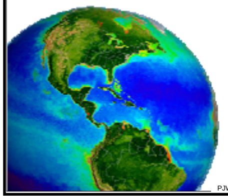
NASA vicarious calibration of on-orbit ocean color satellite instruments



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IOCS System Vicarious Calibration

Darmstadt, Germany

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presentation outline

legacy of the NASA operational approach

H.R. Gordon, "In-orbit calibration strategy for ocean color sensors," Rem. Sens. Environ. 63, 265-278 (1998)

D.K. Clark et al., J. Geophys. Res. 102, 17209-17217 (1997)
D.K. Clark et al., NASA Tech Memo. 2004-211632 (2003)

R.E. Eplee Jr. et al., "Calibration of SeaWiFS. II. Vicarious techniques," Appl. Opt. 40, 6701-6718 (2001)

B.A. Franz, et al., "Sensor-independent approach to the vicarious calibration of satellite ocean color radiometry," Appl. Opt. 46, 5068-5082 (2007).

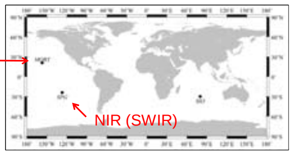
P.J. Werdell et al., Appl. Opt. 46, 5649-5665 (2007)
S.W. Bailey et al., Appl. Opt. 47, 2035-2045 (2008)

In place since SeaWiFS Reprocessing 4 (R2002)

general method

the vicarious calibration:

- minimizes the difference between satellite & ground truth $L_w(\lambda)$
- modifies the integrated instrument + atmospheric correction system
- uses a single set of fractional gains (unity = no correction)
- assumes temporal trends are independently removed
- currently uses the full spectral response of each sensor band



general method

the water-leaving signal from target is:

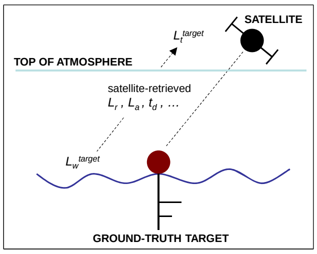
- adjusted to solar/sensor geometries of satellite overpass
  (using BRDF correction of Morel et al. 2002)

- propagated to top-of-atmosphere using satellite-retrieved aerosol properties

vicarious gains are calculated as:

- $g_i(\lambda) = L_{t,i}^{target}(\lambda) / L_{t,i}^{satellite}(\lambda)$

- $g(\lambda) = \Sigma\, g_i(\lambda) / N$
  (specifically, mean of SIQR)



vicarious calibration of NIR bands

$$L_t(\text{NIR}) = L_{r,g,wc,\ldots}(\text{NIR}) + L_a(\text{NIR}) + L_w(\text{NIR})$$

calculated ($L_{r,g,wc,\ldots}$); 0 (L_w)

requires two assumptions:

- L_w in two NIR bands negligible (= 0)
- calibration of longest NIR band is perfect (e.g., g(865) = 1 for SeaWiFS)

calibration of remaining NIR band (e.g., 765 for SeaWiFS):

- possible when aerosol type is known; the associated model can be used in combination with $L_a(865)$ to predict $L_a(765)$
- operationally executed using a 15x15 pixel target in the South Pacific Gyre
  (aerosol model r70f10v01; α = 0.685; assigned using Tahiti AERONET site)
- remains spatially/temporally independent of visible band calibration

vicarious calibration of visible bands

$$L_t(\mathrm{VIS}) = L_{r,g,wc,...}(\mathrm{VIS}) + L_a(\mathrm{VIS}) + L_w(\mathrm{VIS})$$

calculated — from ground-truth target

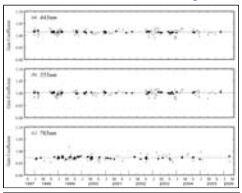
calibration of visible bands:

- uses calibrated NIR bands to dynamically determine local aerosol type & concentration at ground-truth target site, which provides L_a(VIS)

- operationally executed using L_w(VIS) from the Marine Optical BuoY (MOBY) & a 5x5 pixel target centered on the buoy location

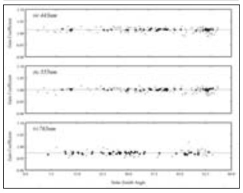
- exclusion criteria follows S.W. Bailey and P.J. Werdell, "A multi-sensor approach for the on-orbit validation of ocean color satellite data products," Rem. Sens. Environ. 102, 12-23 (2006)

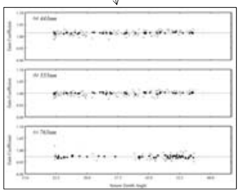
vicarious gain series for SeaWiFS



vicarious gains for 443, 555, 765 nm as a function of:

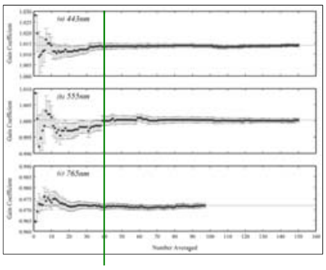
time
solar zenith angle
satellite zenith angle





vicarious gain series for SeaWiFS

gains as a function of sample size



N = 40 (approximately 2.5 yrs of data collection)

previously tested alternative approaches

methods for gain estimation:

- slope & offset in lieu of ratio (~ slope with offset = 0)
- gains calculated at L_w in lieu of L_t
- simultaneous use of *in situ* aerosol optical thickness
- zero Rayleigh (courtesy Zia Ahmad)
- zero aerosol (no NIR contributions by aerosols or water)
- NIR -> SWIR; SWIR -> NIR

data sources:

- modeled $L_w(\lambda)$ (Werdell et al. 2007)
- alternative *in situ* data (NOMAD, BOUSSOLE; Bailey et al. 2008)

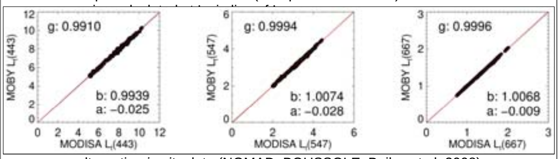
sensitivity analyses (Franz et al. 2007):

- NIR-only calibration (no visible vicarious calibration)
- g(865) = 1.04 or 0.96 (+/- 4% from unity)
- alternative aerosol models

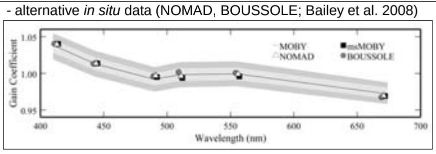
previously tested alternative approaches

methods for gain estimation:

- slope & offset in lieu of ratio (~ slope with offset = 0)



- alternative *in situ* data (NOMAD, BOUSSOLE; Bailey et al. 2008)

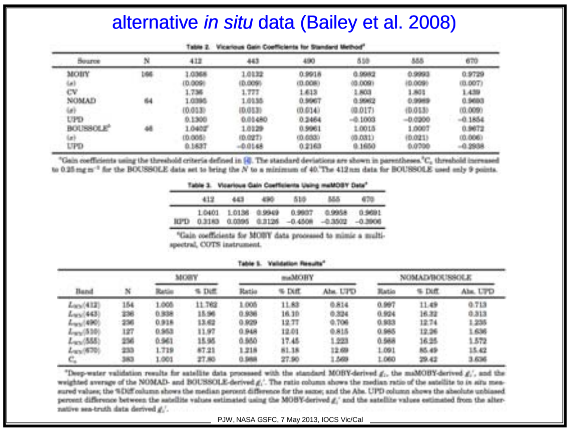


acknowledgements & contact info

additional vicarious calibration info available from:

Sean Bailey
Bryan Franz
Zia Ahmad
Chris Proctor
Gene Eplee
Bob Barnes

http://oceancolor.gsfc.nasa.gov



alternative *in situ* data (Bailey et al. 2008)

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.

Table 3. Vicarious Gain Coefficients Using maMOBY Data[a]

	412	443	490	510	555	670
	1.0401	1.0136	0.9949	0.9937	0.9958	0.9691
RPD	0.3183	0.0395	0.3126	−0.4508	−0.3502	−0.3906

[a]Gain coefficients for MOBY data processed to mimic a multi-spectral, COTS instrument.

Table 5. Validation Results[a]

		MOBY		maMOBY			NOMAD/BOUSSOLE		
Band	N	Ratio	% Diff.	Ratio	% Diff.	Abs. UPD	Ratio	% Diff.	Abs. UPD
$L_{WN}(412)$	154	1.005	11.762	1.005	11.83	0.814	0.997	11.49	0.713
$L_{WN}(443)$	236	0.938	15.96	0.936	16.10	0.324	0.924	16.32	0.313
$L_{WN}(490)$	236	0.918	13.62	0.929	12.77	0.706	0.933	12.74	1.235
$L_{WN}(510)$	127	0.953	11.97	0.948	12.01	0.815	0.965	12.26	1.636
$L_{WN}(555)$	236	0.961	15.95	0.950	17.45	1.223	0.568	16.25	1.572
$L_{WN}(670)$	233	1.719	87.21	1.218	81.18	12.69	1.091	85.49	15.42
C_a	383	1.001	27.80	0.988	27.90	1.569	1.060	29.42	3.636

[a]Deep-water validation results for satellite data processed with the standard MOBY-derived g_i, the maMOBY-derived g_i', and the weighted average of the NOMAD- and BOUSSOLE-derived g_i'. The ratio column shows the median ratio of the satellite to in situ measured values; the %Diff column shows the median percent difference for the same; and the Abs. UPD column shows the absolute unbiased percent difference between the satellite values estimated using the MOBY-derived g_i' and the satellite values estimated from the alternative sea-truth data derived g_i'.

PJW, NASA GSFC, 7 May 2013, IOCS Vic/Cal