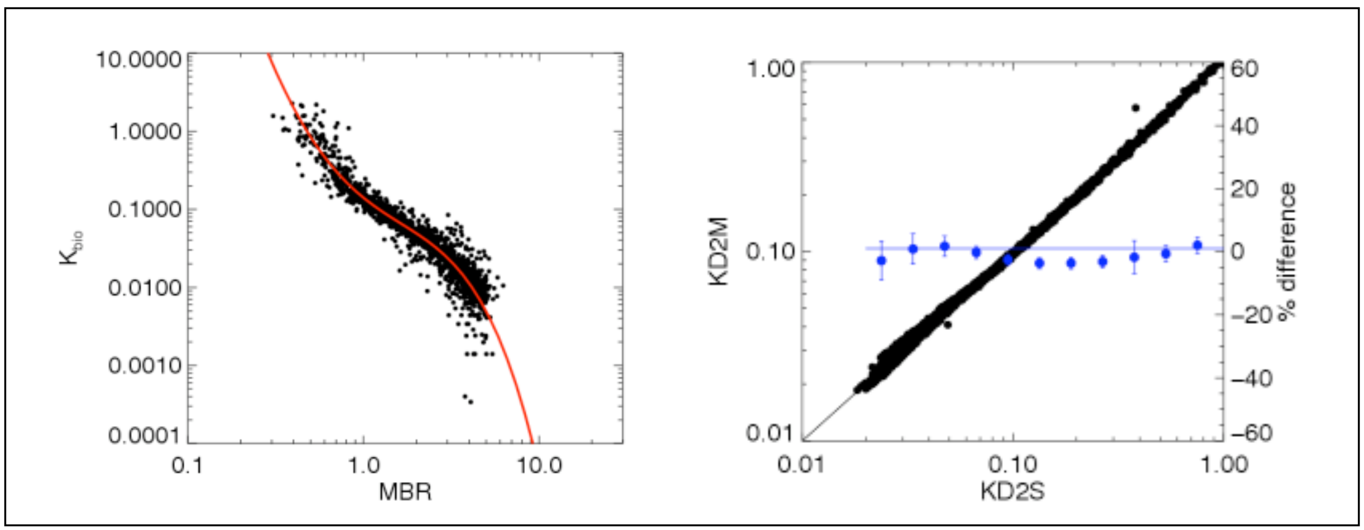
[a] For SeaWiFS.
[b] For MODIS-Aqua.

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 …

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

satellite provides $R_{rs}(\lambda)$

$a(\lambda)$ and $b_b(\lambda)$ are desired products

1

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

2

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

3

Bulk Inversion:

* no predefined shapes
* piece-wise solution: $b_{bp}(\lambda)$, then $a(\lambda)$, via (empirical) $K_d(\lambda)$ via RTE
* ex: LS00

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, LS00, Ciotti, Morel

select r_{rs}[0-] 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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- overview & data policies
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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

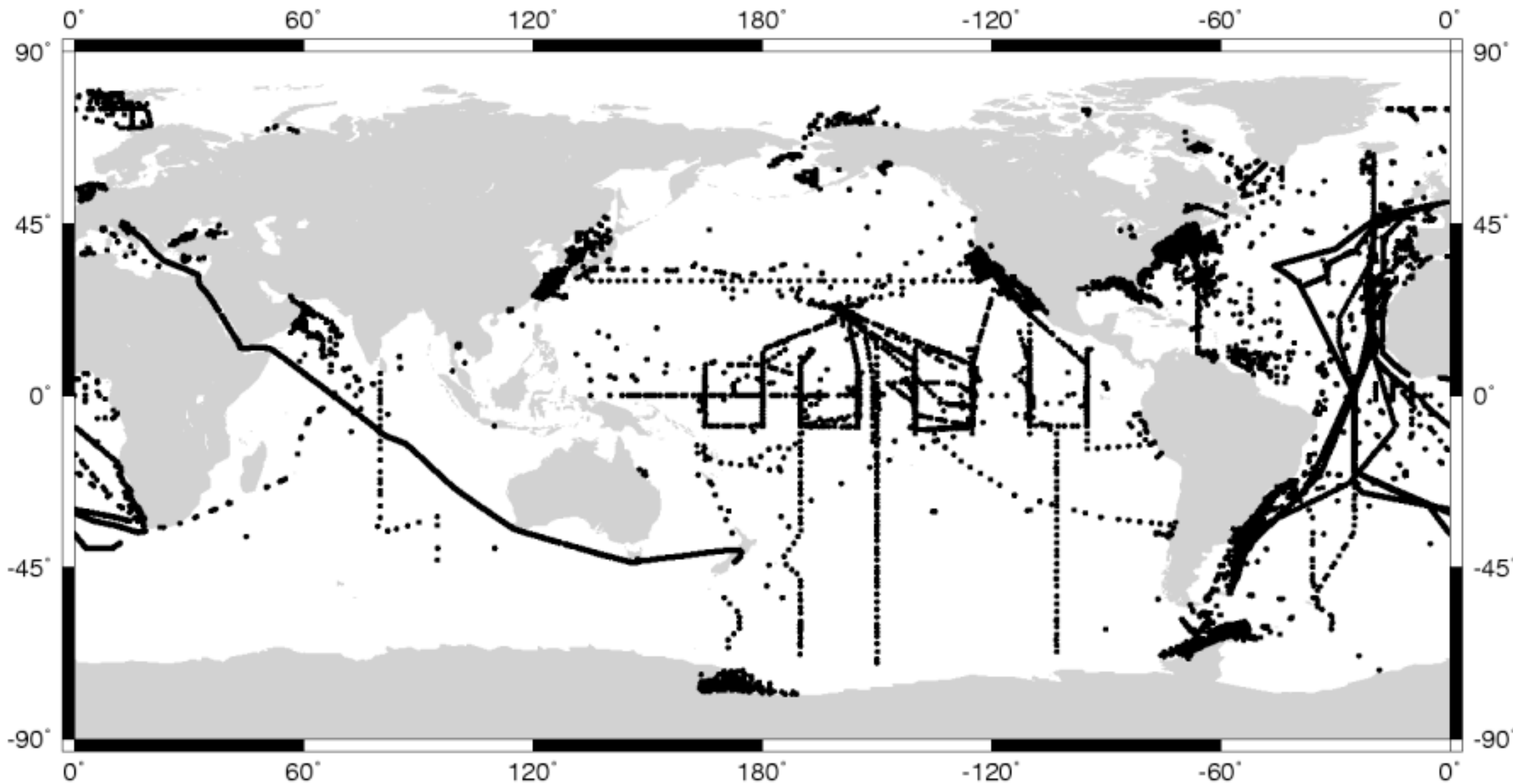
all data are accessible online:

- 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

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

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 chromotography (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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benefits of a centralized archive

consolidated …

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

facilitates …

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

SeaBASS infrastructure

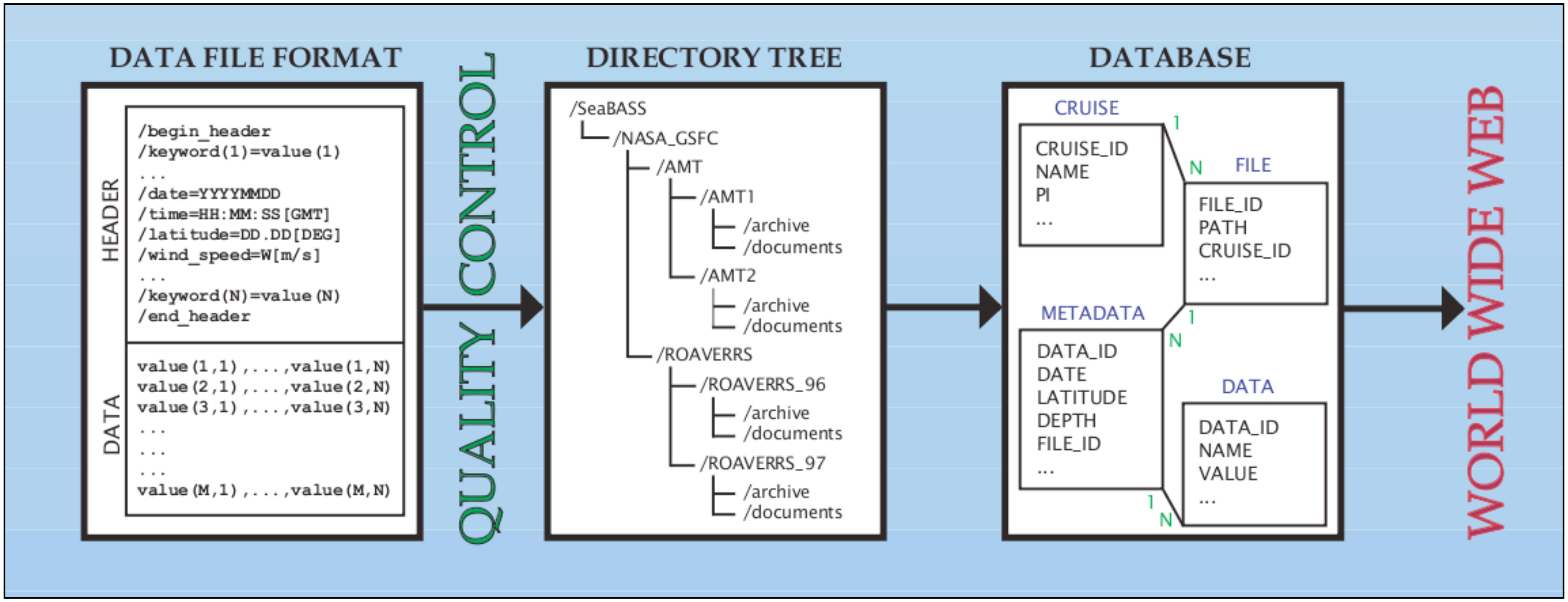
SeaBASS file format:
- ASCII text for platform independence
- matrix of data preceded by predefined metadata headers

```
/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,PHAEO,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,PHAEO,Tpg
/units=hh:mm:ss,m,mg/m^3,mg/m^3,mg/m^3
/end_header
16:01:30        0       2.355   0.785   3.140
16:03:45        5       2.180   1.005   3.185
...
...
```

HEADER
```
/begin_header<cr>
.
.
.
/end_header<cr>
```

DATA
```
value(1,1)<delimiter>value(1,2)<delimiter>value(1,N)<cr>
value(2,1)<delimiter>value(2,2)<delimiter>value(2,N)<cr>
.
.
.
value(M,1)<delimiter>value(M,2)<delimiter>value(M,N)<cr>
```

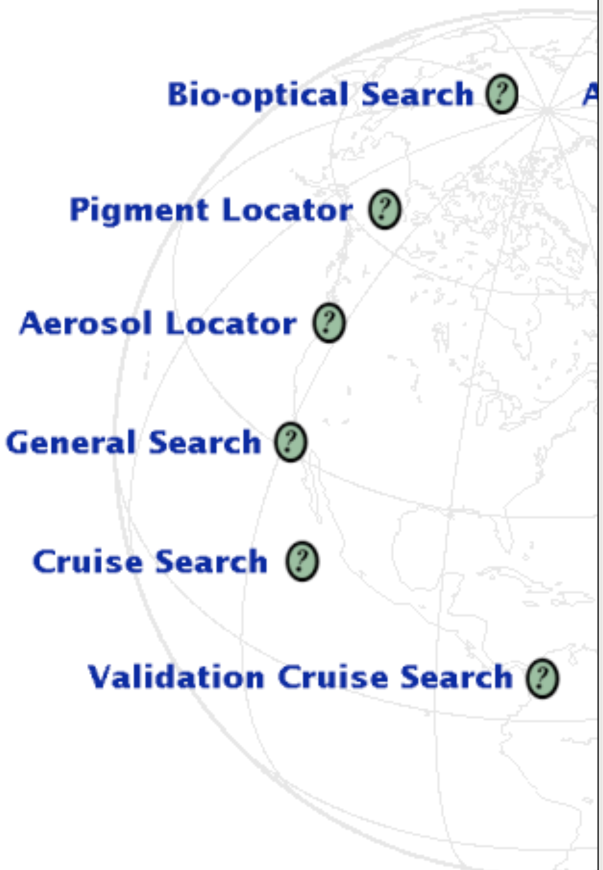
SeaBASS infrastructure

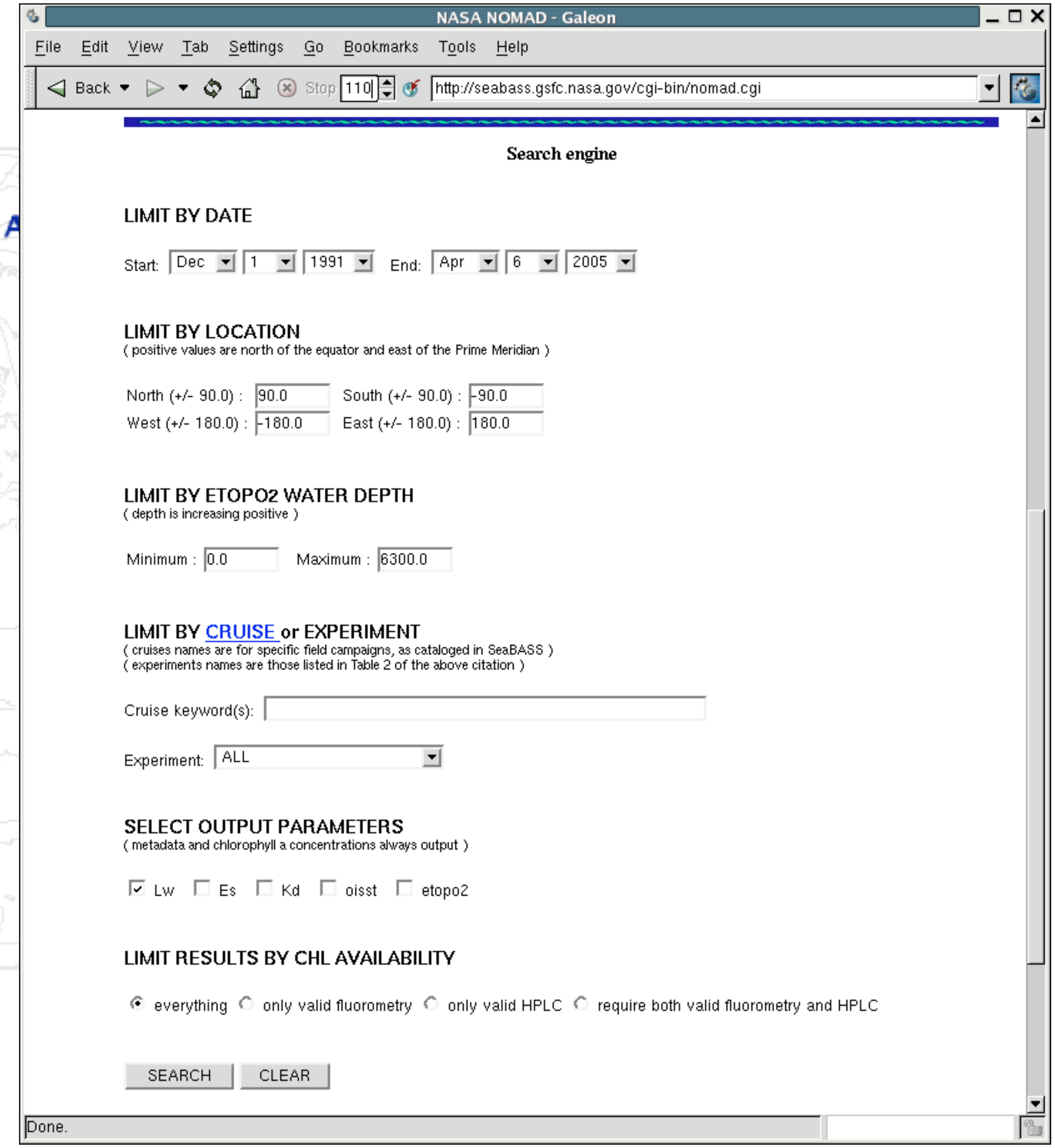


physical storage at NASA Goddard Space Flight Center

relational database management system (MySQL)

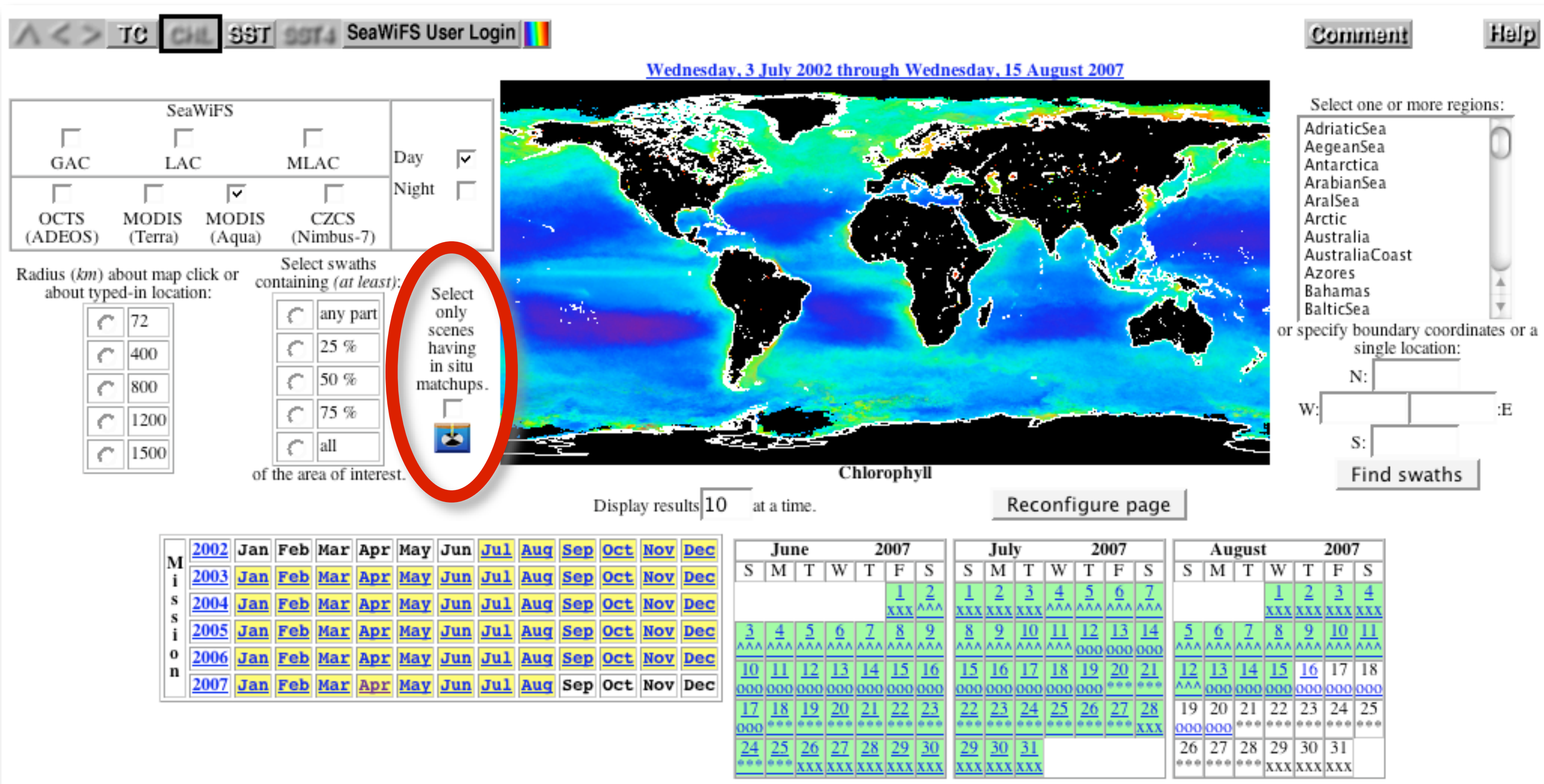
SeaBASS infrastructure





SeaBASS infrastructure

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



SeaBASS infrastructure

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

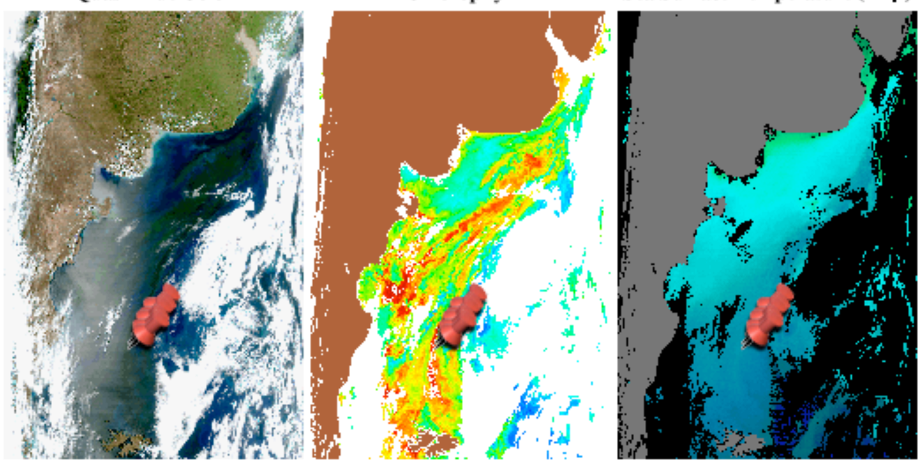
TC CHL SST SST4 SeaWiFS User Login Comment Help

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 bzip2-compressed HDF files.
Documentation on these products can be found HERE.)

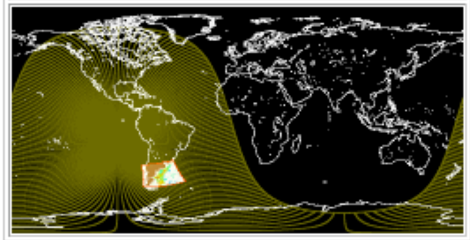
Select this scene

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

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SeaBASS

AOP(λ,z), IOP(λ,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(λ,0^+), IOP(λ, 0^+), & C_a/CTD/bottle(0^+)

no restrictions on coincidence

exclusion criteria applied (×2) / data reduction

calibration quality with protocol adherence

NOMAD

AOP(λ,0^+) + IOP(λ, 0^+) + C_a/CTD/bottle(0^+)

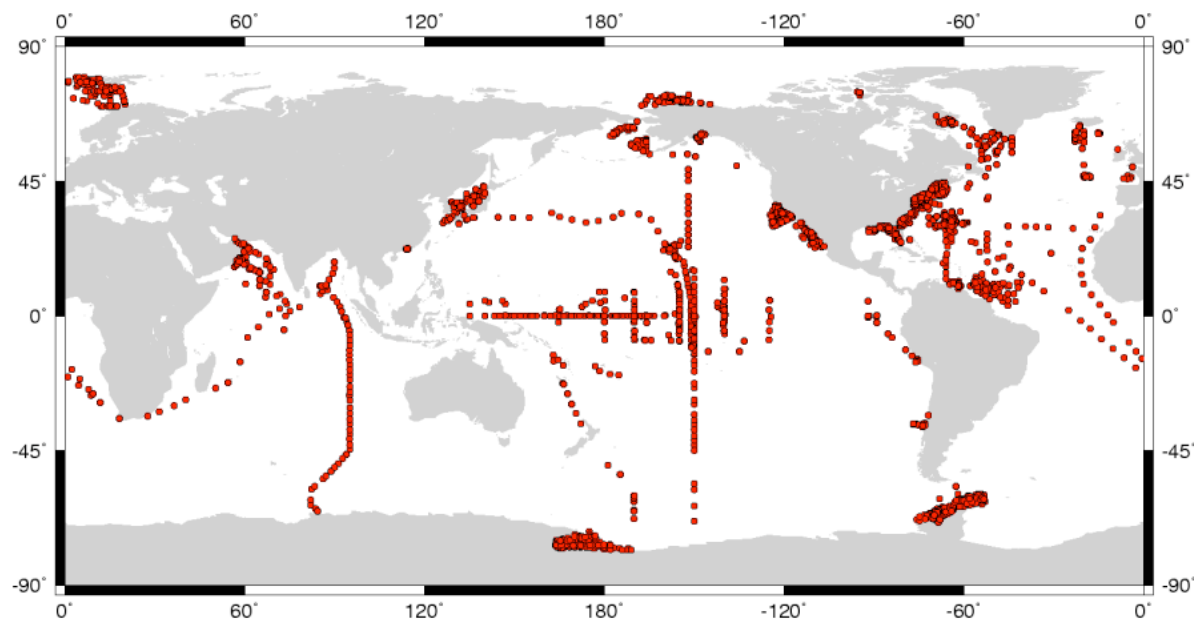
coincidence requirement

data analysis

SeaBASS includes ~12,000 AOP depth profiles …

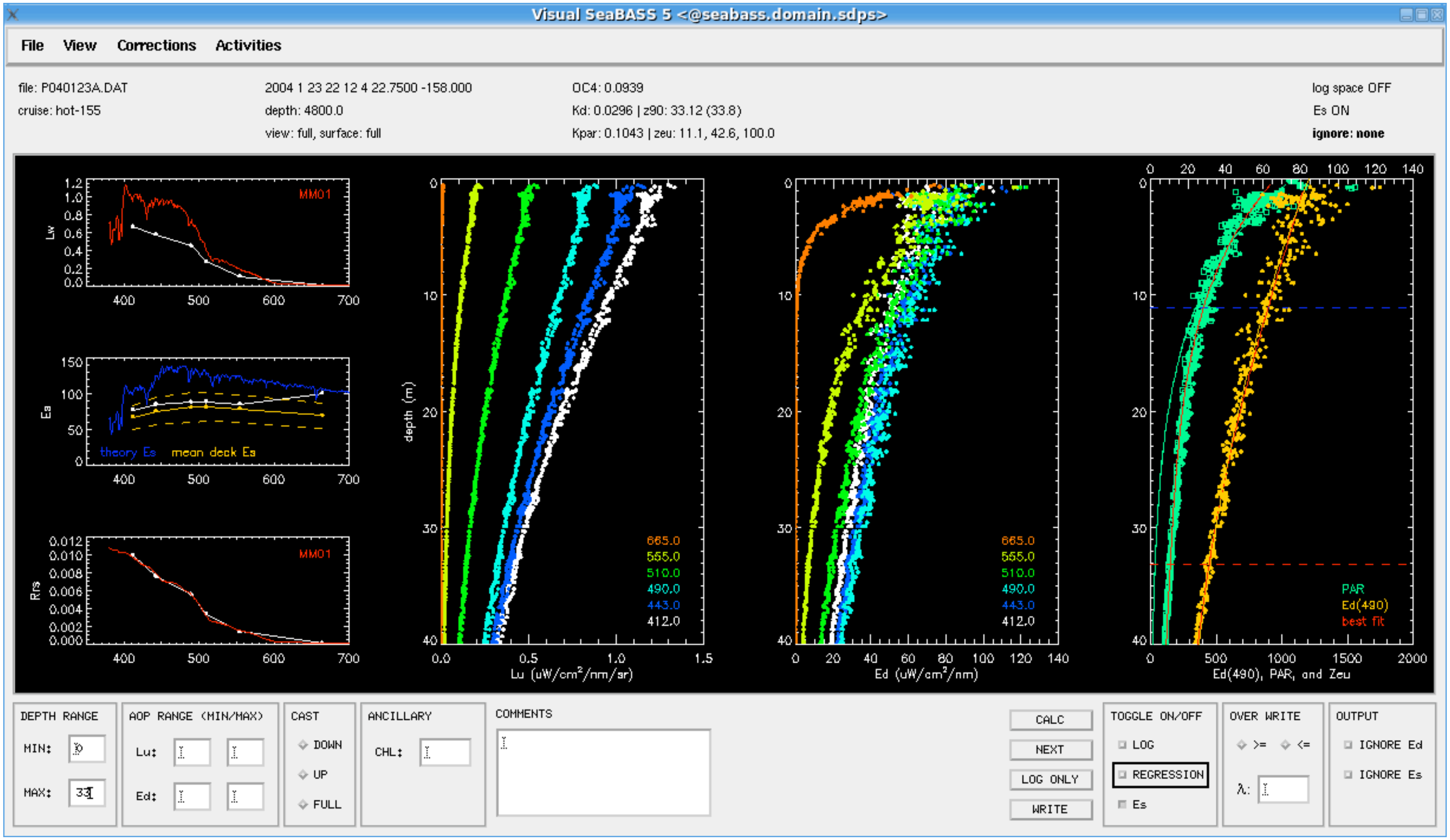
… collected on ~850 field campaigns …

… by ~30 different PIs & a variety of instruments

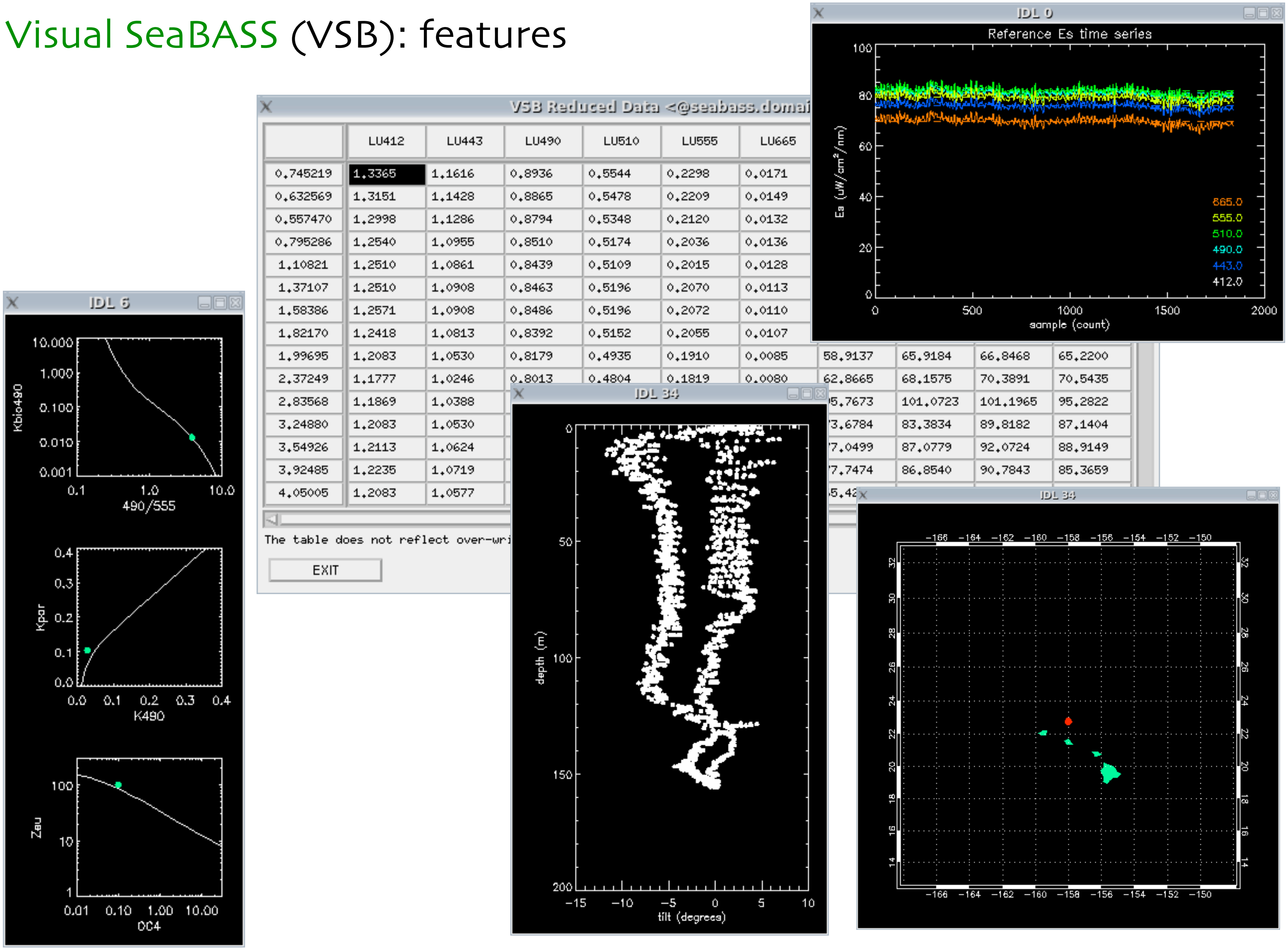


want generic post-processor to minimize PI / instrument differences data analysis

Visual SeaBASS (VSB): main window



Visual SeaBASS (VSB): features



data analysis

calculate & report:

- $L_W(\lambda)$
- $E_D(0^+, \lambda)$, $E_S(\lambda)$
- $K_D(\lambda)$, $z_{90}(\lambda)$ [Mueller 2000; $E_D(z_{90}) = E_D(0^-)\, e^{-1}$]
- K_{PAR}, $z_{PAR}(37,10,1\%)$ [Morel et al. 2007]
- regression statistics [incl. near-surface $K_D(\lambda)$ & $K_{LU}(\lambda)$]
- processing flags

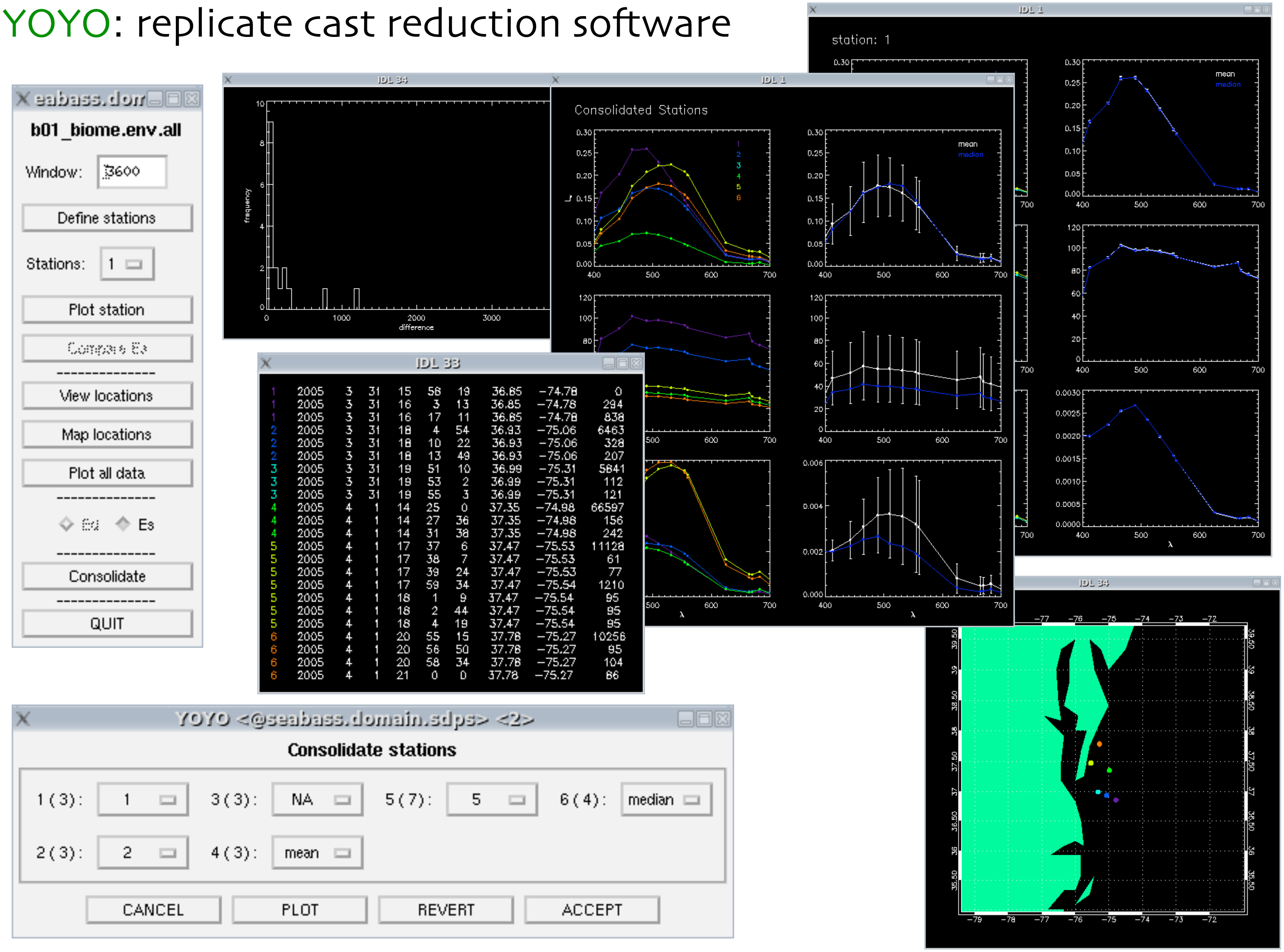
processing notes, extrapolation intervals, & statistics logged

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

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

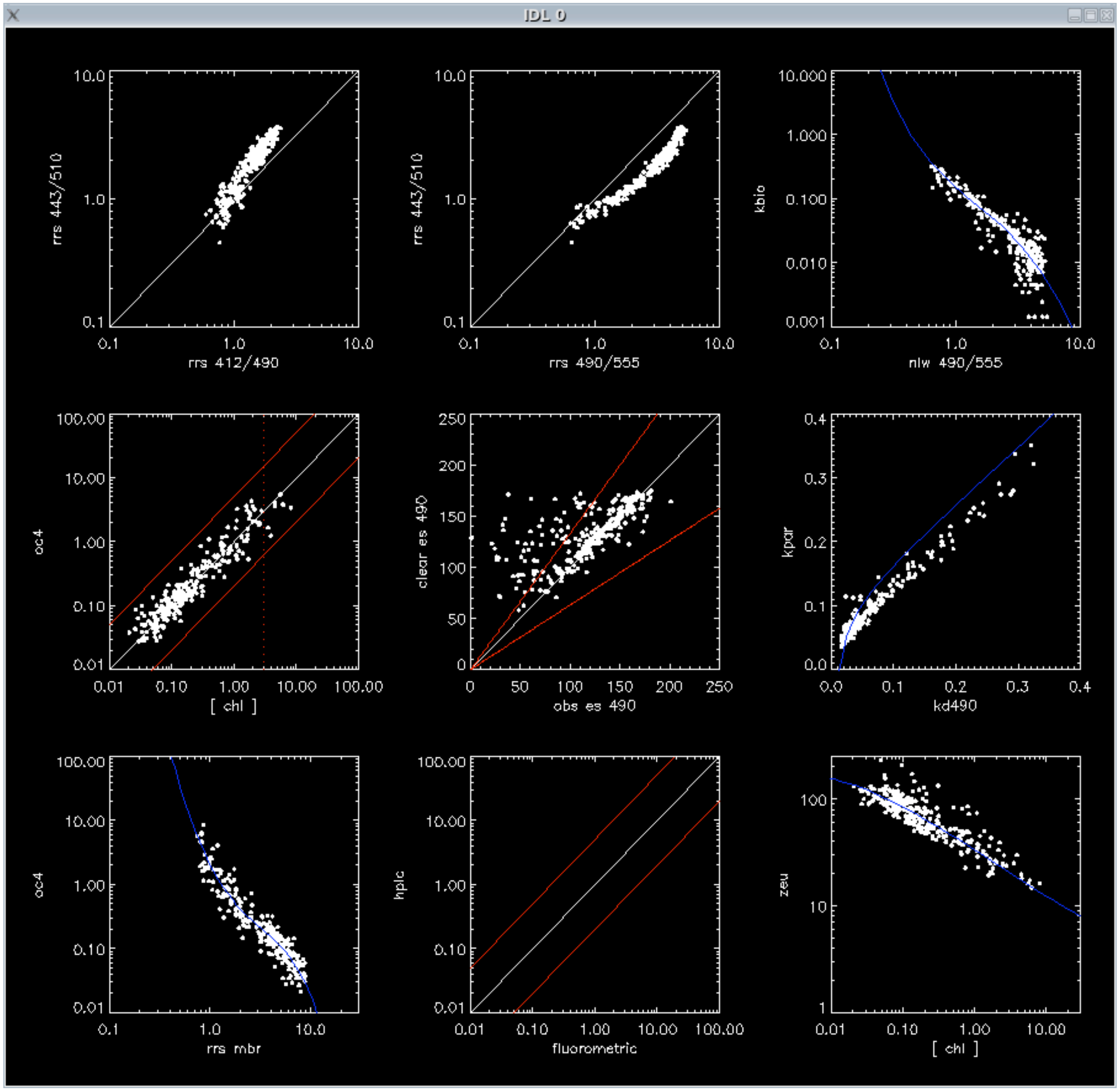
replicates remain & are addressed elsewhere

YOYO: replicate cast reduction software



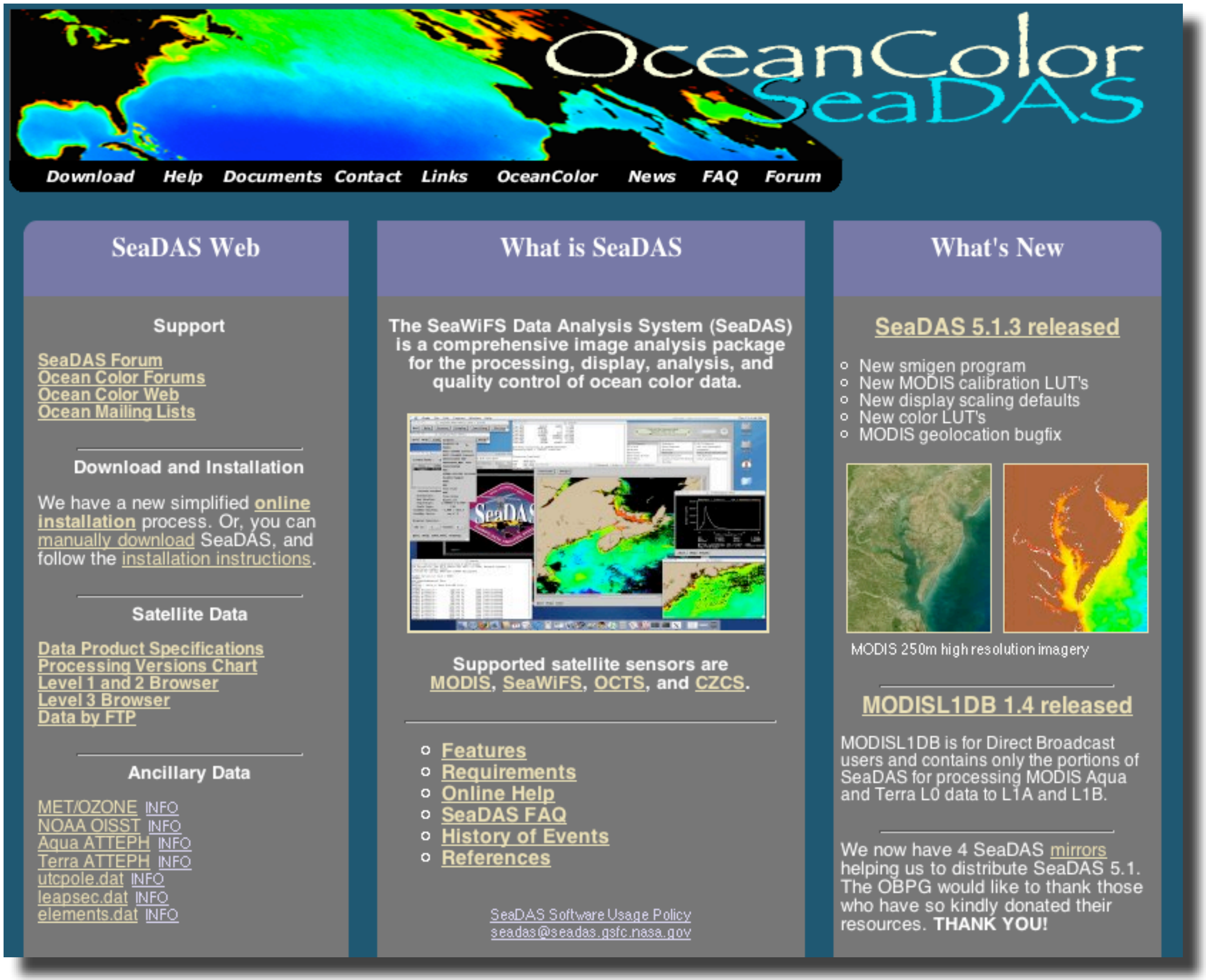
evaluation at the cruise level:

AMT 1 - 8



SeaDAS

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



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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): ±2% in reflectance and ±5% in radiance

MODIS relative accuracy over time
reflective solar bands (0.41–2.1 μm): ±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).