Intercomparison of water leaving radiances from ocean color sensors using *in situ* measurements

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IVOS Workshop – Noordwijk, October 12-14, 2004

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Overview on:

- The CoASTS ocean color cal/val program
- Uncertainties in the *in situ* optical measurements
- Space derived versus *in situ* normalized water leaving radiances

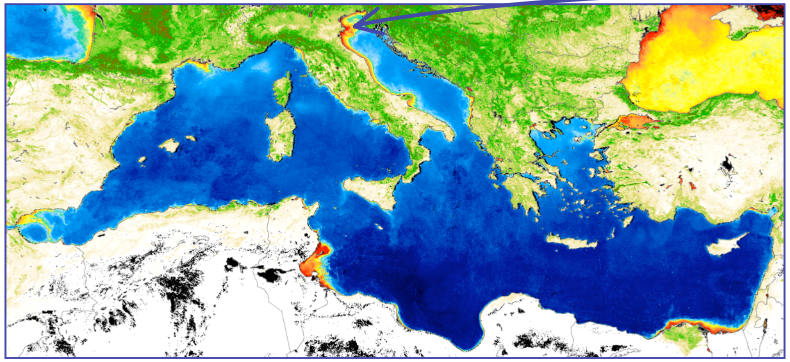
Coastal Atmosphere and Sea Time Series (*CoASTS*)

Objectives: 1. Monthly data collection at the Acqua Alta Oceanographic Tower (AAOT)

2. Data exploitation in ocean color products development and validation.

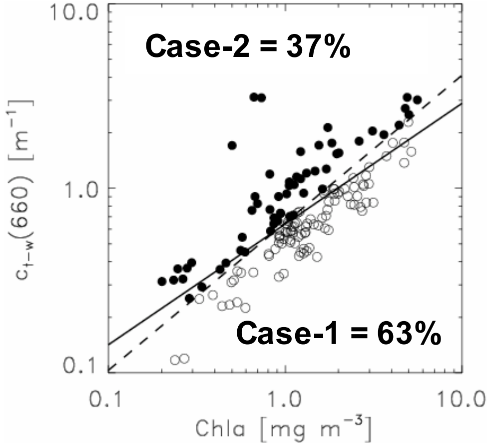
Time frame: July 1995 – September 2005

The AAOT site (45.31 N, 12.50 E)



Monthly Chla composite from SeaWiFS imagery (September 1998)

AAOT

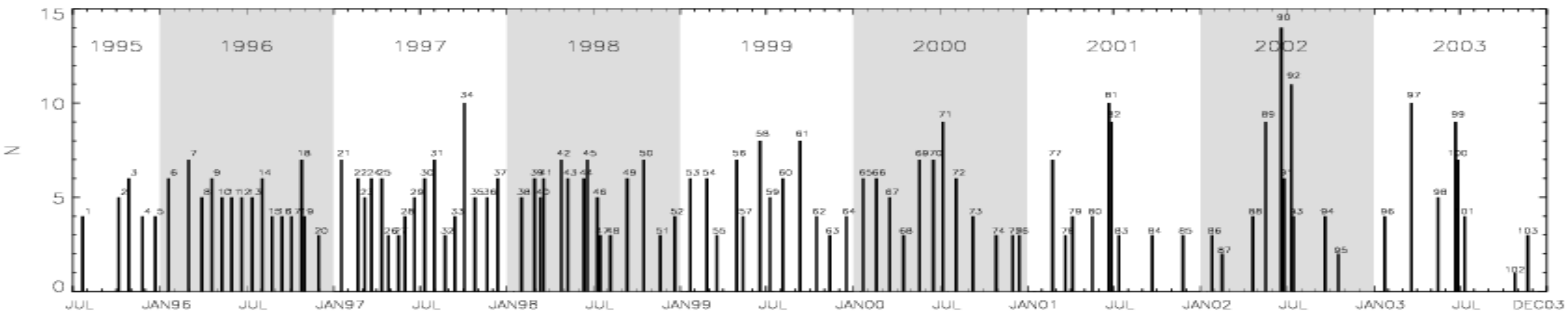


CoASTS campaigns

MERIS (01/03/02)

MODIS (18/12/99)

SeaWiFS (01/08/97)



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CoASTS measurements

Field measurements

- Profiles of $L_u(z,\lambda)$, $E_u(z,\lambda)$, and $E_d(z,\lambda)$
- Profiles of $c(z,\lambda)$ and $a(z,\lambda)$ *(from 01/97)*
- Profiles of $b_b(z,\lambda)$ *(from 04/00)*
- $E_d(0^+,\lambda)$ and $E_i(0^+,\lambda)$
- $E_s(0^+,\lambda)$ and $L_i(0^+,\theta,\phi,\lambda)$
- $L_W(40^0, 90^0, \lambda)$ *(from 04/02)*
- Ancillary ($T_w(z)$,$S_W(z)$,P_a,RH,T_a,W_s,W_d,C,M)

Laboratory measurements

(from water samples at 3 depths)

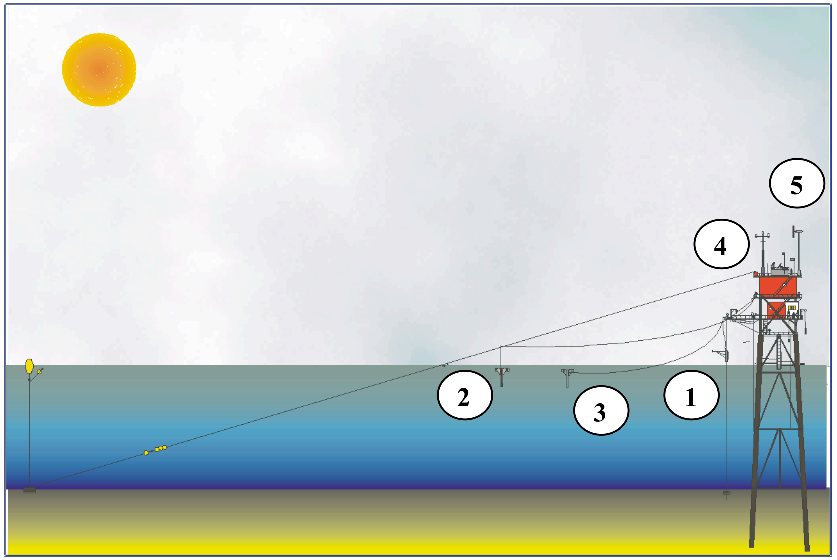
- ***Pigments (HPLC)***
- $a_{ph}(\lambda)$ and $a_{dp}(\lambda)$
- $a_{ys}(\lambda)$
- ***TSM***
- Ancillary (***PSD***) *(up to 10/98)*

G.Zibordi J.F.Berthon, J.P.Doyle, S.Grossi, D. van der Linde, C.Targa, L.Alberotanza. ***Coastal Atmosphere and Sea Time Series (CoASTS), Part 1: A long-term measurement program.*** **NASA TM-2002-206892, vol. 19, S.B.Hooker and E.R.Firestone, Eds., NASA Goddard Space Flight Center, Greenbelt, Maryland, 2002, 29 pp.**

AAOT Optical Systems

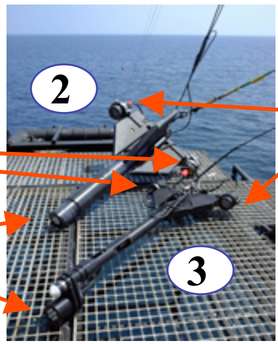
$E_d(0^+,\lambda)$, $E_i(0^+,\lambda)$

$E_s(\lambda)$, $L_i(\theta,\phi,\lambda)$, $L_w(\lambda)$



$E_d(z,\lambda)$

$E_u(z,\lambda)$

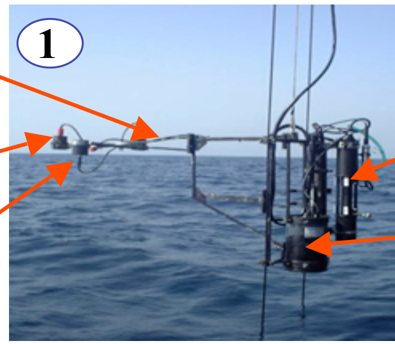


$L_u(z,\lambda)$

$L_u(z,\lambda)$

$E_u(z,\lambda)$

$E_d(z,\lambda)$



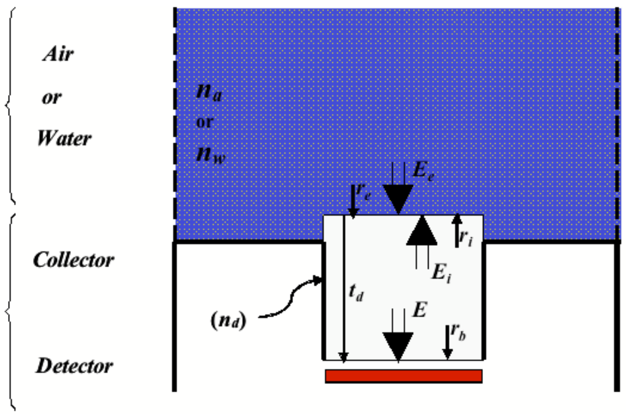
$a(z,\lambda)$

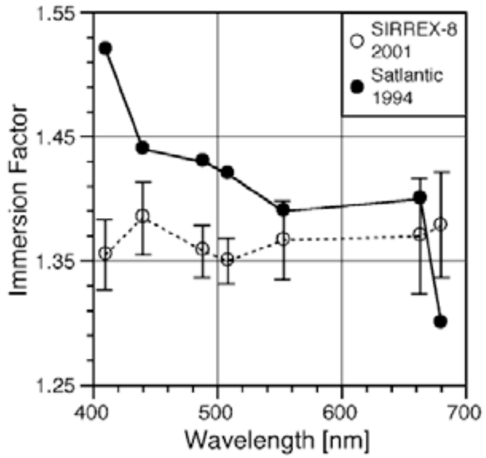
$c(z,\lambda)$

$b_b(z,\lambda)$

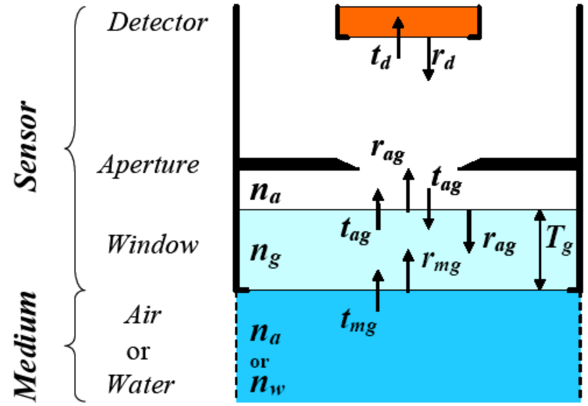
Immersion effects for in-water radiometers

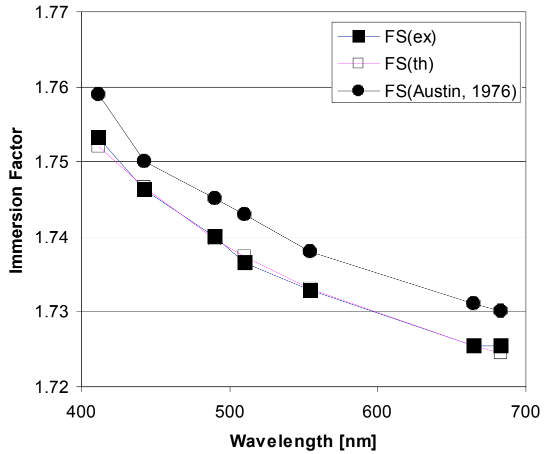
Irradiance





Radiance

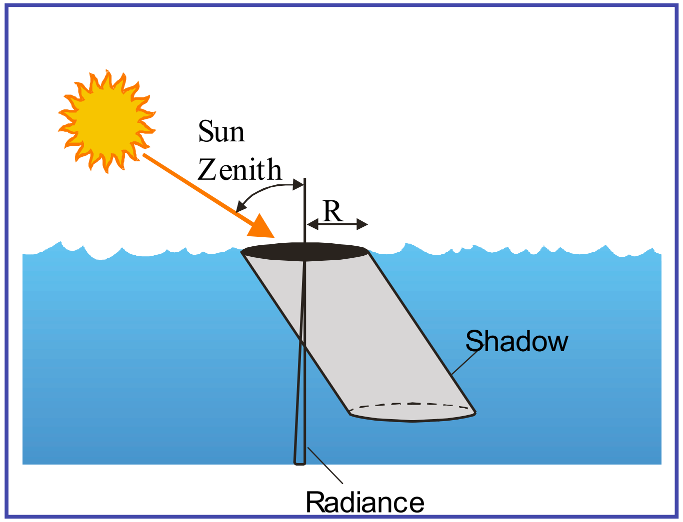


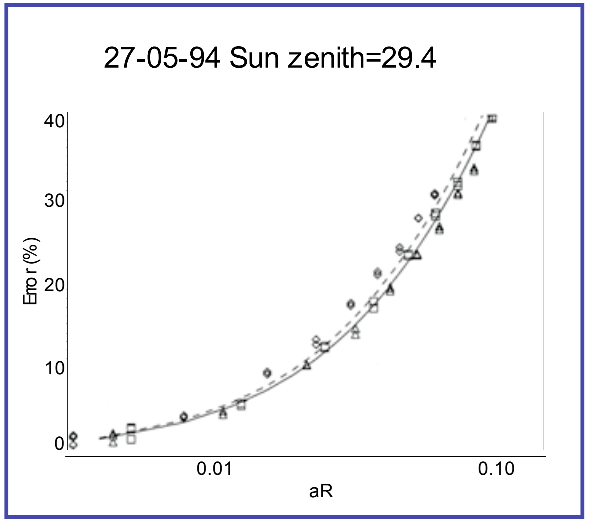


G.Zibordi, S.Hooker, J.Mueller, S.McLean, G.Lazin. Characterization of the immersion coefficient of a class of underwater irradiance sensors. *Journal of Atmospheric and Oceanic Technology*, 21:501-514, 2004.

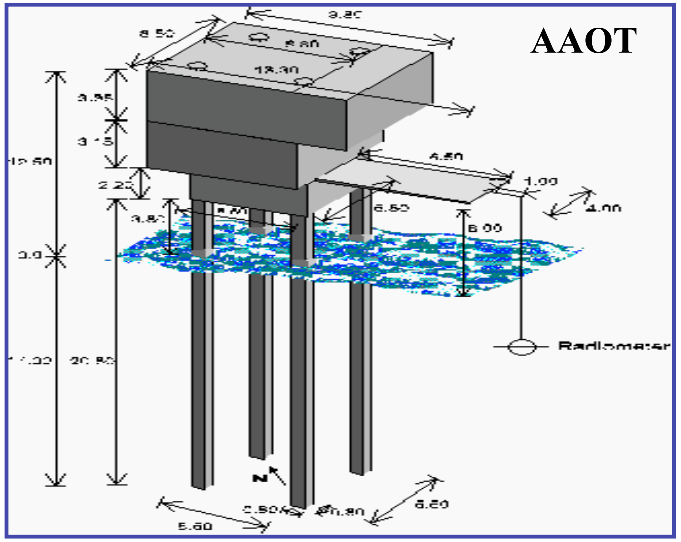
G.Zibordi. Immersion coefficient of in-water radiance instruments: an experimental assessment. *Journal of Atmospheric and Oceanic Technology* (submitted), 2004.

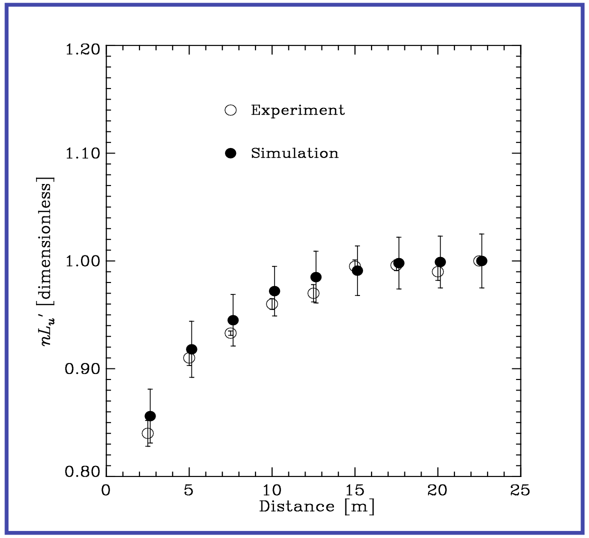
Measurement Uncertainties





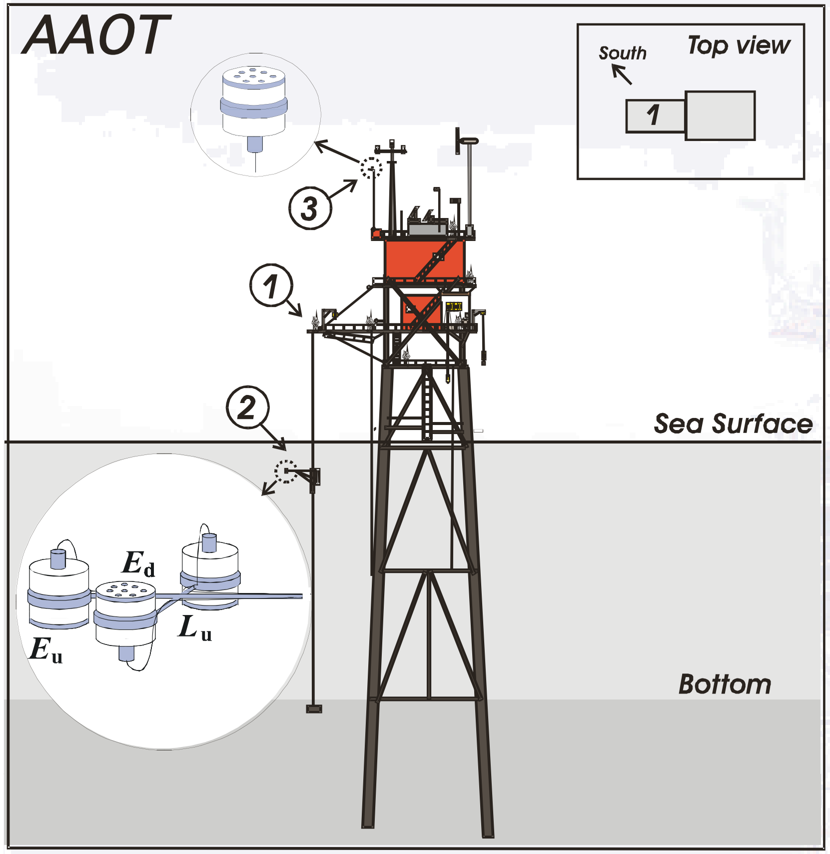
G.Zibordi and G.M.Ferrari, Instrument self shading in underwater optical measurements: experimental data. *Applied Optics*, 34: 2750-2754, 1995.





J.P.Doyle & G.Zibordi. Optical propagation within a 3-dimensional shadowed atmosphere/ocean field: application to large deployment structures. *Applied Optics*, 41:4283-4306, 2002.

In water radiometry

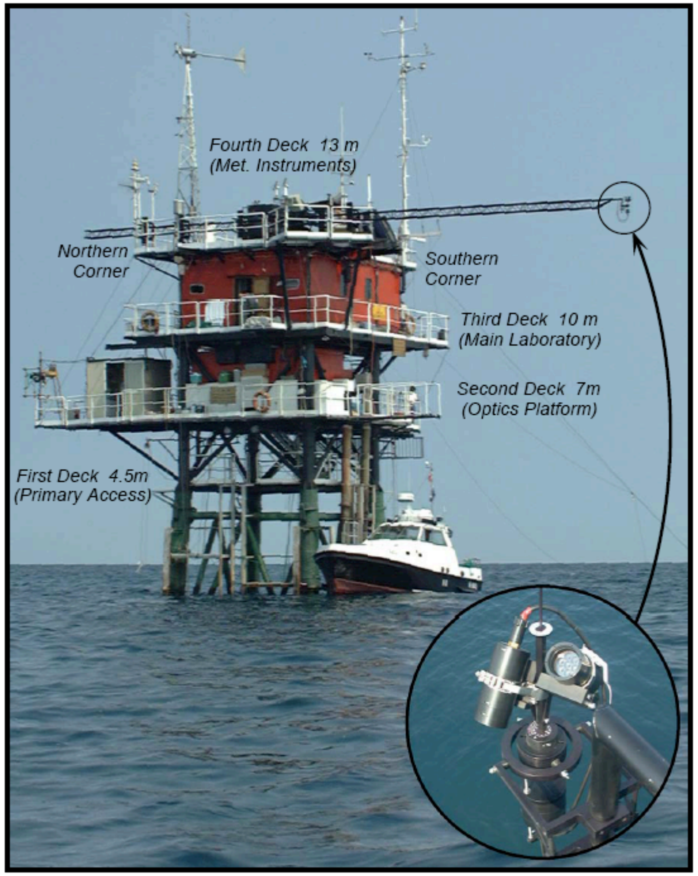


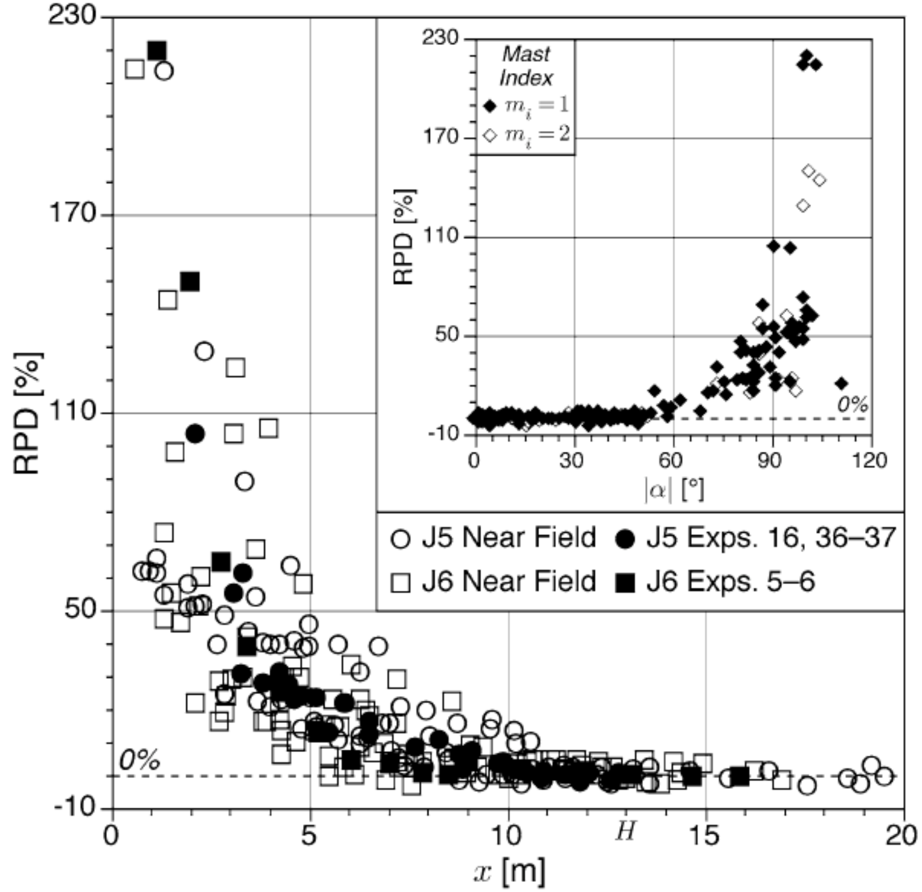
Uncertainties (L_u)	412	443	490	510	555	665
Abs. calibration [1]	2.4	2.3	2.3	2.4	2.4	2.3
Residual shad. pert.	2.5	2.1	1.7	1.6	1.7	3.0
Environ. effects	3.0	3.0	3.1	3.1	3.1	3.1
Quadrature sum	4.6	4.3	4.2	4.2	4.3	4.9

[1] Including the calibration source accuracy, I_f accuracy and instrument stability

G.Zibordi, F. Mélin, S. B. Hooker, D. D'Alimonte and B. Holben. *An autonomous above-water system for the validation of ocean color radiance data. IEEE Transactions in Geoscience and Remote Sensing* (accepted), 2003.

Perturbations in above-water radiance measurements





S. B. Hooker and G.Zibordi. ***Platform Perturbations in above-water radiometry. Applied Optics***, Revised on June 2004**.**

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Above water radiometry

$$L_W^{SP}(\varphi,\theta,\lambda) = L_T(\varphi,\theta,\lambda) - \rho(\varphi,\theta,\theta_0,W)L_i(\varphi,\theta',\lambda)$$

$$(\varphi = \varphi_0 + 90^0; \theta = 40^0; \theta' = 140^0)$$

CE-318 (sea-viewing)

Major uncertainties (L_w)	412	440	500	555	670
Absolute calibration[1]	**2.2**	**2.1**	**2.1**	**2.1**	**2.1**
Viewing angle correction[2]	**1.0**	**1.0**	**1.6**	**1.8**	**0.9**
Environmental perturbations	**4.0**	**3.7**	**3.1**	**3.0**	**12.0**
Quadrature sum	**4.7**	**4.4**	**4.1**	**4.1**	**12.2**

[1] **Including the calibration source accuracy and instrument stability**

[2] **Assuming an arbitrary 25% in the applied correction**

CE-318 (sky-viewing)

G.Zibordi, F. Mélin, S. B. Hooker, D. D'Alimonte and B. Holben. *An autonomous above-water system for the validation of ocean color radiance data. IEEE Transactions in Geoscience and Remote Sensing* , 42:401-415, 2004 .

S.B.Hooker, G.Zibordi, D. van der Linde, D.D'Alimonte, J.F.Berthon and J.Brown. *Tower perturbation measurements in above-water radiometry.* NASA TM 2002-206892, v. 23 S.B.Hooker and E.R.Firestone, Eds., NASA Goddard Space Flight Center, Greenbelt, Maryland, 2003, 35 pp.

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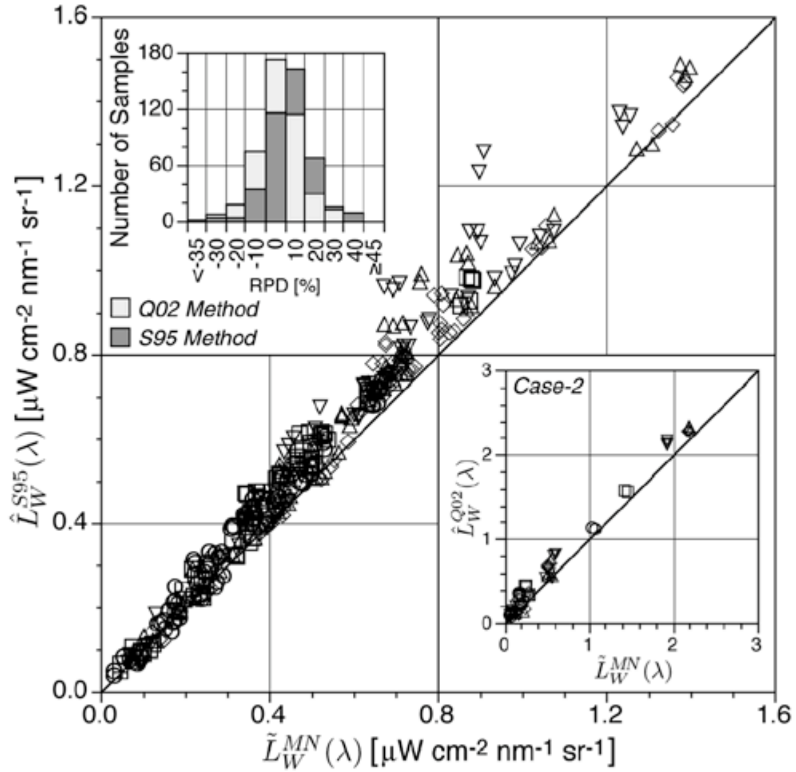
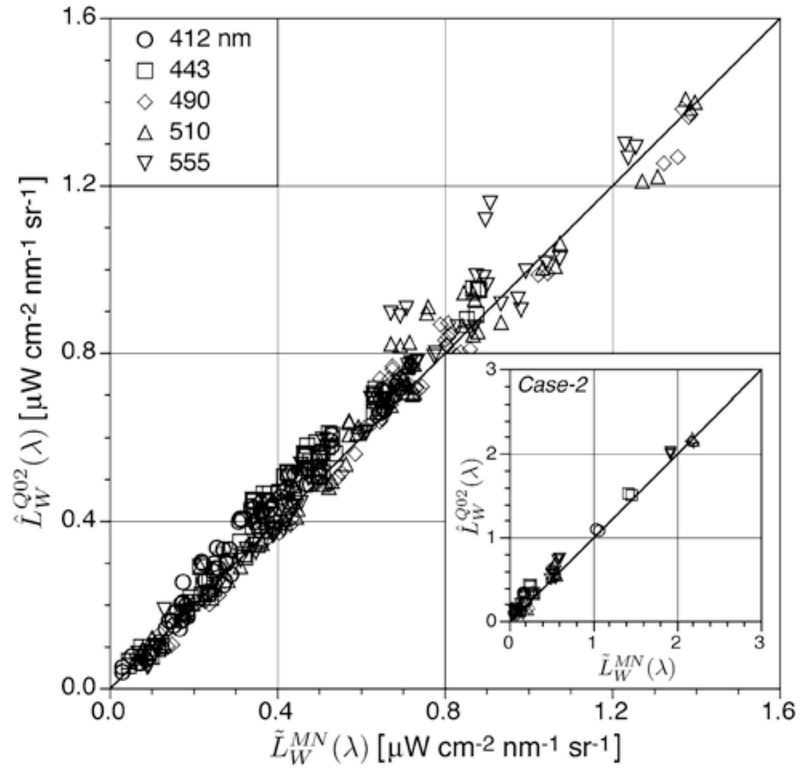
Above- versus in-water

$$L_W^{S95}(\varphi,\theta,\lambda) = L_T(\varphi,\theta,\lambda) - \rho(\varphi,\theta,\theta_0,W)L_i(\varphi,\theta',\lambda) \qquad L_W^{Q02}(\lambda) = L_W^{S95}(\varphi,\theta,\lambda)C_{\Re Q}(\lambda,\theta,\varphi,\theta_0,\tau_a,Chla,W)$$





S.B.Hooker, G.Zibordi, J.-F.Berthon and J.Brown. ***Above water radiometry in shallow coastal waters,*** Applied Optics 21:4254-4268, 2004.

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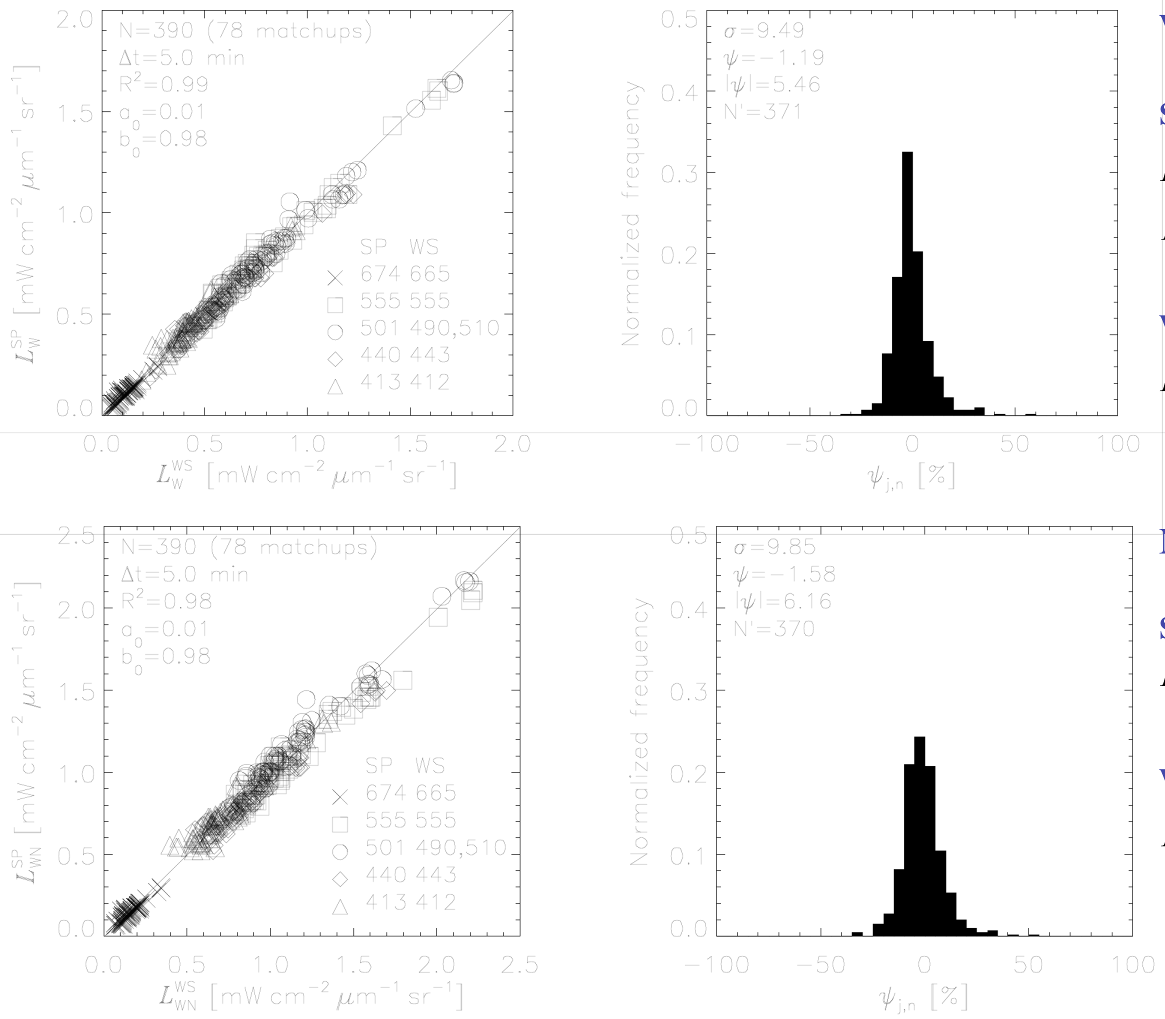
GSFC NASA

Above- versus in-water



Water Leaving Radiance

SeaPRISM

$$L_W^{SP}(\varphi,\theta,\lambda) = L_T(\varphi,\theta,\lambda) - \rho(\varphi,\theta,\theta_0,W)L_i(\varphi,\theta',\lambda)$$

$$L_W^{SP}(\lambda) = L_W^{SP}(\varphi,\theta,\lambda)C_{\Re Q}(\lambda,\theta,\varphi,\theta_0,\tau_a,Chla,W)$$

WiSPER

$$L_W^{WS}(\lambda) = 0.54L_u^{WS}(0^-,\lambda)$$

Normalized Water Leaving Radiance

SeaPRISM

$$L_{WN}^{SP}(\lambda) = L_W^{SP}(\lambda)C_{f/Q}(\lambda,\theta_0,\tau_A,Chla)\left(D^2t_d(\lambda)\cos\theta_0\right)^{-1}$$

WiSPER

$$L_{WN}^{WS}(\lambda) = L_W^{WS}(\lambda)\frac{E_0(\lambda)}{E_d(0^+,\lambda)}C_{f/Q}(\lambda,\theta_0,\tau,Chla)$$

G.Zibordi, F. Mélin, S. B. Hooker, D. D'Alimonte and B. Holben. *An autonomous above-water system for the validation of ocean color radiance data. IEEE Transactions in Geoscience and Remote Sensing,* 42:401-415, 2004 .

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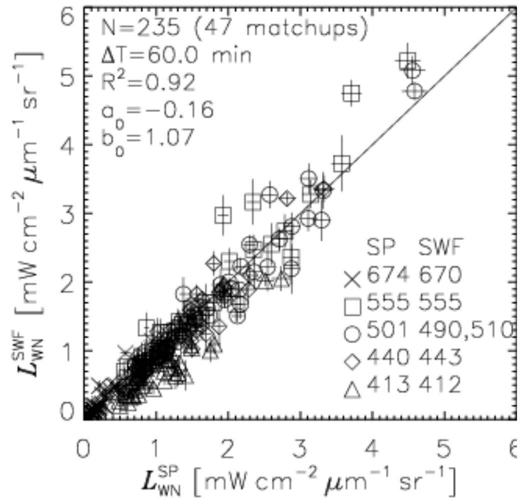
Ocean Color Sensors Intercomparison

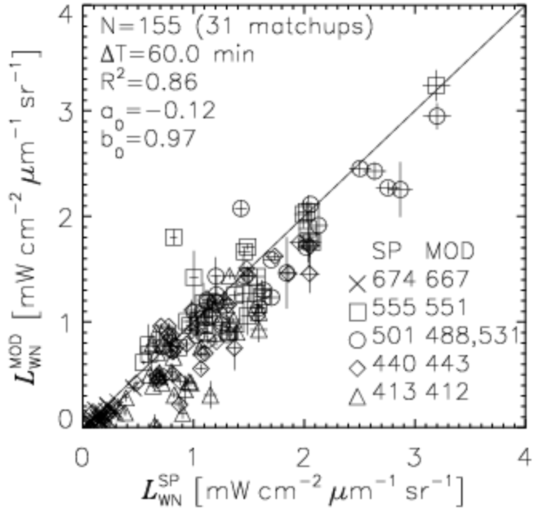
AAOT, May 2002-May 2003, 3X3 pixels, θ<56°, θ_0<70°, ΔT=60 min; L_{WN}>0

APD=-10%



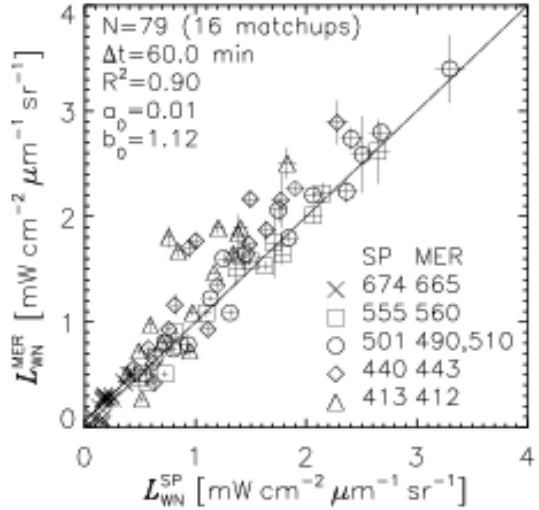
SeaWiFS

APD=-17%



MODIS

APD=+15%



MERIS

G.Zibordi, F. Mélin, S. B. Hooker, D. D'Alimonte and B. Holben. An autonomous above-water system for the validation of ocean color radiance data. *IEEE Transactions in Geoscience and Remote Sensing* , 42:401-415, 2004 .

SeaWiFS vicarious calibration exercises
(June 2002-May 2003 data)

Vicarious correction coefficients at the AAOT site (SeaPRISM data)

Band	Coefficient	StdDev
412	1.031	0.010
443	1.005	0.011
555	0.998	0.020
670	0.977	0.019

Vicarious correction coefficients at the AAOT site (Moby data)

Band	Coefficient
412	1.013
443	0.996
555	0.991
670	0.956

Processed by Sean Bailey – SeaWiFS Project

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Recommendations

- Establishment of in situ measurement sites providing quality assured data for the vicarious calibration of space sensors and the validation of derived products.

- Co-ordination among different sites for the standardization of measurement protocols.

- Creation of time-series of quality assured in situ measurements for the evaluation of long term satellite performances.